Preface

Welcome to 22nd International Conference on Advancement of Construction Management and Real Estate (CRIOCM 2017) in the world’s most livable city Melbourne, Australia. The conference is a joint effort of the Chinese Research Institute of Construction Management (CRIOCM), Swinburne University of Technology and several co-organising universities. The conference offers an international platform for knowledge and technology exchange and is a major event for all experts from industry, public sector and academia to advance the development of construction management and real estate, with a particular focus on construction automation.

This three day event offers in-depth discussions about state-of-the-art research that has been conducted on construction management, construction engineering, 3D concrete printing, building information modelling, sustainable buildings, real estate, urbanisation and occupational health and safety. This year the conference has industry and academia from various parts of the world including China, England, Hong Kong, India, Indonesia, Malaysia, New Zealand, Pakistan, Singapore and South Africa. In response to our call for papers, 144 papers have been finally accepted after rigorous peer reviews.

In addition to the traditional presentations, the conference also hosts a series of forums and workshops, including research methodology workshop, Journal Editors' Forum, and a University-Industry collaboration forum where industry experts and ARC (Australian Research Council) panel experts participate. These workshops and forums aim to generate lively debates and discussions and share knowledge.

We extend our warmest welcome to Melbourne and hope you enjoy informative and prestigious meetings with outstanding construction and real estate professionals.

CRIOCM 2017 Organising Committee
Acknowledgements

The CRIOCM 2017 conference gratefully acknowledges the support of organisations below:

Conference Organiser

- The Chinese Research Institute of Construction Management (CRIOCM),
- Swinburne University of Technology

Co-organisers

- The University of Hong Kong
- Peking University
- Tsinghua University
- Zhejiang University
- Chongqing University
- Shenzhen University
- Tianjin Chengjian University.

Co-Chairman

- Professor Patrick X.W. Zou, Swinburne University of Technology
- Professor Jay Sanjayan, Swinburne University of Technology
- Professor Yuzhe Wu, Zhejiang University/CRIOCM
- Dr Wilson W.S. Lu, The University of Hong Kong/CRIOCM

Secretary-General

- Dr Morshed Alam, Swinburne University of Technology, Australia
- Maria Han, Swinburne University of Technology, Australia
- Xiaoxiao Xu, Swinburne University of Technology, Australia
- Dipika Wagle, Swinburne University of Technology, Australia
- Van Manh Phung, Swinburne University of Technology, Australia
- Peng Peng Li, Swinburne University of Technology, Australia

Members

- Dr Helen Bao, University of Cambridge, UK
- Dr Yufeng (Cindy) Chen, Georgia Southern University, US
- Dr Zhikun Ding, Shenzhen University, China
- Dr Na Dong, Sichuan University, China
- Dr Palaneeswaran Ekambaram, Swinburne University of Technology, Australia
- Dr Robert Evans, Swinburne University of Technology, Australia
- Dr Shang Gao, University of Melbourne, Australia
- Professor Wei Guo, Tianjin Chengjian University
- Dr Dezhi Li, Southeast University
- Professor Jie Li, Nanjing Forestry University, China
- Professor Jian Lin, Peking University, China
• Dr Chao Mao, Chongqing University
• Dr Sungkon Moon, Swinburne University of Technology, Australia
• Dr Xing Ning, Northeast University of Finance and Economics, China
• Dr Jorge Ochoa, University of South Australia, Australia
• Dr Wei Pan, The University of Hong Kong
• Dr Yi Peng, Zhejiang University of Finance & Economics
• Dr Guoyou Qi, East China University of Science and Technology, China
• Professor Aiying Jiao, Tianjin Chengjian University, China
• Dr Chensun Sun, Harbin Institute of Technology
• Dr Vivian W.Y. Tam, Western Sydney University, Australia
• Dr Yongtao Tan, The Hong Kong Polytechnic University
• Dr L Y N Tang, West Virginia University, US
• Dr Pingbo Tang, Arizona State University, US
• Professor Jinyeu Tsou, Chinese University of Hong Kong
• Dr Changzhi Wu, Curtin University, Australia
• Dr Bo Xia, Queensland University of Technology, Australia
• Dr Sheng Xu, Chang-An University, China
• Dr Michael Yam, Hong Kong Polytechnic University
• Dr Rebecca J. Yang, RMIT University, Australia
• Professor Gui Ye, Chongqing University
• Professor Kunhui Ye, Chongqing University
• Dr Mingxuan Yu, Renmin University of China
• Dr Hongping Yuan, Southwest Jiaotong University
• Dr Xiaoling Zhang, City University of Hong Kong
• Dr Xueqing Zhang, Hong Kong University of Science and Technology
• Professor Zhenyu Zhao, North China Electric Power University
• Professor Yimin Zhu, Louisiana State University, USA
• Dr Jian Zuo, University of Adelaide, Australia

International Scientific and Advisory Committee

Co-Chairman

• Professor John Wilson, Swinburne University of Technology, Australia
• Professor Emad Gad, Swinburne University of Technology, Australia
• Professor Liyun Shen, Chongqing University, China
• Professor KW Chau, The University of Hong Kong, China
• Professor Chimay Anumba, University of Florida, US

Members

• Professor Samuel Ariaratnam, Arizona State University, US
• Professor Haijun Bao, Zhejiang University of Finance & Economics
• Professor David Carmichael, University of New South Wales, Australia
• Professor Albert P.C. Chan, The Hong Kong Polytechnic University
• Professor Andrew Dainty, Loughborough University, UK
• Professor Dongping Fang, Tsinghua University
• Professor Changchun Feng, Peking University, China
• Professor Roger Flanagan, University of Reading, UK
• Professor Peter Guthrie, University of Cambridge, UK
• Professor Miklos Hajdu, Szent Istvan University, Hungary
• Professor Markarand Hastak, Purdue University, US
• Professor Eddie Hui, The Hong Kong Polytechnic University
• Professor Edward Jaselskis, NC State University, US
• Professor Craig Langston, Bond University, Australia
• Professor Guijun Li, Central University of Finance and Economics, China
• Professor Heng Li, The Hong Kong Polytechnic University
• Professor Qiming Li, Southeast University
• Professor Anita M M Liu, The University of Hong Kong, Hong Kong
• Professor Guiwen Liu, Chongqing University, China
• Professor Hongyu Liu, Tsinghua University, China
• Professor S.M. Lo, City University of Hong Kong, Hong Kong
• Professor S. P. Low, National University of Singapore, Singapore
• Professor Roger-Bruno Richard, Université de MONTREAL, Canada
• Professor Steve Rowlinson, The University of Hong Kong, Hong Kong
• Professor Mona Shah, National Institute of Construction M&R, India
• Professor Geoffrey Q. P. Shen, The Hong Kong Polytechnic University, Hong Kong
• Professor Jonathan Shi, Louisiana State University, USA
• Professor Qian Shi, Tongji University, China
• Professor Martin Skitmore, Queensland University of Technology, Australia
• Professor Lucio Soibelman, University of Southern California, US
• Professor Jianting Wang, Tianjin Chengjian University, China
• Professor Jiayuan Wang, Shenzhen University, China
• Professor Qingqin Wang, China Academy of Building Research, China
• Professor Shouqing Wang, Tsinghua University, China
• Professor Xiangyu Wang, Curtin University, Australia
• Professor Xu Wang, Chongqing University, China
• Professor Xiaolong Xue, Harbin Institute of Technology, China
• Professor Donglang Yang, Xi’an Jiaotong University, China
• Professor Saixing Zeng, Shanghai Jiaotong University, China
• Professor Hong Zhang, Tsinghua University, China
• Professor Hong Zhang, Zhejiang University, China
# Table of Contents

Research on the Relationship between Building Industrialization and Labor Productivity of China

Case-based Insights to the Rework Costs of Residential Buildings—— A China Perspective

Social Capital, Safety Cognitive and Construction Safety Behavior

Transfer Success Criteria for Public-Private Partnership Infrastructure Projects

Thermal and Chemical Degradation of Portland Cement Concrete in the Military Airbase

Using the Analytical Network Process to Measure the Risk Control Factors of IPD Projects

Causes of Delays in Iranian Gas and Combined Cycle Power Plant Projects

Projects Risk Management Using Artificial Neural Networks Based on Lessons Learned

Sustainable Construction Project Management Critical Success Factors for Developing Countries


Public Housing as Method: Upgrading the Urbanisation Model of Chongqing through a Mega Urban Project

Exploring the Causes of the Policy Failure of China's Real Estate Regulation Policy from the Perspective of the Inner Problems of the Policy


Properties of Carbon-Conditioned Recycled Aggregate

A China's residential energy saving estimation model based on IPAT equation and LMDI decomposition

Selection of Most Suitable Pipe Material for Water Supply Projects

Construction risk tolerance: workers versus site-managers

Physical and Mechanical Properties of High-Performance Lightweight Concrete

Construction Productivity: The Case of Malaysia

A statistical yearbook data-based calculation method for building floor space in China and analysis on energy intensity

Life-cycle costing as a tool for selecting optimum solutions for insulated floors in Australia

Understanding Behavioral Diversity of Onsite Employees in International Projects, Integrated Simulation Approach

An analysis framework of risk interactions in international construction projects: A Bayesian network approach

Research on the Risk Factors of BIM Application in Construction Enterprises
Research on Policy Path of Culture-led regeneration: Based on government Roles analysis .................................................................209
Resilience for construction project-based organizations: definition, critical factors and improvement strategies ........................................217
A Framework of Enhanced Location Based Management System Using Simulation Models ..............................................................225
System reliability optimization research for the construction project quality-cost tradeoff via modified Genetic Algorithm ........................................233
Vertical Integration and Goodwill: The Case of Real Estate Companies ................241
Critical Risk Identification in One Belt-One Road Highway Project in Serbia ....248
Land Finance and Urban Diversity: the Empirical Evidence .........................256
Using Mobile Phone Data for Social Infrastructure Planning ..........................265
Research on the Transformation Path from Traditional Construction Method to Off-site Construction - Taking Chinese Enterprises as Example .........................281
Industrial ecosystem evolution of off-site construction industry: based on a multiple case study ........................................................................................................290
Supplier selection model in construction ........................................................298
The Significance of the Life Cycle Embodied Energy in Shopping Centres in Australia .................................................................305
Critical Factors Affecting the Implementation of Urban Renewal Projects: Case Study in Shenzhen .........................................................316
Gender Equality in Singapore’s Construction Industry ....................................324
A bibliometric analysis of research on building energy performance gap .......333
Study on the Influence of Urban Rail Transit on Residential Rental Based on Hedonic Model -Taking Hangzhou Metro Line 1 as an Example .........................341
The Impact of Financial Factors on Commercial Housing’s price ———An Empirical Study based on VAR Model .................................................................347
Bibliometric Analysis of Building Information Modelling (BIM) in the Construction Industry .................................................................356
Factors Affecting Informal Housing Price Discounts At City Level In China ....366
Exploring The Planning Orientation of Different Types of Characteristic Towns: Based on The Perspective of Population, Industry and Land Integration .........................................................377
Towards an Ex-post Evaluation of PPP Projects .................................................392
Housing the Young People: Their housing stress and willing to stay ..............401
Acculturation of Project-Induced Immigrants: A Gender Difference Perspective ...........412
Analysis on Coupling Relationship of Financing Capability and the Competitiveness of
Exploring health and well-being of workers on a large multinational construction project

Critical Risk Factors for Transnational Public-Private Partnership Projects: A Literature Review

Driver and challenges facing leadership in adopting sustainability in the built environment: a developer’s perspective

The Synergy between New Urbanization and Land Use Efficiency—A Case Study of Dingzhou City in Hebei Province

Risk Identification and Assessment for Construction and Commissioning Stages of Building Energy Retrofit Projects

Trends in Housing Offsite Manufacturing Supply Chain Management (HOSCM) Research

Comparative Study of Crew Performance Measurement Methods: Case Study of Steel Fixers

Analysis of the Feature Small-town Origins and Scope in the Period of Transition

Technical Review of Automated Monitoring System for Concrete Curing

DEA-based Efficiency Analysis For Industrial Land Use: A Case Study of Chinese Development Zones

Analysis of Interest conflicts between the Stakeholders about Architectural Heritage Protection

The rule of law index for land administration in China

Energy Efficiency Framework for Malaysia’s Green Office Building Occupants

Exposition of Conceptual Construction Cost: a Review of Modelling Techniques

ABM-based Environmental Performance Simulation Study of Demolition Waste Management Policies in Shenzhen, China

Developing Lean Management Framework for Building Information Modelling (BIM)-based Construction Project

Cooperative Innovation Behavior Incentive Mechanism for Project-based Supply Chain

A preliminary framework for site planning and sitedesign in green buildings

An Exploration on the Planning and Positioning of Characteristic Towns in China: The Perspective of Industrial Agglomeration and Ecological Livability

Predesign Quantity Estimation for Building Information Modelling using Support Vector Machine

Mapping global public interests in green buildings
More Inclusive Approaches to Smart Cities: No one is left behind ........................................ 903
Changes of Industrial Structure and Its Regional Difference in Zhejiang Province .......... 911
Characterizing the environmental impacts and their occupational health risks during decorative and renovating projects ................................................................. 919
Analysis of the operation relationship between commercial real estate price and macroeconomic—Take Chongqing city as an example ............................................... 927
Achieving Sustainable Construction in South Africa Through Digitalization: An Exploratory Study .............................................................. 935
Organisational Attributes that Determine Design for Occupational Safety and Health Capability ................................................................. 943
An analysis of Stakeholder Management in Design & Build projects in South Australia, from a client’s perspective ................................................................. 951
Lessons and Revelations of Sino - Thai Railway Project .............................................. 959
An overview of multi-project scheduling problems in India with resource constrained and unconstrained settings ................................................................. 967
Building Information Modelling within the Australian Prefabrication: Findings of Opportunities and Barriers ................................................................. 975
Research on the Efficiency of Commercial Real Estate Development from a TFP Perspective ........................................................................................................ 983
Ensuring Teams Integrate Better: Views from Malaysian Construction Builders .............. 992
Quantification of Carbon Emissions of Air Conditioners in Buildings: A Case Study of Shenzhen, China ................................................................. 1000
Transition Towards Solar-Powered Buildings?--Understanding the Debates on Building Integrated Photovoltaics in Singapore Using Q Methodology .............................................. 1008
Evaluation of Green Production in Building Materials Enterprises ................................ 1016
Theme Based Comparison of International Green Neighbourhood Assessment Systems ........................................................................................................ 1027
BIM- and IoT-based Framework for Building Energy Consumption and Indoor Human Comfort Management ................................................................. 1035
Absenteeism due to Manual Handling Job Demands in Australian Construction Industry ........................................................................................................ 1043
China’s AEC Industry and BIM Adoption Challenges: Understanding the Influence of Positive and Negative Mindsets ........................................................................ 1050
A Review of Underused Urban Land Redevelopment in China ..................................... 1058
An Investigation into the Water Infrastructure PPP Failures in Europe: A Case Study Approach ........................................................................................................ 1065
Study of Global Waste Quantification Models ................................................................. 1072
Characterizing the Carbon Emission from Buildings’ Decoration Process: A LCA Study ........................................................................................................ 1080
Critical need for urban regeneration in Perth – a holistic view for sustainable strategy development ........................................................................................................ 1088
Lean and Green: A Conceptual Model for Integrated Targets Design in Construction Projects .................................................................1096
Causes and impact of work related stress amongst construction health and safety managers .............................................................................................................1105
Asymmetric Viewpoints on Solutions Which Enhance Construction Safety: A Social Network Analysis Approach ............................................................1113
Research on application maturity evaluation of BIM in construction project ..........1121
Demystifying the Socio-technical Context of Deploying Distributed PV Systems within the Building Industry ...........................................................................1130
Sustainable Construction Waste Management in Adelaide ................................1138
Addressing the human cost in sustainability rating tools .........................................1147
Carbon emission analysis during the life-cycle of prefabricated buildings: a case study in Shenzhen, China .................................................................................1155
Barriers to the Implementation of Occupational Health and Safety Legislation in the Nigerian Construction Industry .................................................................1163
Empirical Study of Knowledge Management Enablers in Large Construction Organisations ..................................................................................................1171
Opportunities for Improving Construction Health and Safety Using Real-time H&S Management Innovations .................................................................1179
Safety training in construction: a review of training methods and effectiveness .......1189
Design Factors Influencing Energy Performance Gap in Building Retrofit Projects 1197
Characteristic Towns in China under the Background of the Internet+ : Origins, Actions and Risks ........................................................................................................ 1206
Occupant behaviour and its implications in energy use – A literature review ............1214
An Overview of Building Lifecycle Embodied Carbon Emissions Research ............1222
Risk factors for alliance infrastructure construction projects: A study in New Zealand ..................................................................................................................1230
Managing Construction Risks with Equitable Contractual Exclusions ......................1240
Research on the long-term effect mechanism of urban housing market development in China ..................................................................................................1250
Properties of improved magnesium phosphate cement and its Carbon Fiber Composites ..............................................................................................................1262
Real Time Locating System for Construction Safety Management: An explanatory investigation in the Australia ........................................................................1270
System Dialectics of Low or Zero Carbon Building ..................................................1277
Research on the Relationship between Building Industrialization and Labor Productivity of China

Ren, H.¹, Tang, M.H²*, Huo, T.F³ and Chen, Y.⁴

Abstract: This paper analyzes the relationship between building industrialization and labor productivity. Based on Cobb-Douglas production function, the labor productivity model is established to evaluate the effect degree of building industrialization of labor productivity, then a case study of China’s construction industry from 2000 to 2014 is used to evaluate the effect degree. The results demonstrate that the effect of building industrialization on the labor productivity is greater than capital investment, with the percentage of building industrialization increasing by 57.28%, and the percentage of capital investment increasing by 42.72%. Overall the results indicated that building industrialization is an effective way to improve labor productivity in the construction industry.

Key words: Construction industry; Labor productivity; Cobb-Douglas production function; Building industrialization

¹ Ren, H.
School of Construction Management and Real Estate, Chongqing University, China
E-mail: teie@foxmail.com

² Tang, M.H
Corresponding author, School of Construction Management and Real Estate, Chongqing University, China
E-mail: 1341751509@qq.com

³ Huo, T.F
School of Construction Management and Real Estate, Chongqing University, China
E-mail: htf2010@sina.cn

⁴ Chen, Y.
E-mail: 992903250@qq.com
1 Introduction

In recent years, construction industry of China has developed rapidly and become the leader of Chinese economic development. Construction industry is one of the pillar industries of Chinese national economy, the gross output value of the construction industry increased from 345.52 billion yuan to 1805.57 billion yuan from 2005 to 2015, the end of the total output value is 5.3 times of the beginning. Meanwhile, the share of construction added value in GDP also increased from 5.58% in 2005 to 6.86% in 2015, the proportion is much higher than other industries. However, the mechanization level of construction industry in China is low. At present the on-site manual production mode is widely used in construction industry production, and production processes are still dominated by manual operation, which directly lead to the low labor productivity of construction industry of China. According to the study report from US Institute of Construction shows that labor waste and ineffective work is up to 57% in the construction production process, labor productivity is less than one-half of the manufacturing industry. The current labor productivity cannot meet the demand for labor in the construction industry. Therefore, to ensure the development of construction industry and national economy, investing a lot of cheap labor and increasing labor are the basic solution. But China's demographic dividend and the turning point in the population have been disappearing since 2012, which would have a significant impact on labor productivity of construction industry. In recent years, the growth rate of labor productivity in construction industry of China has decreased significantly or even negative, and the lack of labor productivity has affected the development of the construction industry and posed a threat to Chinese economic. As stated above, improving the efficiency of labor production in construction industry is the inevitable choice to solve the shortage of labor force and ensure the sustainable development of construction industry.

The relationship between the building industrialization and the labor saving in construction industry is shown in Table 1. It can be seen that the industrialization of construction industry is proportional to the labor saving, and the higher the proportion of industrialization, the more labor saving and the lower the demand for the labor force in the construction industry. Therefore, building industrialization plays an important role in saving labor force, it can improve the efficiency of labor production greatly and ensure the rapid development of the construction industry.

<table>
<thead>
<tr>
<th>Index</th>
<th>Japan</th>
<th>Russia</th>
<th>France</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building industrialization rate (%)</td>
<td>60</td>
<td>60</td>
<td>40</td>
<td>53.33</td>
</tr>
<tr>
<td>labor saving rate (%)</td>
<td>75</td>
<td>75</td>
<td>42.5</td>
<td>64.17</td>
</tr>
</tbody>
</table>

The labor productivity in the construction industry is directly related to the output efficiency, and researches on labor productivity are very wide, including studying the productivity in the construction industry by estimating a production function to assign weights to various factors responsible for productivity change between 1968 and 1978, measuring the productivity at site level of three European national construction industries and analyzing the reasons, predicting the labor productivity of common industrial construction activities in Canada using fuzzy expert systems, studying construction labor productivity by the PMV-based model, and comparing construction industry labor productivity between P.R .China and more developed countries using...
the productivity and purchasing power parity theories\cite{7-9}.

The following of this paper is made up as follows. The next section measures the labor productivity of Chinese construction industry from 2000 to 2014, then analyzes the influencing factors of labor productivity in construction industry using the Cobb-Douglas function, and an empirical study from 2005 to 2014 is then presented and discussed, the last section is conclusions.

2 Cobb-Douglas function

The Cobb-Douglas production function is a quantitative model that is widely used to measure the relationship between the quantity of inputs and maximum production. In this paper, a constructing equation mode is established to measure the relationship between building industrialization and labor productivity, by analyzing the Cobb-Douglas production function and Solow’s growth equation. The Cobb-Douglas production function assumes that the proportion of inputs in the total ratio of the same, labor and marginal substitution rate of the cost unchanged \cite{10}, the expression is as follow

\[ Y = AK^\alpha L^{1-\alpha} \]  \hspace{1cm} (1)

Where \( Y \) is output, \( K \) is capital investment, \( L \) is labor force; \( \alpha \) is output elastic coefficients of capita; \( A \) is a constant. It is necessary to take time as a variable when consider the relationship between output, labor force and capital investment at one moment. And the Solow’s growth equation is calculated by

\[ Y_t = A_t K_t^\alpha L_t^{1-\alpha} \]  \hspace{1cm} (2)

Where \( Y_t, L_t^{1-\alpha}, A_t, K_t^\alpha \) are expressed as output, labor input, building industrialization level, capital investment respectively at \( t \) time. Let the left and the right side of the equation divided by labor input at \( t \) time, which is determined by the following formula:

\[ \frac{Y_t}{K_t} = A_t \left( \frac{K_t}{L_t} \right)^\alpha \]  \hspace{1cm} (3)

\( \frac{Y_t}{K_t} \) is the labor productivity of construction industry at \( t \) time by phase \( W_t \), logarithmic to equation (3) is calculated by

\[ \ln W_t = \ln A_t + \alpha \ln \frac{K_t}{L_t} \]  \hspace{1cm} (4)

The derivative of equation (4) is calculated by

\[ \frac{\Delta W}{W} = \frac{\Delta A}{A} + \alpha \frac{\Delta Q}{Q} \]  \hspace{1cm} (5)

\( \frac{\Delta W}{W} \) is the average growth rate of labor productivity at a time by phase \( r; \frac{\Delta A}{A} \) is the average speed of increase of building industrialization by phase \( m; \frac{\Delta Q}{Q} \) is the average annual growth of capital equipment ratio by phase \( q \), which is calculated by

\[ r = m + \alpha q \]  \hspace{1cm} (6)

The growth rate of capital equipment ratio (\( \alpha q \)) and the growth rate of construction industrialization (\( m \)) determine construction labor productivity (\( r \)) and they show a linear
correlation. Furthermore, $E_1$ is the degree of promotion of the efficiency of building industrialization for labor productivity of construction industry; $E_2$ is the degree of promotion of capital investment for labor productivity, which is calculated by

$$E_1 = \frac{m}{r} \times 100\%$$  \hspace{1cm} (7) \\
$$E_2 = \frac{n_2}{r} \times 100\%$$  \hspace{1cm} (8)

Then the relationship between labor productivity and industrial construction can be quantified and analyzed.

3 Analysis on Influence Factors of labor productivity

3.1 Measuring process

This paper chooses the number of staff and workers in construction, the value-added of construction and the net value of fixed assets as the sample from 2000 to 2014, which are from the China Statistical Yearbook (2000 -2015). In order to eliminate the impact of inflation, the nominal GDP is converted into the real GDP for all years respectively, based on the price of 2000. As shown in Table 2.

Table 2 Main Indicators of Construction Industry of China from 2005 to 2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of staff and workers in construction (million people)</th>
<th>Value-added of construction (billion yuan)</th>
<th>Net value of fixed assets (billion yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2097.45</td>
<td>3341.09</td>
<td>2831.25</td>
</tr>
<tr>
<td>2001</td>
<td>2283.40</td>
<td>4023.57</td>
<td>3571.63</td>
</tr>
<tr>
<td>2002</td>
<td>2432.34</td>
<td>3822.42</td>
<td>4318.76</td>
</tr>
<tr>
<td>2003</td>
<td>2663.49</td>
<td>4654.71</td>
<td>4547.58</td>
</tr>
<tr>
<td>2004</td>
<td>2688.63</td>
<td>5615.75</td>
<td>4928.40</td>
</tr>
<tr>
<td>2005</td>
<td>2945.20</td>
<td>6899.71</td>
<td>5056.50</td>
</tr>
<tr>
<td>2006</td>
<td>3153.10</td>
<td>8116.39</td>
<td>5520.02</td>
</tr>
<tr>
<td>2007</td>
<td>3446.68</td>
<td>9944.35</td>
<td>5990.69</td>
</tr>
<tr>
<td>2008</td>
<td>3849.50</td>
<td>12488.95</td>
<td>6654.69</td>
</tr>
<tr>
<td>2009</td>
<td>4149.90</td>
<td>15619.82</td>
<td>7591.92</td>
</tr>
<tr>
<td>2010</td>
<td>4708.34</td>
<td>18983.54</td>
<td>8299.91</td>
</tr>
<tr>
<td>2011</td>
<td>5021.72</td>
<td>22070.98</td>
<td>8889.91</td>
</tr>
<tr>
<td>2012</td>
<td>4629.06</td>
<td>26583.31</td>
<td>9582.58</td>
</tr>
<tr>
<td>2013</td>
<td>5271.45</td>
<td>33071.51</td>
<td>9910.36</td>
</tr>
<tr>
<td>2014</td>
<td>5563.47</td>
<td>35270.15</td>
<td>10630.41</td>
</tr>
</tbody>
</table>

* The economic indicators are calculated at comparable prices.

Based on dates (Table 2), the annual labor productivity, capital equipment rate and its change value can be calculated. For the determination of $m$ and $\alpha$ parameters can be used to experience value method, point estimate method and least square method \[^{11}\]. The experience value method is used to estimate the $m$ and $\alpha$ parameters from the past experience, but due to the uncertainty and complexity of economic problems, the estimated parameter values of this method tend to be larger; the point estimate method is based on the study of the two points of the study interval, but the method does not take into account the change of the economic indicators between the two points, so the parameter value obtained is not the optimal value\[^{12}\]; the least square method takes into account the whole time interval when estimating the interval of the parameters, which can make
up for the shortcomings of the experience value method and the point estimate method. Therefore, the following will be used to the least square method, which is calculated by

$$\alpha = \frac{\sum x \cdot q - \sum x \sum q}{n \sum x^2 - (\sum x)^2}$$ \hspace{1cm} (9)

$$m = \frac{\sum x}{n} - \frac{\alpha \sum q}{n}$$ \hspace{1cm} (10)

<table>
<thead>
<tr>
<th>Factors</th>
<th>Average annual growth rate (%)</th>
<th>Effect degree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The average growth rate of labor productivity</td>
<td>18.37</td>
<td>100</td>
</tr>
<tr>
<td>Construction industrialization</td>
<td>10.52</td>
<td>57.28</td>
</tr>
<tr>
<td>Capital equipment</td>
<td>7.85</td>
<td>42.72</td>
</tr>
</tbody>
</table>

### 3.2 Results analysis

As shown in Table 3, the labor productivity of the construction industry has been booming year after year, and annual average increase rate of labor productivity is 18.73% from 2000 to 2015. Fig.2 shows that labor productivity increase from 15900 per person to 63400 yuan per person from 2000 to 2014, which increase four times. But compared with the industrialized countries, the labor productivity of construction industry of China is low, according to the statistics, labor productivity of China is only one-twelfth of the United States and one-eleventh of Japan \(^{13}\). The reason is that the construction mechanization is relatively low, and there is needed a lot of manual work during production. The efficiency of traditional manual operation is easily affected by technical proficiency, professional skill and enthusiasm of workers, so the traditional manual operation is considered less efficient than construction industrialization.

In the case of no change in the scale profit of construction industry, namely the sum of the coefficient of elasticity of effect degree is 1, the output elastic coefficients of capital is \(\alpha = 0.142\), the output elastic coefficients of labor is \(\beta = 1 - \alpha = 0.858\), and the later enhanced more than the former, which means that labor input is the main reason for the rapid development of construction industry in China. Cheap labor can reduce the cost of building work, and it may be the simplest method to improve the construction development, compared with technological innovation, the improvement of mechanized degree. However, problems such as aging populations of construction industry and the recruitment difficulties have gradually been highlighted which caused by China's demographic dividend and the turning point in the population, construction industry is facing a critical shortage of labor. Therefore, improving the efficiency of labor production in construction industry is the inevitable choice to solve the shortage of labor force.

The effect degree of building industrialization and the capital equipment on labor productivity is 57.28%, and 47.28% respectively, the effect degree of building industrialization is greater than capital equipment, so building industrialization is a more important factor to promote the growth of labor productivity. Compared with the traditional manual produce method, building industrialization depends on the operation of machinery instead of manual actions. Module, standardization of design methods can be used to reduce the types and quantity of parts, enhance the versatility of parts, and realize mass production in factory. Then the prefabricated concrete component can be fabricated only by running mechanic equipment on the construction site, and
this way can reduce the impact from natural factors and human factors on construction period, so that the construction time is also under the control, and labor productivity is obviously increased. For example, the industrial level of building industrialization is have reached 75% in Europe and 70% in Japan\textsuperscript{[14]}, because of the high level of industrial construction, the labor productivity of the construction industry in these countries has also increased rapidly. In 2008, the added value of labor productivity in Germany was 115.62 million yuan per person, but in China was 3.24 million yuan per person\textsuperscript{[15]}. Therefore, the building industrialization can increase the level of mechanization of construction and has a significant impact on the labor productivity of the construction industry, and further alleviate the demand for labor shortage.

4 Conclusion

In this paper, we use decomposes the labor productivity in construction industry into building industrialization and capital investment using Cobb-Douglas production function, then an empirical study is done to measure the impact of these factors on labor productivity. It shows that the output elastic coefficients of labor enhanced more than capital, which indicates that construction groups always lie on a huge supply of cheap labor in construction industry instead of technological innovation. And it also shows that the effect degree of building industrialization on labor productivity is 57.28%, the capital equipment is 47.28%, and the effect of building industrialization on the labor productivity of construction industry is greater than capital investment, which can highly improve the labor productivity of construction industry. Improving building industrialization level is an effective way to enhance the labor productivity of the construction industry in China, but as a new production method, there are too many obstacles in the process of implementation. Therefore, Chinese government needs to develop policies to speed up construction industrialization, especially in standard production and mass production which can reduce costs of construction enterprises. The reduction of production cost is a critical factor for construction enterprises, and more companies may adopt construction industrialization, then building industrialization can gradually take the place of traditional manual operation, finally labor productivity of construction industry can be improved effectively.

References:


Case-based Insights to the Rework Costs of Residential Buildings
----- A China Perspective

Gui Ye¹, Qinjun Liu²*, Yi Peng³, Hongxia Wang⁴ and Shilian Zhang⁵

Abstract: Rework is a pervasive problem worldwide and a major cause to the increase in the cost of residential buildings. The pursuit for cost reduction of building construction projects requires careful study on rework and rework cost. Based on the details of six residential buildings in China, this paper presents insights to the rework costs within the Chinese construction context. The analysis result reveals that average rework cost for building projects is about 4.95% of the total project cost. The top three factors contributing to rework costs are contractor field management, design management and client management. And the top three sub-causes are poor communication between client and project users, overdesigned assignment and limited time leading to design weakness or mistakes, and erroneous order. It has been further found that the main liability bearers (client, contractor and designer) for rework costs do not commit corresponding responsibility. These findings lead to a proposal of initiative rework approach for reducing overall rework cost and increasing project value at the same time. This paper provides valuable reference to help project managers understand the major rework causes and adopt proper measures to improve rework management performance in implementing residential buildings. Other building industries can also learn from these findings in controlling rework costs and adopt initiative rework approach for increasing project value under specific circumstances.

Keywords: Residential building; Rework cost; Case study; China

¹ Gui Ye,
School of Construction and Real Estate, Chongqing Univ., China

²* Qinjun Liu,
Corresponding author, School of Construction and Real Estate, Chongqing Univ., China
E-mail: 314797025@qq.com

³ Yi Peng,
School of Urban Rural Planning and Management, Zhejiang Univ. of Finance & Economics, China

⁴ Hongxia Wang,
School of Management, Southwest Univ. of Political Science & Law, China

⁵ Shilian Zhang
School of Construction and Real Estate, Chongqing Univ., China
1 Introduction

Rework is a pervasive problem in construction projects (Han et al. 2013) that significantly affects the objects of construction projects. Reducing field rework is widely regarded as an effective way of improving construction performance in terms of productivity, cost, and schedule (Zhang et al. 2012). The rework cost in major civil engineering projects ranges from 5 to 20% of the project cost (Burati et al. 1992; Barber et al. 2000). The average cost of rework in residential building projects is 3.15% of the contract value (Love and Li 2000), which is a crucial factor that influences building industry profit and development. The aim of this study is to reveal the rework costs for residential building projects in China.

2 Literature Review

The tasks of correcting errors and attending to changes in scope, quality deviations, and nonconformance are commonly referred to as rework, which is a wasteful and non value-adding activity (Love et al. 2016). Based on existing literature on rework cost, rework cost is the sum of all input and loss during rework process, which includes initiative and passive rework costs. Initiative rework means obtaining further function or value to rework despite the fact that the objects have satisfied expected goals. Passive rework means the objects have not satisfied the expected goals, and thus, the objects have to be redone to guarantee function needs. Josephson and Hammarlund (1999) analyzed seven kinds of constructions, which include residential, public, and commercial buildings; they found that rework cost ranges from 2.3% to 9.4% of the contract price of the project. This finding indicates that rework costs are influenced by different kinds of projects. Moreover, rework costs of different types of project in different countries also vary greatly. Table 1 listed the rework cost rate of different types of project in different countries.

<table>
<thead>
<tr>
<th>Source</th>
<th>Country</th>
<th>Project type</th>
<th>Ratio of rework cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burati et al. (1992)</td>
<td>America</td>
<td>Industrial project</td>
<td>12.4% of project cost</td>
</tr>
<tr>
<td>Abdul-Rahman (1995)</td>
<td>England</td>
<td>Infrastructure project</td>
<td>5% of contract value</td>
</tr>
<tr>
<td>Nyle'n (1996)</td>
<td>Sweden</td>
<td>Infrastructure project</td>
<td>10% of contract value</td>
</tr>
<tr>
<td>CIDA (1995)</td>
<td>Australia</td>
<td>Industrial project</td>
<td>10% of project cost</td>
</tr>
<tr>
<td>CII (2005)</td>
<td>----------</td>
<td>Residential/Industrial/Infrastructure project</td>
<td>5% of total construction cost</td>
</tr>
<tr>
<td>Oyewobi et al. (2011)</td>
<td>Nigeria</td>
<td>Residential project</td>
<td>4.49% of total construction cost</td>
</tr>
<tr>
<td>Hammarlund and Josephson (1991)</td>
<td>Sweden</td>
<td>Residential project</td>
<td>4% of actual production cost</td>
</tr>
<tr>
<td>Josephson (1991)</td>
<td>Sweden</td>
<td>Residential/Public/</td>
<td>ranged from 2.3 to 9.4% of the</td>
</tr>
</tbody>
</table>
Hammarlund (1999)  Industrial/Commercial project  contract value of each project
Josephson and Larsson (2002)  Sweden  Residential project  4.4% of construction value
Love and Li (2000)  Australia  Residential/Industrial project  3.15% (residential) and 2.40% (industrial) of contract value
Love (2002(a))  Australia  Residential project  12% of project cost
Love et al. (2004)  Sweden  Industrial project  12% of project cost
Love et al. (2010)  Australia  Infrastructure project  10.29% of contract value

3 Research Methodology

Cased-based approach is adopted in this study to examine the rework cost for building projects. Six cases were investigated in details in this study to collect data through interviews, project documentation, and on-site observations.

3.1 A Framework of Rework Activities

Based on the classification of rework activities from Josephson et al. (2002), this paper established a framework of rework activities within two dimensions---design-generated rework and construction-generated rework, as shown in Table 2.

Table 2. A Framework of Rework Activities (adapted from Josephson et al.2002)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rework caused by design</td>
<td>1.1 Change—Change during design stage</td>
</tr>
<tr>
<td></td>
<td>1.2 Error—Error during design stage</td>
</tr>
<tr>
<td></td>
<td>1.3 Omission—Omission during design stage</td>
</tr>
<tr>
<td></td>
<td>1.4 Operational improvement—Voluntary rework during design stage</td>
</tr>
<tr>
<td>2. Rework caused by construction</td>
<td>2.1 Error—Error during construction stage</td>
</tr>
<tr>
<td></td>
<td>2.2 Omission—Omission during construction stage</td>
</tr>
<tr>
<td></td>
<td>2.3 Damage—Damage during construction stage</td>
</tr>
<tr>
<td></td>
<td>2.4 Operational improvement—Voluntary rework during construction stage</td>
</tr>
</tbody>
</table>

3.2 Data Collection

Three research personnel were employed and placed on sites as observers. The data collection procedure followed major prescriptions in doing fieldwork research (Dane, 1990). Various sources were utilized to collect rework data including documentary sources, interviews, and on-site observations. A total of 1170 rework documents of six cases were received after signing the confidentiality agreement.

Documentary sources include static and dynamic records. Static records include documents signed before project implementation, such as the contracts, schedule, drawings. Dynamic records
are documents that reflect the dynamic process of the project, such as daily logs of implementation and supervision, meeting summary, monthly progress reports, and rework bills. Interview transcriptions are records of the interviews conducted to each entity at the construction project. Key persons involved in the rework activities were interviewed by the researcher using a predefined interview protocol about rework activities and cost. Respondents include clients, designers, supervisors, developers, suppliers, and managers. Field records refer to records of the field observation of researchers on rework activities and cost. The data collected was described using a form (Figure 1), particularly to capture causes of rework, processes, responsibilities, and classification.

**Project Number:** XLM012  
**Date:** 2016.09.01

<table>
<thead>
<tr>
<th>Type of rework</th>
<th>Scratch of the wall</th>
<th>Time</th>
<th>14:23</th>
<th>Reported by</th>
<th>Site manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position of rework</td>
<td>Interior walls at the stairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Causes of rework</td>
<td>Insufficient protection for the project completed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Induced by</td>
<td>Sub – contractor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change of cost</td>
<td>An increase of rework cost by 78 yuan (RMB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paid by</td>
<td>Sub – contractor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change of construction period</td>
<td>An increase of construction period by 3 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Description**

Project of rework: X002.  
Details of rework:  
The sub-contractor was doing fit-out work at the third floor.  
Due to the negligence of the workers, they scratched the interior walls on the stairs at the second floor when they were conveying doors from the ground floor to the third floor. So rework must be done before the remove of materials.  
Cost increase: material cost (35 RMB) + equipment/tools cost (13 RMB) + labor cost (30 RMB)

**Fig. 1. Example of the collection of rework data**

### 4 Result

To have better understanding of rework cost, relevant crucial variables need to be counted. The three variables are rework cost rate ($R$), rework frequency/price ($F_1$) and rework frequency/period ($F_2$). Statistical techniques are used to calculate these variables. The calculation formulas are as follows:

$$R = \frac{\text{Rework cost}}{\text{Project price}} \quad (1)$$
F1= Rework frequency / Project price \hspace{1cm} (2)
F2= Rework frequency / Project period \hspace{1cm} (3)

The calculating results are shown in Table 3.

<table>
<thead>
<tr>
<th>Project</th>
<th>Types</th>
<th>Developer qualification</th>
<th>Rework cost rate (R)</th>
<th>Frequency/Price (F1)</th>
<th>Frequency/period (F2)</th>
</tr>
</thead>
</table>
| X001    | Villa  
(2 layers ) | First                   | 3.54%                | 1.68                 | 21.17                  |
|         | Small high    |                         |                      |                      |                        |
| X002    | rise  
(18 layers) | First                   | 4.44%                | 0.08                 | 10.12                  |
| X003    | Multi-layer  
(7 layers) | Second                  | 6.27%                | 0.57                 | 11.25                  |
| X004    | Multi-layer  
(6 layers) | First                   | 3.13%                | 0.42                 | 13.13                  |
| X005    | High-rise  
(31 layers) | First                   | 2.07%                | 0.09                 | 11.67                  |
| X006    | Multi-layer  
(7 layers) | Third                   | 10.27%               | 0.73                 | 29.71                  |
| Average |                |                         | 4.95%                | 0.59                 | 16.18                  |

After integrating rework data from the three documentary sources, a total number of 2,425 rework activities were detected and registered by the research personnel placed on the six sites during the periods of observation. Rework cost is about 5,127,947.84 RMB. It can be seen from Table 3 that the percentage of rework cost ranges from 2.07% to 10.27%. The average rework cost rate is 4.95%. In consideration of the characteristics of Chinese residential projects, this study employed the classification system of rework causes from Ye et al. (2015). The rework causes of the six projects would be divided into eleven categories according to the classification of rework cause of Ye et al. (2015). Table 4 lists the rework costs incurred by different rework causes.
Table 4. The Summary of Rework Cost Based on Rework Causes

<table>
<thead>
<tr>
<th>Category of rework cause</th>
<th>X001</th>
<th>X002</th>
<th>X003</th>
<th>X004</th>
<th>X005</th>
<th>X006</th>
<th>Total rework cost (RMB)</th>
<th>Percentage in total rework cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design management</td>
<td>2677.5</td>
<td>665760</td>
<td>34628.15</td>
<td>31283.2</td>
<td>147346.9</td>
<td>87903.15</td>
<td>969598.8837</td>
<td>18.91%</td>
</tr>
<tr>
<td>Project communication management</td>
<td>2677.5</td>
<td>221920</td>
<td>20776.89</td>
<td>15641.6</td>
<td>147346.9</td>
<td>175806.3</td>
<td>584169.1769</td>
<td>11.39%</td>
</tr>
<tr>
<td>Contractor field management</td>
<td>21420</td>
<td>221920</td>
<td>34628.15</td>
<td>46924.8</td>
<td>442040.6</td>
<td>26370.5</td>
<td>1030643.043</td>
<td>20.10%</td>
</tr>
<tr>
<td>Project scope management</td>
<td>5355</td>
<td>221920</td>
<td>24239.71</td>
<td>15641.6</td>
<td>26522.44</td>
<td>43951.58</td>
<td>337630.3226</td>
<td>6.58%</td>
</tr>
<tr>
<td>Initiative rework</td>
<td>2677.5</td>
<td>665760</td>
<td>17314.08</td>
<td>3910.4</td>
<td>139979.5</td>
<td>87903.15</td>
<td>318360.663</td>
<td>6.21%</td>
</tr>
<tr>
<td>Project plan changes</td>
<td>2677.5</td>
<td>99864</td>
<td>70987.72</td>
<td>4692.48</td>
<td>29469.38</td>
<td>43951.58</td>
<td>251642.6478</td>
<td>4.91%</td>
</tr>
<tr>
<td>Sub – contractor management</td>
<td>7497</td>
<td>377264</td>
<td>43285.19</td>
<td>3910.4</td>
<td>47151</td>
<td>61532.21</td>
<td>540639.8007</td>
<td>10.54%</td>
</tr>
<tr>
<td>Contract documentation</td>
<td>2677.5</td>
<td>221920</td>
<td>3462.815</td>
<td>14859.52</td>
<td>14734.69</td>
<td>26370.95</td>
<td>84297.46933</td>
<td>1.64%</td>
</tr>
<tr>
<td>Client management</td>
<td>2677.5</td>
<td>221920</td>
<td>65793.49</td>
<td>15641.6</td>
<td>405203.9</td>
<td>43951.58</td>
<td>755188.076</td>
<td>14.73%</td>
</tr>
<tr>
<td>External environment</td>
<td>535.5</td>
<td>22192</td>
<td>6925.631</td>
<td>1564.16</td>
<td>44204.06</td>
<td>0</td>
<td>75421.3527</td>
<td>1.47%</td>
</tr>
<tr>
<td>Total</td>
<td>53550</td>
<td>2219200</td>
<td>346281.5</td>
<td>156416</td>
<td>1473469</td>
<td>879031.5</td>
<td>5127947.837</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

It can be found in Table 4 that the contractor field management, design management, and client management are the highest three category of causes for total rework cost. Besides, each cause has its sub-causes which provide specific rework mistakes or defects, as shown in Table 5. The most important sub-cause is “the poor communication between client and users (CL1),” which is 8.1% of total rework cost. “Overfull design assignment with limited time induces mistake of design (DM1)” is 7% of total rework cost. “Erroneous order (PI2)” accounts for 6.95% of total rework cost. Hence, these three sub-causes can be considered key research objects in our future study.
<table>
<thead>
<tr>
<th>Factor (category of reasons)</th>
<th>Variable included in the factor (sub-causes)</th>
<th>Contribution to rework costs (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Contractor field management related factor</td>
<td>CM1 Ineligible technique</td>
<td>6.63%</td>
</tr>
<tr>
<td></td>
<td>CM2 Ineligible material</td>
<td>5.63%</td>
</tr>
<tr>
<td></td>
<td>CM3 No check the material or equipment</td>
<td>1.41%</td>
</tr>
<tr>
<td></td>
<td>CM4 Ineligible quality of construction process</td>
<td>1.61%</td>
</tr>
<tr>
<td></td>
<td>CM5 Non-Standard construction</td>
<td>2.21%</td>
</tr>
<tr>
<td></td>
<td>CM6 Misunderstanding the design intention</td>
<td>1.61%</td>
</tr>
<tr>
<td></td>
<td>CM7 Low quality of equipment</td>
<td>1.00%</td>
</tr>
<tr>
<td>F2 External environment related factor</td>
<td>EX1 Abnormal natural conditions</td>
<td>0.81%</td>
</tr>
<tr>
<td></td>
<td>EX2 New demands of users</td>
<td>0.22%</td>
</tr>
<tr>
<td></td>
<td>EX3 Users are unidentified with exiting standards</td>
<td>0.16%</td>
</tr>
<tr>
<td></td>
<td>EX4 Shortage of equipment or the price changes greatly</td>
<td>0.28%</td>
</tr>
<tr>
<td>F3 Contract management related factor</td>
<td>CD1 Fuzziness of project scope in contract</td>
<td>0.49%</td>
</tr>
<tr>
<td></td>
<td>CD2 Unfulfilled contract</td>
<td>0.46%</td>
</tr>
<tr>
<td></td>
<td>CD3 Ambiguity or contradiction of contract</td>
<td>0.41%</td>
</tr>
<tr>
<td></td>
<td>CD4 Low fee or the fee not pay in time</td>
<td>0.28%</td>
</tr>
<tr>
<td>F4 Subcontractor management related factor</td>
<td>SC1 Sub contractors are separated from each other</td>
<td>3.16%</td>
</tr>
<tr>
<td></td>
<td>SC2 Poor communication between professionals</td>
<td>2.95%</td>
</tr>
<tr>
<td></td>
<td>SC3 Poor protection of projects</td>
<td>2.42%</td>
</tr>
<tr>
<td></td>
<td>SC4 Poor communication between constructors</td>
<td>2.00%</td>
</tr>
<tr>
<td>F5 Design management related factor</td>
<td>DM1 Overfull design assignment with limited time leading to mistake of design</td>
<td>7.00%</td>
</tr>
<tr>
<td></td>
<td>DM2 The poor communication between majors leading to mistake of design works</td>
<td>6.05%</td>
</tr>
<tr>
<td></td>
<td>DM3 Design works separate from constructional condition</td>
<td>5.86%</td>
</tr>
<tr>
<td>F6 Project communication management related factor</td>
<td>PI1 Understanding error</td>
<td>4.44%</td>
</tr>
<tr>
<td></td>
<td>PI2 Erroneous order</td>
<td>6.95%</td>
</tr>
<tr>
<td>F7 Project plan changes related factor</td>
<td>PC1 Construction material or equipment changed</td>
<td>1.86%</td>
</tr>
<tr>
<td></td>
<td>PC2 Construction plan changed</td>
<td>1.72%</td>
</tr>
<tr>
<td></td>
<td>PC3 Budgetary changed</td>
<td>1.32%</td>
</tr>
<tr>
<td>F8 Initiative rework related factor</td>
<td>IR1 Initiative rework of realizing project goal better</td>
<td>4.66%</td>
</tr>
<tr>
<td></td>
<td>IR2 Initiative rework of improving design quality</td>
<td>1.55%</td>
</tr>
<tr>
<td>Related Factor</td>
<td>Sub-cause</td>
<td>Percentage</td>
</tr>
<tr>
<td>---------------</td>
<td>-----------</td>
<td>------------</td>
</tr>
<tr>
<td>F9 Client management</td>
<td>CL1: The poor communication between client and project users</td>
<td>8.10%</td>
</tr>
<tr>
<td></td>
<td>CL2: No constructional condition</td>
<td>6.63%</td>
</tr>
<tr>
<td>F10 Project scope management</td>
<td>PS1: Project scope changed</td>
<td>3.56%</td>
</tr>
<tr>
<td></td>
<td>PS2: Project function changed</td>
<td>3.03%</td>
</tr>
<tr>
<td>F11 Project process management</td>
<td>PP1: Fuzziness of project management</td>
<td>2.29%</td>
</tr>
<tr>
<td></td>
<td>PP2: Non-implementation of project management process</td>
<td>1.23%</td>
</tr>
</tbody>
</table>

### 5 Conclusion

Based on six cases studies, this research found that rework cost is significant in building works in China, with average value of 4.95% of the total project cost. Moreover, it is found that rework cost rate has significant correlations with the complexity of projects, as well as the qualification level of building developers. The study reveals that the main causes for rework costs include contractor field management, design management and client management. And the three major sub-causes are poor communication between client and project users (CL1), overfull design assignment with limited time leading to mistakes in design (DM1), and erroneous order (PI2). The study further illustrates that the main liability-bearers for rework do not take up corresponding responsibilities. For reducing rework costs and increasing project value, this study proposes the adoption of initiative rework approach.

The study contributes to the improvement of project management in China by providing reference for reducing rework costs. As China has the largest building sectors, the improvement of Chinese building industry can in turn make contributions to the development of building industry globally. The study also contributes to the development of literature in the field of project cost management. For practical implication, the present study provides reference and help project managers understand where the major causes of rework costs are. Thus, project managers could take proper methods to reduce rework cost and improve project cost management as a whole.

It is appreciated that the data used in this study are direct rework costs only. It is recommended for our future research to incorporate indirect rework cost into analysis. Moreover, the number of study cases could be increased and this is planned for our future study. Further research efforts are also proposed to investigate the application of initiative rework approach for improving the performance of managing reworks.

### Acknowledgements

This work was supported by the National Natural Science Foundation of China [grant number 71471023]; Fundamental Research Funds for the Central Universities [grant number 106112016CDJSK03XK07]; Youth Foundation of Ministry of Education of China [grant number...
number 12YJCZH255]; International Research Center for Sustainable Built Environment and Research Center of Construction Economics and Management of Chongqing University.

Reference


Social Capital, Safety Cognitive and Construction Safety Behavior

Wu, X.Y.\textsuperscript{1*}, Li, S.Q\textsuperscript{2} and Fan, M.\textsuperscript{3}

Abstract: In order to analyze the influence of construction individual and organization, atmosphere, and other social factors on construction workers safety behavior, this paper built an influencing factor system of construction worker safety behavior based on the theory of social capital, cognitive psychology, and designed the questionnaire for construction workers in China. The paper made an empirical analysis on the relationship among social capital, safety cognitive and safety behavior by using factor analysis and structural equation model (SEM) theory. The results show that: safety cognitive plays a significant positive correlation on safety behavior and both the cognitive dimension and the relational dimension play a significant positive impact on safety cognitive and safety behavior. However, the impact of the structural dimension of social capital on safety cognitive and safety behavior is not significant. The results provide a new thought to improve workers’ safety behavior for construction enterprises.

Keywords: Social capital; Safety cognitive; Safety behavior; Empirical analysis.

\textsuperscript{1*} Wu, X.Y.
Corresponding author, School of Management Science and Engineering, Tianjin University of Finance and Economics, China
E-mail: xywu2014@126.com

\textsuperscript{2} Li, S.Q.
School of Management Science and Engineering, Tianjin University of Finance and Economics, China

\textsuperscript{3} Fan, M.
School of Management Science and Engineering, Tianjin University of Finance and Economics, China
1 Introduction

A series of accident causation theories suggest that the employee’s unsafe behavior and the object’s unsafe condition cause the safety accidents directly. Meanwhile, the reasons of employee’s unsafe behavior have been focused all the time. Heinrich pointed out that human’s shortcomings, which is caused by genetic factors and social environment, leads to employee’s unsafe behavior[1]. On this basis, Surry proposed the accident model theory based on cognitive process analysis. In this model, the accident was divided into dangerous appear and dangerous release, in which any one of employee’s feeling, understanding and behavior response going wrong will result in accident[2].

The researches on the reasons of unsafe behavior mainly contain individual physiological characteristics and psychological characteristics, organization safety management and social environment. It’s helpful for enterprises to improve employees’ safety behavior and get good safety performance, but except for the above aspects, construction workers’ behavior is also affected by “relationship”, such as the relationship among individuals, organization and social environment. Especially when construction workers are lack of safety knowledge and awareness, they are more susceptible by “relationship” in networked and complex society. Some socialists called the relationship as social capital, and there have been plenty researches suggested that social capital has positive impact on social or economic activities[3][4]. However, the study of social capital based on construction workers is rare. The aim of this paper is to find whether social capital affects construction workers’ safety behavior, and if it does, how it affects.

This paper built an influencing factor system including social capital, safety cognitive and safety behavior, designed the questionnaire and made an empirical analysis by using structural equation model theory. The results provide a new thought to improve workers’ safety behavior for construction enterprises.

2 Literature Review and Hypotheses

2.1 Safety cognitive and safety behavior

Neisser defined cognitive as the whole process including sensory input, transformation, processing, store, restoration, and application[5]. Ajzen and Fishbein proposed the theory of reasoned action and the theory of planned action based on cognitive perspective. The theories suggest that environment around people and their knowledge affect people’s behavior attitudes, subjective norm, and perceived behavioral control and then these three elements decide people’s behavior intention and behavior[6]. Allahyari et al. pointed that the higher rate of cognitive failure leads to higher risk of accidents through the analysis of accidents[7]. Fugas studied the important role of safety cognitive as a mediator between safety climate and safety behavior[8]. According to the above literature analysis, this paper divided employee’s safety cognitive into safety awareness, safety knowledge and safety attitude, and put forward the first hypothesis H1:

H1: Construction workers’ safety cognitive is positive correlation with their safety behavior.

2.2 Social capital, safety cognitive and safety behavior

The origin of social capital is the studies of social network. Bourdieu, the French sociologist, gave the first definition of social capital. He pointed out that social capital is an actual or potential
resource aggregation closely combining with some kind lasting relationship network which is accepted by most people, and each individual in the network has the right to get some resource\cite{9}. Burt proposed “structural hole theory” which also points out that the position of individuals in network has great impact on their behavior\cite{10}. In order to measuring social capital, Nahapiet and Ghoshal designed three dimensions including structural dimension, cognitive dimension and relational dimension, which made an important contribution to the development of social capital. Structural dimension means the centricity and contact strength of individuals, cognitive dimension means the shared values and knowledge between individuals or groups, and relational dimension means the trust and emotions between individuals and groups\cite{11}. Social capital is related to organizational culture or climate, but not the same, the former is more concerned with the structure and conduct of social interaction, both internal and external to a company or organization, the latter means more about generalized values or norms in the company or organization\cite{12}. Rao analyzed the causes of accidents based on social capital, and he found out that not only the obvious measures such as safety training and safety code, but social capital factors such as social network and the trust between individuals have an effect on the accidents\cite{13}. Kines proved that it can improve construction site safety through strengthening communication between foremen and workers\cite{14}.

Construction enterprises have strong staff mobility\cite{15}, it’s easy to do unsafe behavior for them because most workers are unfamiliar with each other and their jobs initially. In this condition, individuals’ social capital such as centricity, trust and shared values play an important role for keeping them from unsafe behavior. In order to explain the relationship between social capital and safety behavior, the paper put forward the following hypotheses:

H2: Construction workers’ social capital is positive correlation with their safety cognitive.
H2a: Structural dimension of social capital is positive correlation with safety cognitive;
H2b: Cognitive dimension of social capital is positive correlation with safety cognitive;
H2c: Relational dimension of social capital is positive correlation with safety cognitive;
H3: Construction workers’ social capital is positive correlation with their safety behavior.
H3a: Structural dimension of social capital is positive correlation with safety behavior;
H3b: Cognitive dimension of social capital is positive correlation with safety behavior;
H3c: Relational dimension of social capital is positive correlation with safety behavior;

Based on the literature review and hypotheses, we built the conceptual model including social capital, safety cognitive and safety behavior (as shown in Figure.1). It shows that safety behavior is affected by social capital both directly and indirectly. Direct effect is shown by H3a, H3b and H3c, and indirect effect is shown by H2a, H2b and H2c. In this way, safety cognitive serves an intermediary between social capital and safety behavior.

3 Methodology

3.1 Questionnaire design

In order to get data for empirical analysis, we need to choose indexes for each variable. The paper summarized some acknowledged measurement indexes of social capital, safety awareness and safety behavior through the related literatures. The structure dimension of social capital includes the connection and familiarity among employees, the cognitive dimension of social capital includes shared vision, the relation dimension of social capital includes confidence, and the safety
awareness includes consciousness, knowledge and skills and attitudes. And safety behavior is commonly divided into safety obedience, obeying safety codes, and safety participation, attending safety education. On the basis, a relevant scale was determined, as shown in Table.1. Measuring item was designed with 5 levels of Likert Scale, taking 5 measures for each question, from "strongly disagree" to "strongly agree" respectively for 1 ~ 5 points.

3.2 Data analysis

330 out of 350 questionnaires have been taken back and after screening of consistency and logicality 316 questionnaires have been adopted. The projects include civil construction(60.13%), industrial building projects(16.77%), municipal utilities(13.61%) and other projects(9.49%), Most respondents education level is the high school and college level, accounting for 28.16% and 39.24% respectively, followed by 17.72% undergraduate level. Most respondents are the professional and technical personnel (55.38%), which play an important role in getting workers safety conditions, followed by the first-line managers, the project managers who have a clear understanding about employees’ safety behavior, accounting for 23.10%.

4 Results and Discussion

4.1 Reliability and validity

Before the factor analysis, it is necessary to test the reliability and validity of the questionnaire. By using SPSS19.0 the paper has calculated that the reliability coefficient of the questionnaire is 0.890>0.8, proved that the questionnaire has good reliability. Validity test can be divided into content validity and structure validity. The content validity of the questionnaire refers to the expression degree of the corresponding item of variable and the appropriateness of measuring range. To improve the content validity, the method of expert evaluation and field research are widely adopted to revise the item. Structure validity, generally measured by the Kaiser-Meyer-Olkin (KMO) coefficient and the Bartlett test. The results shows that the KMO value of 0.892 is greater than 0.7, and Bartlett test sig.=0.000<0.005 and it is reasonable and necessary to do exploratory factor analysis.
Table 1 Rotating component matrix

<table>
<thead>
<tr>
<th>Items</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>a1 workers are familiar with each other</td>
<td>0.797</td>
</tr>
<tr>
<td>a2 workers often exchange views on safety issues</td>
<td>0.845</td>
</tr>
<tr>
<td>a3 workers often have dinners after work</td>
<td>0.532</td>
</tr>
<tr>
<td>b1 workers make efforts for company development</td>
<td>0.674</td>
</tr>
<tr>
<td>b2 workers have a clear understanding on company’s development</td>
<td>0.732</td>
</tr>
<tr>
<td>b3 workers are proud of being a member of the company</td>
<td>0.750</td>
</tr>
<tr>
<td>b4 workers reach an agreement on teamwork focused</td>
<td>0.661</td>
</tr>
<tr>
<td>c1 workers trust each other</td>
<td>0.641</td>
</tr>
<tr>
<td>c2 pay attention to interpersonal relationships</td>
<td>0.545</td>
</tr>
<tr>
<td>c3 help each other</td>
<td>0.523</td>
</tr>
<tr>
<td>c4 project supervisor consider suggestions seriously</td>
<td>0.428</td>
</tr>
<tr>
<td>m1 keep high vigilance when working</td>
<td>0.782</td>
</tr>
<tr>
<td>m2 find risk in time based on experience</td>
<td>0.768</td>
</tr>
<tr>
<td>m3 skills and knowledge are enough to go through work</td>
<td>0.593</td>
</tr>
<tr>
<td>m4 eliminate accident potential in time</td>
<td>0.809</td>
</tr>
<tr>
<td>m5 keep yourself mood out of work</td>
<td>0.535</td>
</tr>
<tr>
<td>m6 work with best state</td>
<td>0.466</td>
</tr>
<tr>
<td>n1 volunteered for safety education activities</td>
<td>0.640</td>
</tr>
<tr>
<td>n2 correct colleagues mistakes actively</td>
<td>0.839</td>
</tr>
<tr>
<td>n3 often suggest something about safety</td>
<td>0.499</td>
</tr>
<tr>
<td>n4 observe safety specification</td>
<td>0.686</td>
</tr>
<tr>
<td>Explained the cumulative total variance</td>
<td>20.571</td>
</tr>
</tbody>
</table>

4.2 Exploratory factor analysis

The data are randomly divided into two parts, respectively for exploratory factor analysis and structural equation model analysis. The former is also completed by SPSS19.0, using principal component analysis (PCA) to extract common factor with the principle of eigenvalues greater than 1. Factor loading matrix after orthogonal rotation is shown in Table 1.

The Table 1 shows that extraction of common factors, which can explain most of the variables, is consistent with the assumption put forward when the questionnaire is designed. The five common factors named respectively: structure dimension, cognitive dimension, relationships, dimensions, safety awareness and safety behavior. In addition, because the factor loading of the three variables (c4, m6, n3) is less than 0.5 and can not clearly reflect the characteristics of the common factors, these variables are eliminated in the structural equation model analysis. Exploratory factor analysis has laid a foundation for the construction of the structural equation model and the analysis below.

4.3 Structural model analysis
4.3.1 Results of the model

According to the assumptions above and factor analysis, AMOS17.0 software is used to build the structure equation model of social capital, safety cognition and behavior, but the fitting degree of the model is not that good, so further correction for the model is necessary. Based on the Modification Indices (MI) and estimated Par Charge the model can be corrected step by step. Build covariant relationship among error terms whose MI are large, and then get the final model after the two correction steps, as shown in Figure.2.

![Diagram](image)

Model fitting index: RMSEA=0.045, GFI=0.912, CFI=0.933, PGFI=0.656

**Figure 2. Modified structural equation model**

The Figure.2 shows that correction of the model is respectively establishment of error term covariant relationship between the m1 and n4, the m4 and n2. The fitting degree of the final mode is up to standard that means it has adapted to the theoretical model and actual data in absolute adaptation index, value-added adaptation index and contracted adapter indicators, showing that the construction of model is effective.

4.3.2 Discussion

The relationship among variables is significant except that structural dimension has no significant impact on safety cognition and safety behavior. The relationship among variables can be explained as follows:

1. Safety cognition and safety behavior have significantly positive correlation ($r=0.272$, $P=0.034$). Level on safety cognition has a positive effect on security behavior, which also confirms Ajzen’s planned behavior theory in the field of security applications. Safety behavior of construction personnel is determined by their security behavioral intention, whereas safety behavior intention is also under the influence of safety cognition level, including safety consciousness, safety attitudes, safety knowledge and skill level. A high level of safety cognition essentially makes people form the tendency to safety behavior, prompting security behavior. So the H1 is supported.

2. Relationship between structural dimension of social capital and safety cognition is not significant ($r=0.210$, $P=0.112$). Structural dimension of social capital refers to individual centrality or connection intensity with others. Although it is pointed out in Burt's structural hole theory that people or companies with higher structure dimensions level have an edge in the competition, but when in the face of safety issues in the construction work, there is no obviously positive correlation between individual centrality and connection intensity and safety cognition. This may because frequent
connection or informal gathering of construction workers can not prompt employees to strengthen safety cognition, on the contrary, personal centricity is so strong that key emphasis in work may be reduced, thus distracting the attention to safety. To a certain extent, the view Kines points out that strengthening the connection between foreman and construction workers helps to improve construction safety\(^{[14]}\), focuses on the structure dimension of site managers, rather than the construction workers, so the H2a is not supported.

(3) Cognitive dimension of social capital and safety cognitive have significant positive correlation \((r=0.267, P=0.028)\). Cognitive dimension of social capital usually refers to consistency of the employees' values and enterprise values, or the commitment employees put forward for the shared vision of the enterprise. When construction enterprises view safety as the primary goal, if construction workers be consistent with the enterprise without interference by other factors, they would be more vigilant when doing construction work, and would work with the best state as far as possible, so as to improve their safety awareness. So the H2b is supported.

(4) Relational dimension of social capital and safety cognitive have significantly positive correlation \((r=0.367, P=0.005)\). Relational dimensions of social capital include trust among the staff, helping each other and personal relationships. Because the mobility of construction workers in most team is high, and there is inevitable contact when different professional teams do construction work, whether construction workers trust each other rapidly to form a good interpersonal relationship circle has important influence for the individual to maintain a good psychological states at work. Having good interpersonal relationships can also make them improve their safety knowledge and skills when doing construction work, so as to improve their safety cognitive. So the H2c is correct.

(5) Relationship between structural dimension of social capital and safety behavior is not significant \((r=0.162, P=0.200)\). The same to relationship between structure dimension and safety cognition, in construction enterprises, level of the social capital structure dimension of construction workers does not significantly affect their safety behavior; on the contrary, the strong centricity will produce sense of superiority, thus making the personals ignore the importance of their behavior for safety operation, and then produce unsafe behavior. So the H3a is not supported.

(6) Cognitive dimension of social capital and safety behavior have significantly positive correlation \((r=0.436, P=0.002)\). Cognitive dimension of social capital will restrain unsafe behavior and motivate safety behavior of employees by establishing informal norms between employees and enterprises. Construction workers’ recognition on "safety first" and other targets of the enterprises is a kind of informal norm, and it directly affect this construction workers, so as to change their behavioral decision. So the H3b is supported.

(7) Relational dimension of social capital and safety behavior have significantly positive correlation \((r=0.416, P=0.005)\). Apart from indirectly affect employee behavior by influencing safety cognition, relational dimension of social capital also directly affect safety behavior. As the relationship dimension level of the individuals is high, this “good relationship” with their colleagues will promote them to try to make a safe behavior on some key issues, so as to avoid damaging the “relationship” with their colleagues. So the H3c is supported.

5 Conclusions

Based on social capital theory, cognitive psychology and safety behavior theory, this paper put forward the views that for promoting employees’ safety behavior it is necessary to focus on trust
relationships between colleagues, the values of the individual and other social network level factors. The result has provided a new thought for construction enterprises to improve level of employees' safety behavior. And how construction enterprises cultivate the employee's level of social capital and improve their individual social capital will be one of the directions of future research.

Funding

The authors wish to thank the Natural Science Foundation of China (Grant Nos. 71171140; 71571130) for their generous funding of this study.

References

Transfer Success Criteria for Public-Private Partnership Infrastructure Projects

Bao, F.Y.¹², Chen, C.³* and Chan, A.P.C.⁴

Abstract: For numerous public-private partnership (PPP) infrastructure projects, transfer is the last phase of the concession period. It has been observed that unsuccessful management of transfer phase leads to returned projects with substandard residual value and status. Unfortunately, both practice experience and research on how to manage transfer phase is limited. Serving as part of a systematic research on transfer phase of PPP project, this paper aims to develop a transfer success (TS) criteria framework. In this paper, TS is defined as the integration of transfer product success (TPS) and transfer management success (TMS). TPS focuses on realizing the goal and purpose of transfer, while TMS evaluates the process-based performance of transfer management. A series of TS success criteria are identified from literature, and then classified according to the definition of TS. It is hoped that the proposed TS criteria framework would aid the government to receive project assets with desirable state; thereby succeeding post-transfer operation of the infrastructure can be achieved.

Keywords: Public-Private Partnership; Life Cycle; Transfer Phase; Success Criteria; Framework.

¹² Bao, F.Y.
Institute for Disaster Management and Reconstruction, Sichuan University, China; Department of Building and Real Estate, The Hong Kong Polytechnic University, China

³* Chen, C.
Corresponding author, Business School, Sichuan University, China
Email: chenchuan.scu@qq.com

⁴ Chan, A.P.C.
Department of Building and Real Estate, The Hong Kong Polytechnic University, China
1 Introduction
The normal range of the public-private partnership (PPP) life cycle (PLC) is 10 to 30 years and includes several phases. For a considerable number of PPP projects, the last phase of concession period (i.e., transfer phase) is to transfer project assets back to the government [1]. Via transfer phase, the government longs to receive the project assets, which has been operated by the project company for decades, with desirable actual status. This objective is challenging as the transfer phase is rather short (usually one to two years) compared to the long PLC, while the tasks need completing within the phase are tremendous. Moreover, the private sector tends to decrease the effort in maintenance during the last period of concession agreement, which may result in substandard residual value and condition of the assets [2]. Thus, transfer phase should be well taken care of to ensure that the government possesses actual knowledge of assets received so that the private sector’s opportunistic behaviours could be reduced or even eliminated. As a result, the condition of the returned infrastructure could be good enough to provide sustainable public service or product.

Among various PPP research topics, success is obviously one of the foci [3]. Previous research has found that not all PPP projects have achieved equal success; some of them even totally failed or have been cancelled, causing mountains of social resource wastes [4]. To alleviate the problem, researchers have made great efforts to figure out how to achieve PPP project success [5-7]. Those studies mostly refer to the success of earlier phases of the PLC, e.g., procurement or deliverable success [8]. Whereas few previous studies focused on the success of transfer phase. Furthermore, the practice experience and guidelines on transfer are limited possibly because a small number of projects have reached this phase [1]. In this context, poor management of transfer phase tends to occur and result in unexpected low residual value and performance of assets returned [9, 10]. As time goes by, increasing projects will enter the transfer phase, and consequently, the poor outcome of transfer management may even go worse. In this case, a systematic research on how to guarantee transfer success (TS) is essential. This paper serves as part of a systematic research on transfer phase, and aims to establish a TS criteria framework by reviewing relevant literature, identifying success criteria for TS, and in turn classifying and discussing the TS criteria. Hopefully, the results of the study could help the government receive project assets with good condition that is necessary for succeeding post-transfer operation of the infrastructure. The research outcomes can also provide reliable foundation for systematic investigation on the transfer phase.

The next section reports some important studies on success, followed by the development of TS criteria framework. Conclusions and future directions of the paper are presented in the last section.

2 Literature Review
A fact is that no unanimous definition for success has yet been reached. Some tentative definitions for success tend to be viewed as ambiguous from either the perspectives of stakeholders or the stages of the project’s life cycle [11]. This section briefly introduces the research findings about success in construction and PPP domains.

2.1 Success for Construction Projects
Over the past 60 years, cost, time and quality, which are called the iron triangle, have become the most common criteria for measuring the success of project management [12]. This is understandable because time and cost may be the most perspicuous parameters for calculating the performance of a project when nothing much is known about the project. Quality can also be used to measure the performance of functional and technical specifications [13]. However, the truth that projects continue to fail has demonstrated that using only the iron triangle criteria cannot guarantee the success of a project. This reality indicates that a much wider range of considerations on project success criteria is necessary. To name a few, Chan, A. P. C. and Chan, A. P. L. [14] specified the success criteria of construction projects by presenting an integrated framework containing iron triangle, commercial value, environment performance, user satisfaction, participants’ satisfaction, and health and safety. Relying on logical framework method (LFM),
Baccarini, D. [13] promoted project success definition by defining two components of it: product success, which refers to the project goal and purpose, and project management success, which focuses on the process of the project.

2.2 Success for PPP Projects

PPP infrastructure projects are complicated, and involve not only the construction stage, but also operation and maintenance. To resolve research difficulties raised by the complexity, prior researchers analysed PPP success criteria by focusing on distinct phases of PLC. Aziz, A. M. A. [15] summarised eight principles for PPP implementation at the program level. Ng, S. T., Wong, Y. M. W., et al. [16] explored important critical success factors (CSFs) for feasibility assessment. For procurement phase, CSFs influencing procurement success have been investigated by many researchers [17-19]. Chou, J.-S. and Leatemia, G. T. [20] investigated the critical process and factors for successful ex-post evaluation of PPP projects. Some previous research discussed success from comprehensive perspectives, of which life cycle perspective is a critical one. For example, Yuan, J., Zeng, A. Y., et al. [21] identified performance objectives, key performance indicators (KPIs) for PPP from life cycle perspective as well as other perspectives. Henjewele, C., Sun, M., et al. [22] compared life cycle performances of PPP projects in different sectors in UK, and concluded that not a few PPP projects suffered time and cost overruns as well as requirement changes. Based on the LFM concept mentioned previously, Liu, J., Love, P. E. D., et al. [23] analysed the life cycle success of PPP projects and proposed process-based CSFs. Analysis on literature indicates that CSFs and success criteria were utilized interchangeably by most of the previous research. Nevertheless, Osei-Kyei, R., Chan, A. P. C., et al. [24] emphasized and clarified the difference between CSFs and success criteria, and proposed a set of PPP success criteria through an international experts survey.

Several research on general PPP success has partly referred to the transfer phase. For instance, Yuan, J., Zeng, A. Y., et al. [21] claimed that a successful transfer of PPP projects may need factors like training of new employees, transfer price, standards of project facilities upon transfer, etc. Lin, Q., Shou Qing, W., et al. [25] presented three CSFs for transfer, namely, technology transfer, operation in good condition and overhauling guarantees. However, no existing research has yet systematically examined success of this phase.

To conclude, the brief review on literature shows two major deficiencies in existing research on success for PPP infrastructure projects: (1) most existing success criteria were presented dispersedly; some of them even still confusing with CSFs; (3) the transfer phase lacks systematic research on success criteria. This paper attempts to bridge the aforementioned knowledge gaps by applying the LFM concept to the development of TS criteria framework. The detailed introduction of LFM and framework development process are as followed.

3 Developing TS Criteria Framework

3.1 Defining TS through LFM

LFM emphasizes that a project’s various objectives can be formulated using a hierarchical structure where cause-effect relationships exist between different levels of objectives [13]. That is, project success contains two components: product success and project management success. The former, product success, regards to project goal and project purpose. The project goal pertains more to long-term objective, while the project purpose emphasizes near-term. Project management success focuses on the project process, i.e., on what are needed in the process and how the process is conducted. Normally, product success is more critical than project management in construction industry [13].

Although LFM was initially explored in defining success for traditional construction projects, previous studies have also testified its effectiveness in PPP area [23]. Therefore, this paper defined TS through this proven concept. Specifically, TS herein comprises two levels: transfer product success (TPS) and transfer management success (TMS) (Figure 1). TPS deals with the final effect of the transfer management, pertaining to goal and purpose of the transfer. Transfer goal is related to the long-term objective of the transfer. At the end of the concession period, infrastructure will
be transferred back to the government, and then will continue to provide public product or service. In this context, the transfer goal should include the continuous product/service provision objective plus other long-term objectives. To accomplish this goal, a near-term objective, which is defined as transfer purpose, is that the assets handed back must be in good condition and equipped with necessary technology and other supportive means. TMS concerns the process of the transfer management, comprising three aspects: (1) time and cost requirements; (2) efficiency of transfer process; and (3) stakeholder satisfaction. These three aspects represent a process-based perspective aiming to ensure the entire transfer process is in line with the goal of transfer.

According to LFM concept, there is a “how-why” Logic in the TS definition. As shown in Fig. 1, “how” denotes means and “why” denotes ends. Through the “how-why” logic chain, the relationship between the five objectives is defined clearly as follows. To the question, “How can the transfer goal be achieved?” the answer is transfer purpose. If the question is, “How can transfer purpose be achieved?” The answer is transfer outputs, and so on. Similarly, starting with inputs, the objective on the left side interprets why the objective on the right is necessary.

### 3.2 Criteria for measuring TS

Based on the definition of TS, two transfer performance objectives have been established. The first refers to the principles or standards of judging whether transfer outcomes are favourable, i.e., TPS; the second the performance of the transfer process, i.e., TMS. The next significant step for developing the TS criteria framework is to identify specific success criteria for each objective. As stated in literature review section, Osei-Kyei, R., Chan, A. P. C., et al. summarized a set of 15 PPP projects success criteria. Compared to other research on success criteria, their research findings seemed more reliable because they were derived from extensive review on PPP success research and have been testified by international PPP experts. Considering the fact that transfer phase is part of the PLC, a handful of general success criteria for PLC may provide a sufficient source of criteria for TS. Hence a total of 14 TS criteria were finally identified by referring to the 15 success criteria of Osei-Kyei, R., Chan, A. P. C., et al. Their criteria were rephrased and refined in order to be in accordance with the nature of transfer phase other than general PLC. Table 1 summarizes the 14 criterial for measuring success of transfer.

<table>
<thead>
<tr>
<th>Performance objectives</th>
<th>Success criteria</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS</td>
<td>Effective technology transfer</td>
<td>Technical knowledge, know how, etc. are entirely transferred to the public party.</td>
</tr>
<tr>
<td>Environment impact</td>
<td>Transfer does not impact the safety of the employees, end users or environment.</td>
<td></td>
</tr>
<tr>
<td>Extended cooperation</td>
<td>Cooperation could be extended for a certain period after transfer to enjoy quality warranty offered by the private sector.</td>
<td></td>
</tr>
<tr>
<td>Acceptable value and serviceability</td>
<td>Assets transferred meet the expectation on residual value and serviceability.</td>
<td></td>
</tr>
<tr>
<td>Keeping continuous product/service provision</td>
<td>A project transferred is capable of providing the same quality product/service as before transfer.</td>
<td></td>
</tr>
<tr>
<td>Profitability</td>
<td>A steady income is achieved in post-transfer operation.</td>
<td></td>
</tr>
<tr>
<td>Keeping contributing to local economic development</td>
<td>A project transferred is continuously beneficial to local economic development.</td>
<td></td>
</tr>
<tr>
<td>Authentic and reliable VFM evaluation</td>
<td>An authentic and reliable VFM evaluation report is resulted from transfer process.</td>
<td></td>
</tr>
<tr>
<td>TMS</td>
<td>Reduced changes and disputes</td>
<td>Concession agreement changes and disputes are minimized throughout the transfer phase.</td>
</tr>
<tr>
<td>Reduced employees’ objections</td>
<td>The reductions of objections from employees who feel unfair treatment, benefit loss etc.</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Reduced public and politic objections</td>
<td>The reduction of objections from the public or politic who are against increase in tariffs, lack of transparency, corruption etc.</td>
<td></td>
</tr>
<tr>
<td>Effective risk management</td>
<td>Risks in transfer phase are appropriately identified and allocated.</td>
<td></td>
</tr>
<tr>
<td>Meeting budget</td>
<td>Transfer management is conducted without any cost overruns.</td>
<td></td>
</tr>
<tr>
<td>Meeting time</td>
<td>Assets are transferred back to the government on time.</td>
<td></td>
</tr>
</tbody>
</table>

4 Discussion

4.1 Criteria for measuring TPS

As stated previously, TPS has the final effect on transfer management, and its performance objectives contain the transfer goal and purpose. TPS is higher than TMS in terms of importance according to the theory of project management success [13]. This may interpret why some governments agree to accept PPP projects even that are with poor life-cycle performance [9]. To measure TPS, eight criteria have been identified (Table 1), which can be further classified into transfer goal and transfer purpose.

**Transfer goal.** Transfer is the end point of the PPP contract and also the start of the post-transfer operation. The infrastructure transferred is expected to provide continuous service/product to satisfy the public need as the time before transfer [26]. Accordingly, to support regular operation of facilities and equipment, reasonable profit or income should be guaranteed. What is more, as part of the community, the project is also expected to contribute to the economic development of the region where it belongs. Therefore, to meet the transfer goal, three TS criteria should be measured:

- Keeping continuous product/service provision;
- Profitability; and
- Keeping contributing to local economic development.

**Transfer purpose.** As mentioned earlier, to achieve transfer goal, the immediate purpose of transfer is to ensure the good condition of the assets transferred. Here “good condition” can be understood from multiple perspectives. For example, to achieve the goal abovementioned, a basic condition is to guarantee the assets transferred with acceptable residual value and serviceability; in the meanwhile, technology, know-how, etc. which are necessary for operation should be transferred as well [29]. What is more, the good condition can be further ensured by extending part of project company’s maintenance obligation for quality warranty for some time after transfer; in other words, cooperation between parties need to be extended. In addition to the internal condition, the project also has to be environmentally friendly during the operation process. Besides, VFM is an effective means to evaluate the contribution of the project to the development of regional economy throughout the PLC. As a result, five TS criteria can be classified into transfer purpose:

- Acceptable value and serviceability;
- Effective technology transfer;
- Environment impaction;
- Extended cooperation; and
- Authentic and reliable VFM evaluation.

4.2 Criteria for measuring TMS

**Time and cost.** In transfer, meeting time arrangement is very important, because many tasks, such as overhaul, asset assessment and performance tests etc. should be completed within a relatively short term (typically one to two years) in advance of the concession expiry date [26]. Reasonable
budget should also be planned early to fuel those tasks. VFM evaluation, for instance, needs to be emphasized in terms of time and cost preparation because it involves the investigation on the entire PLC performance and the participation of various departments, which are all the government’s responsibilities. Consequently, for measuring TMS, two basic criteria are considered:

- Meeting time; and
- Meeting budget.

**Efficiency.** This set of criteria measures how efficiently the TS is managed \[^{13}\]. Ideally, the most efficient situation is that the transfer is conducted with minimum changes in the agreement. However, efficiency can be undermined by inevitable changes during the long concession term causing renegotiation between the government and the private sector \[^{30}\]. To minimize the probability of unfavourable events, effective risk management should be conducted prior to their occurrence. In other words, efficiency of the transfer management process can be measured by evaluating two aspects:

- Reduced changes and disputes; and
- Effective risk management.

**Stakeholder satisfaction.** Stakeholder opposition is one of the main reasons for PPP failure \[^{31}\]. In PPPs, different groups have different anticipations that should be integrated into the project development process \[^{52}\]. The main stakeholders that may be significantly impacted by transfer are employees and the publics (normally represented by the government). Objections from those two groups of stakeholders tend to be harmful to the regular operation of the project. For example, if employees who are responsible for the operation of the equipment feel unfair about the transfer arrangement, they may protest the transfer; if so, the operation of the project will be disturbed. Similarly, if the publics (or the political bodies) are against the transfer process due to the lack of transparency, corruptions etc., the regular operation cannot be guaranteed, either. Therefore, a successful transfer may include concerns on two groups of stakeholders:

- Reduced employees’ objections; and
- Reduced public and politic objections.

### 5 Conclusions

Transfer phase of PPP infrastructure projects plays an important role on guaranteeing good condition of the project asset transferred, which is a significant basis for post-transfer operation. Unfortunately, little about transfer phase has been known by both the academia and the industries. This paper serves as part of a systematic research scheme on how to manage transfer phase of PPP infrastructure projects. This research aimed to develop a criteria framework for measuring TS of a PPP infrastructure project. The definition TS contains two components: TPS and TMS, representing a two-level of hierarchical structure for measuring TS. TPS, a higher level of success objective, comprises transfer goal and transfer purpose; TMS, the subordinated one, consists of three sets of criteria: time and cost, efficiency, and stakeholder satisfactions. A total of 14 TS criteria have been identified by reviewing previous studies and refining existing success criteria for general PLC. Then the refined TS criteria have been classified into the hierarchical TS structure. The proposed success criteria framework can facilitate effective and efficient management throughout the transfer phase as well as ex post operation of public assets. The findings of this research also can contribute to the body of knowledge in terms of PPP project management. In the future, the success criteria framework in this paper will be validated and promoted. Hopefully, a detailed measuring system for transfer success will be established.

### References


Thermal and Chemical Degradation of Portland Cement Concrete in the Military Airbase

Sukanta Kumer Shill1*, Safat Al-Deen2, Mahmud Ashraf3

Abstract: The military airbase especially aprons and the rigid pavement are often exposed to engine oil, hydraulic fluid, Jet oil, extreme heat shocks, and varied lengths of repetitive cyclic heat loading. Oils spillage during maintenance of aircraft on the parking apron or venting of oil from the aircraft after the main engine starting is a common phenomenon and inevitable in the airbase. Considering this, the paper presents the degrading mechanism of ordinary Portland cement (OPC) and Portland limestone cement (PLC) concrete in the parking apron and rigid pavement of military airbase. This study identifies the potentially damaging compounds (hydrocarbons) likely present on the airbase. The chemical reactions between Portland cement and the hydrocarbons and their consequences in the airbase concrete are also presented in the study. The effect of auxiliary power units (APUs) exhaust temperature on the airbase concrete and the combined effect of heat and spilled chemical is explained in the present study. The study reveals that APUs exhaust temperature is sufficient enough to develop thermal cracks in the concrete, as a result, the permeability of concrete increases that allows more chemical spillage in the concrete. The spilled hydrocarbons react greatly with the Portland cement and produce soft salty brittle materials on the top cementitious layer of OPC and PLC concrete that is known as scale. The APUs exhaust temperature accelerates the pace of chemical reaction and the surface degradation process of OPC and PLC concrete in the military airbase.

Keywords: Airbase, jet exhaust, chemical damage, high temperature, scaling
1 Introduction

Ordinary Portland cement (OPC) is the most common type of cement for general use in civil engineering construction around the world from the mid-19th century. The OPC is produced from the hydraulic lime and usually originates from limestone. Due to widespread availability and low cost of the limestone, the production cost of OPC is reasonably low. Consequently, the OPC was widely used in the construction of aprons and rigid pavements of the military airbase to support the fighter aircraft. Moreover, Portland limestone cement (PLC) is also widely used around the world. The addition of limestone in the Portland cement has some technical, environmental and economic benefits. It reduces the global carbon dioxide emission, increases the strength of cement and saves the energy. PLC has been used in Europe for over decades. Canadian Standards Association (CSA) has allowed the incorporation of limestone in Portland cement since 1983 [1]. Recently, America, Australia, China, India and other some countries around the world is also using limestone as mineral additives in the Portland cement.

The airbase apron and rigid pavement concrete surfaces are regularly exposed to extremely severe circumstances not often experienced by other concrete surfaces. In addition to the expected dynamic loads, these pavements are often exposed to engine oil, hydraulic fluid, jet fuel, extreme heat shocks, and varied lengths of repetitive cyclic heat loading. McVay et al. reported that both the United States Air Force and Navy have been experiencing concrete scaling on their B-1 and F/A-18 parking aprons [2-4]. Moreover, military airbases in Australia also have been experiencing concrete scaling for over three decades, since the F/A-18 was purchased and placed into service in 1984 [5]. Usually, such concrete damage takes place in the form of scaling, or else it peels off from the wearing surfaces, is a regular occurrence in the airbase. This scaling is arisen within the first six to eighteen months because of cyclic running and maintenance of aircraft on the concrete [2]. Further, scaling develops progressively at a shallow depth of 6mm to 13mm beneath the top surface of concrete [2, 6]. However, the Department of the Air Force of USA has stated in their engineering technical letters that scaling damage occurs on the top 25 to 50mm of the rigid pavement [7]. This scaling can generate a significant amount of foreign object debris (FOD) in the form of released aggregate and poses a significant threat to the safety of both aircraft and personnel. FOD of any quantity is not tolerated in military airfields, as if a single piece of loose aggregate enter into a jet engine, it might be exploded, which can cause hundreds of thousands of dollars of damage with potential loss of human life of limb [8]. As reported in airfield pavement maintenance manual of the Royal Australian Air Force (RAAF) any scaling event to be rectified and states that scaling alone can classify the pavement as failed and be a severe hindrance to the safe operation of aircraft [9].

OPC lost 55% of its compressive strength after 7 days of continuous exposure to engine oil and water at high temperature [3]. Further, the Portland cement binder should be replaced by a neutral pH cement binder in the case of military airbase construction [4]. Most of the published papers concluded that the airbase concrete is subjected to surface scaling due to its high pH value [2-4, 6]. Moreover, McVay et al. identified that ester presence in both engine oil and hydraulic oil reacts with the calcium hydroxides present in OPC concrete and produces calcium salt and alcohol [2]. This calcium salt of the fatty acids are soft, slightly soluble in water and known as scale on the top surface of the concrete. However, the actual process of chemical and thermal degrading mechanisms and military airbase circumstances are still left unanswered.

The purposes of this paper are to identify the damaging chemical compounds that are likely present in the military airbase, the actual process of chemical degradation of OPC and PLC concrete as well as to re-evaluate the thermal degradation of military airbase concrete. In the light of this, the paper presents the chemical reactions and chemical degradation process when military airbase parking aprons are exposed to ester based synthetic hydrocarbons under the exhaust gas temperature of auxiliary power units (APUs) of modern combat aircraft such as F/A-18s, B-1s, V-22 Ospreys. Further, the paper presents the actual military airfield conditions those are responsible and affect the durability of concrete.

2 Military Airfield Circumstances

Oils spillage during maintenance of aircraft on the parking apron or venting of oil from the old aircraft after the main engine starting is a common phenomenon and inevitable in the airbase.
Usually, the military airbase is exposed to by the three primary hydrocarbons, such as engine oil (MIL-PRF-23699 or MIL-L-7808), jet fuel (F-34 or similar), and hydraulic oil (MIL-PRF-83282). Engine oils are saturated ester based lubricants. Jet fuel is almost hundred percent kerosene, and hydraulic oil is the synthetic hydrocarbon-based on phosphate-esters and is hygroscopic [10]. The chemical breakdown of the potentially damaging compounds of those oils is presented in Table 1.

### Table 1 Breakdown of hydrocarbons likely present on airbase

<table>
<thead>
<tr>
<th>Fluid name</th>
<th>Military designation</th>
<th>Potentially damaging compounds</th>
<th>Concentration %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine oil</td>
<td>MIL-PRF-23699</td>
<td>Fatty acids, C5-9, tetraesters with pentaerythritol</td>
<td>≥70 - ≤90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatty acids, C5-9, hexaesters with dipentaerythritol</td>
<td>≥5 - ≤10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tris(methylphenyl) phosphate</td>
<td>≤5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Benzenamine, N-phenyl-1, reaction products with 2,4,4-trimethylpentene</td>
<td>≤5</td>
</tr>
<tr>
<td>Jet fuel</td>
<td>F-34/AVTUR/FSI</td>
<td>Kerosene (petroleum), hydrodesulphurised</td>
<td>0-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kerosene</td>
<td>0-100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diethylene glycol monomethyl ether</td>
<td>0-0.15</td>
</tr>
<tr>
<td>Hydraulic oil</td>
<td>MIL-PRF-83282</td>
<td>1-Decene, tetramer, mixed with 1-decene trimer, hydrogenated</td>
<td>≥60 - ≤100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,2',6,6' tetra-tert-butyl-4,4'-methylenediphenol</td>
<td>≤10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distillates (petroleum), hydrotreated heavy paraffinic</td>
<td>≤10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Phenol, isobutylated, phosphate (3:1) [Triphenyl phosphate &gt; 25%]</td>
<td>≤10</td>
</tr>
</tbody>
</table>

Furthermore, the airbase concrete surfaces are often saturated by the rainwater and sometimes the water table is found at the surface level of concrete. In addition to that, the military airbase is subjected to thermal cycle by the APUs exhaust of aircraft. McVay et al. reported that the surface temperature of airbase concrete is about 175 °C when it is subjected to APUs exhaust for both F/A-18 and B-1 aircraft [3]. APUs exert the exhaust on the military airbase concrete at radial nature and the maximum surface temperature of concrete at the centre of the footprint is 177°C with a velocity of 229 km/h [11]. Figure 1 indicates the surface temperature of concrete at the APUs impingement zone.

![Figure 1. The surface temperature of concrete at the APUs impingement zone](image)
Moreover, Duane also has stated that the maximum surface temperature of airbase concrete is 175 °C and the heating rate is over 3 °C/sec in the first 15 seconds and approximately 70 °C/min in the first minute when subjected to APUs exhaust of F/A-18 [5]. The surface heating profile of airbase concrete is shown in Figure 2. Interestingly the maximum temperature of pavement was only reached after the APU went into an overdrive mode during the shutdown sequence, which can be seen in Figure 2 as the peak near the end of the recorded data. Furthermore, Figure 3 shows the hydrocarbons are floating on the run-off water on an apron of the airbase.

![Figure 2. The surface temperature profile of airbase concrete when exposed to the F/A-18 APUs exhaust [5].](image)

![Figure 3. Oils are floating on the run-off water on an apron](image)

### 3 OPC and PLC Concrete

Both the Portland cement clinker and limestone contain a large percent of calcium oxide (CaO). Table 2 presents the typical chemical composition of clinker and limestone. When calcium oxide comes into contact with water it produces calcium hydroxide. Equation 1 shows the hydration of calcium oxide.

\[
CaO (s) + H_2O(l) \rightarrow Ca(OH)_2(s)
\]

The calcium hydroxide, \(Ca(OH)_2\) is traditionally known as slaked lime, has a pH value of 12.20, and this strong alkaline material can react with most of the acids. Normally, the percent of solid calcium hydroxide is 20 to 25 in hardened cement paste. Furthermore, the unreacted clinker and limestone powder also might be exist in the hardened concrete.

According to the European pre-standard prEN 197-1, the limestone content in type II/A-L and type II/B-L cement are 6–20% and 21–35%, respectively, with the primary requirement is \(CaCO_3\) content in the limestone must be greater than 75% [12]. Further, it is believed that the future use of PLC around the world will be increased significantly [13].

<table>
<thead>
<tr>
<th>Composition (%)</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>SO₃</th>
<th>LOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinker</td>
<td>21.79</td>
<td>5.13</td>
<td>3.59</td>
<td>66.42</td>
<td>1.71</td>
<td>0.55</td>
<td>0.09</td>
<td>0.52</td>
<td>1.5</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.61</td>
<td>0.15</td>
<td>0.17</td>
<td>53.36</td>
<td>1.47</td>
<td>0.02</td>
<td>0.00</td>
<td>-</td>
<td>43.54</td>
</tr>
</tbody>
</table>
4 Degradation of Military Airbase Concrete

4.1 Chemical degradation

Engine oil contains fatty acids, C5-9, tetraesters with pentaerythritol up to 90% and fatty acids, C5-9, hexaesters with dipentaerythritol up to 10%. Similarly, McVay et al. stated that the ester content in the lubricating oil and hydraulic oil are 95% and 30%, respectively [3]. This ester is soluble in normal water in presence of heat. When these esters come into contact with water in presence of heat, it hydrolyses to carboxylic acid and alcohol. The equation 2 explains the hydrolysis of the ester.

\[ CH_3COOR'(ester) + H_2O \xrightarrow{heat} CH_3COOH (carboxylic acid) + R'OH \]  

Typically, the carboxylic acid is colourless liquid with very strong odours (pungent smell) and this acid is a weak acid having a pH of around 2 to 6. Despite being a weak acid, carboxylic acid behaves like any other acid and can react with soluble and insoluble alkalis and carbonate to form salts and water. The equation (3) and (4) present how the carboxylic acid reacts with alkali and carbonate.

\[ CH_3COOH + Ca(OH)_2 (calcium hydroxide) \rightarrow Ca(CH_3COO)_2 (calcium salt) + H_2O \]  

These calcium salts of fatty acid are soft, soapy materials that have the rancid odour, which supports the physical properties of damaged samples collected by the US Air force [2]. Thus, the produced calcium salts in both equations are known as scale in the military airbase. Moreover, the pace of reaction depends on the temperature and pH value of cement. Since OPC and PLC both have a pH value greater than 12, and APUs exhaust makes the surface temperature of concrete around 175 °C, therefore, this reaction happens at a very faster rate on the top cementitious layer of concrete.

Both the engine oil and hydraulic oil containing phosphate esters in the form of triesters(methylphenyl) phosphate and triphenyl phosphate. These compounds help to lubricate steel and reduce wear due to heat and friction. The triphenyl phosphate is a colourless ester (triesters) of phosphoric acid and phenol. It is used as a flame retardant and plasticizer in hydraulic fluids. Triphenyl phosphate is biodegradable under anaerobic conditions and soluble in water [14, 15].

These phosphate esters present in both the engine oil and hydraulic oil can be formed in phosphoric acid when it comes into contact with water at high temperature [16]. Equation (5) illustrates how phosphoric acid can be formed from phosphate ester.

\[ C_{18}H_{15}PO_4 (phosphate ester) + H_2O \xrightarrow{T=150-220^\circ C} C_{18}H_{15}PO_4 (unreacted fluid) + H_3PO_4 (phosphoric acid) + C_{18}H_{15}OH \]  

In addition to that, a small percent of red phosphorus is also added to the engine oil to act as a scavenger for oxygen and water. The red phosphorus can be oxidised simply in the air and produces phosphorus pentoxide. Equation (6) shows the production of phosphorus pentoxide.

\[ P (red phosphorus) + O_2 \rightarrow P_2O_5 (phosphorus pentoxide) \]

The phosphorus pentoxide reacts with water, even though it can react with the moisture in the air, to form phosphoric acid. Equation (7) presents the production of phosphoric acid from phosphorus pentoxide.

\[ P_2O_5 + H_2O \rightarrow H_3PO_4 (phosphoric acid) \]

These phosphoric acids produced from phosphate ester and red phosphorus can react with the calcium hydroxide presents in OPC concrete and react with calcium carbonate present in PLC concrete. Equation (8) and (9) show the reaction between phosphoric acid and calcium hydroxide and reaction with calcium carbonate, respectively.
\[ H_3PO_4 + Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + H_2O \] … (8)

\[ H_3PO_4 + CaCO_3 \rightarrow Ca_3(PO_4)_2 + CO_2 + H_2O \] … (9)

The phosphate esters and the red phosphorus could be decomposed in water and air oxidation in presence of heat and produces phosphoric acid. These phosphoric acids can attack the OPC and PLC concrete and produces calcium phosphate in the top cementitious layer, resulting in a soft, spongy material also known as scale. In summary, when the scale is being developed in the top cementitious layer of concrete, the top layer of concrete becomes more brittle and reduces the elasticity of concrete. As a result, aggregates or plate-like pieces peel off from the top layer of the concrete due to mechanical abrasion that contributes a significant amount of FOD in the military airbase. Figure 4 shows the effect of scaling on an airbase apron.

![Figure 4 Aggregates are peeled off from the top layer of the concrete on an airbase apron.](image)

### 4.2 Thermal degradation

The peak temperature and the rate of heating have a major influence on the thermal degradation process of OPC and PLC concrete. When that concrete is exposed to APUs exhaust temperature, the free water evaporates in the range of 30 -105 °C, gypsum and ettringite are decomposed in the range of 110 -170 °C and the C-S-H gel dehydration occurs at 180 °C [17]. Moreover, Portland cement concrete starts to lose its chemically bonded water at around 121 °C and the highest rate of dehydration occurs at around 177 °C [18]. Further, Hager argues that the structure of Portland cement paste damages partially due to dehydration at a temperature of 105 °C [19].

Often vapour pressures in the pore of saturated concrete are detrimental eventually be sufficient to cause tensile cracks in Portland cement concrete because concrete temperature beneath an F/A-18 reaches 140 °C in about 2 minutes. Furthermore, when gypsum and beneficial crystal ettringite are decomposed, sulphate reacts with aluminum and calcium and start to expand the volume of mass. As a result, micro-cracks are developed around the aggregate that decreases the elasticity and increases the permeability of concrete. Finally, if the chemically bound water is started evaporating, the strength of concrete decreases exponentially because 50% of cement paste strength is contributed by the cohesive force of C-S-H gel.

The aggregates in the concrete also play a vital role in the thermal degradation of concrete at high temperature. When concrete is exposed to high temperature, the volume of aggregates also expands according to the thermal expansion coefficient of aggregate used. Higher the thermal expansion coefficient of aggregate higher the expansion of the volume of concrete because generally, the aggregate is more than 70% in concrete. Consequently, tensile stresses are developed around the aggregates that also produces micro-cracks in the concrete. Ultimately, more penetration of oils and water in the upper layer of concrete and faster the surface degradation process.
4.3 Combined effect of thermal and chemical

Travis & Mobasher explained that heat causes micro-cracking in the concrete that directly increases the permeability and decreases the elastic modulus of concrete [20]. The increased permeability would allow more hydrocarbons to penetrate the concrete and increase both the surface and interface area between the concrete and the damaging compounds present in engine oil, hydraulic oil, and Jet fuel. Therefore, when hydrocarbons come into contact repeatedly with the cement paste and unsaturated dust of OPC and PLC concrete under the cyclic APUs exhaust heat, the chemical degradation of airbase concrete take place on a larger scale at a faster pace.

5 Probable Solution

McVay et al. [2] proposed neutral pH cement that is aluminum and/or magnesium phosphate cement, Hironaka & Malvar [6] recommended the magnesium ammonium phosphate cement for the military airbase concrete. In the study, the authors suggest geopolymer concrete and/or polymer-modified concrete containing heat resistant aggregates such as expanded shale, expanded slate, basalt, and limestone as coarse aggregate for military airbase repairing and construction. The geopolymer concrete has superior acid resistance [21, 22], spalling resistance and heat-resisting capacity than OPC due to their low differential gradients and thermal incompatibility between the geopolymer paste and aggregates [23]. Moreover, Polymer-modified concrete has low pH value, higher flexural strength and has a greater resistance to acid and base at elevated temperature [24]. In summary, the military airbase concrete should be made of high-strength concrete containing heat resistance aggregates and must have a lower permeability because lower permeable concrete has a greater resistance to chemical interactions.

6 Conclusion

APUs exhaust heat is sufficient enough to cause micro-cracks in OPC and PLC concrete at the military airbase, resulting in an increase of permeability and decrease of elasticity of concrete; consequently, more hydrocarbons have penetrated the interface of concrete. The APUs exhaust heat helps to hydrolyse the spilled chemical compounds and accelerates the pace of chemical reactions between cement and chemicals.

Both the engine oil and hydraulic oil contain a large amount of ester of fatty acid. These esters of fatty acid hydrolyse to carboxylic acid and alcohol. The carboxylic acid reacts with calcium hydroxide presents in OPC and calcium carbonate presence in PLC concrete, produces calcium salt and water at the top cementitious layer of concrete. These calcium salts of fatty acid are soft, soapy materials that have the rancid odour, are known as scale in the military airbase. Both the engine oil and hydraulic oil also containing phosphate esters and a small percent of red phosphorus. These phosphate esters and red phosphorus could be decomposed in water and air in presence of heat and produces phosphoric acid. These phosphoric acids can attack the OPC and PLC concrete and produces calcium phosphate in the top cementitious layer, resulting in a soft, spongy material also known as scale. When the scale is being developed, the top layer of concrete becomes more brittle and reduces the elasticity of concrete. As a result, aggregates or plate-like pieces peel off from the top layer of the concrete due to mechanical abrasion that contributes a significant amount of FOD in the military airbase. Therefore, the authors suggest geo-polymer concrete and polymer-modified concrete with heat resistant aggregates such as expanded shale, expanded slate, basalt, and limestone as coarse aggregate for military airbase repairing and construction.

References


[24] ACI Committee 548. ACI 548.3R-03: *Polymer-Modified Concrete*, American Concrete Institute (ACI), 2003.
Using the Analytical Network Process to Measure the Risk Control Factors of IPD Projects

LUO Lan¹, ZHU Mengcheng² and XIE Jianxun³*

Abstract: Integrated Project Delivery (IPD) can help resolve the problems such as cost overruns, schedule delays and low efficiency caused by inconsistent goals of the various participants during the period of project construction, and risk control plays an important role in developing IPD projects. Combining literature review with expert investigation, the Analytical Network Process (ANP) method was adopted to build the measurement model of risk control factors within the IPD projects. With the help of a Super Decisions (SD) software, the weight of risk control factors for IPD projects were calculated and factors were sorted accordingly, thus the key factors of risk control for IPD projects were identified, which would provide a reference for the implementation of the IPD project in China.

Key words: IPD projects; the risk control factors; measurement; Analytical Network Process

¹ LUO Lan
School of Civil Engineering and Architecture, Nanchang University, China;
Email: mengling2391@163.com.

² ZHU Mengcheng
School of Civil Engineering and Architecture, Nanchang University, China;
Email:283287360@qq.com.

³* XIE Jianxun
Corresponding author: Research Institute of Complex Engineering & Management, School of Economics and Management, Tongji University, China;
Email: xiejianxun1979@163.com.
**Introduction**

In the traditional trading model, the endless changes in design, errors, short duration, inefficient production, slow communication and overruns in international projects have plagued practitioners in the construction industry\[^1\]. Based on the statistics of the US Construction Industry Association and the Australian Treasury, 62% of the projects completed by the beginning of this century were over budgeted; about 40% of the projects were overdue and 30% of the projects did not meet the owners' demand \[^3\]. In this regard, construction industry has created a new construction project delivery model - Integrated Project Delivery (IPD), the American Institute of Architects (AIA 2007) defines it as: "a project delivery method, personnel, systems, business structures and practices are integrated into a process. All participants after the integration take full advantage of the wisdom and practical experience to optimize and improve the project at all stages of the project, add value to the owners, reduce waste, and maximize project overall efficiency and value."

Many scholars had done on the IPD model analysis, Zhang (2010)\[^1\] believed that in the IPD transaction mode, the major participants of project team involved in the early stage, and team members through the IPD contract interconnected, made the consistently risks and interests. Through the survey, Kent et al. (2010)\[^8\] found that IPD model can save cost 70.3%, shortening the duration of 69.4%, reducing engineering changes 70.3%, and reducing the project safety accident 21.6%.

Although the IPD model has so many obvious advantages in reducing waste and costs, reducing rework to shorten the construction period and increasing the value to the owners, there is a lack of research on measuring and managing IPD project risk control factors. Based on the literature review and expert survey, the network analysis method (ANP) was used to construct the measurement model of the risk control factors of the IPD project, so as to measure the key factors of the IPD project risks. The research would provide scientific decision support for IPD project management in practice, which has important theoretical significance for IPD project management.

**1 Literature review**

With the development of Building Information Model (BIM) technology, BIM technology-based IPD projects will lead to a new construction project management model, That will maximize the integration of building professionals to achieve the information sharing and efficient collaboration across functional teams\[^4\]. In the preliminary design stage, the IPD project uses the BIM model to detect the design problem in advance by the model detection collision, to communicate with the relevant parties in time, to optimize the risk in the design stage and reduce the major changes caused by the mistake. In the construction phase of the project, through the information collection and upload by relevant workers on the construction site, the parties can get the circumstances of construction site, the project manager is clearly to the duration, cost, quality control, this is beneficial to the project visual management. In the facility management phase, the IPD projects take the routine maintenance management of the project through the BIM information management system.

Scholars have put forward the key factors of IPD projects implementation from the characteristics of IPD. For instances, Yang (2015)\[^3\] pointed that the IPD projects has the characteristics of integrated and sincere cooperation, based on the characteristics of the whole life
cycle and lean thinking, the emphasis is on the construction environment of mutual trust and cooperation, real-time information exchange, diligent communication, work together to solve the problems in the project. To create a good atmosphere of cooperation, it must focus on the organizational structure, cooperation agreement, the implementation process, technical support and other aspects to give attention to optimize the IPD projects management process. Zhang (2013) believed that there are six key categories determined the successful implementation of IPD model in China including the establishment and organization of collaborative work teams, project planning, risk sharing and benefit sharing, the use of BIM technology and lean construction ideas, mutual respect and trust between stakeholders, transparent communication within the team. Bao (2013) stated that the lean construction provides an advanced construction methods and management models for IPD projects, and the use of BIM technology makes IPD technical tools has a perfect function, BIM's core functions support the key technologies in implementation of lean construction. Wang (2013) believed that IPD is different from the traditional project, and the main features is shown as the parties involved in the early intervention and full participation, IPD unique contract form, open communication and resource sharing based on BIM, the integration of the risk and benefits of participants, the elimination of responsibility, collaboration innovation and make decision together. Xu (2011) believed that IPD has the following characteristics: a very high degree of collaboration process, rely heavily on personal and professional technical knowledge, establish a BIM-based open information sharing, establish collaborative partnerships, make decision based on Value, improve procurement and scheduling, improve cost efficiency, improve delivery of documents, and use new technologies. Kent (2010) summarized that IPD model could improve the collaborative decision-making ability and level of collaboration of project team through knowledge sharing, early intervention, risk sharing, and benefit sharing.

Overall, it can be seen that some scholars have tried to explore the key factors of IPD projects, but lack of measuring quantitatively the key factors of risk control for IPD projects. It could concluded that IPD projects risk control factors affect each other, therefore, this study tried to use qualitative methods to measure the IPD projects risk control key factors.

2 ANP

Analytical Network Process (ANP) is a decision-making method for non-independent feedback systems proposed by Professor Saaty of the University of Pittsburgh in 1996. ANP method is based on Analytic Hierarchy Process (AHP), which considers the feedback and dependence of the hierarchy and the internal elements. More accurately describe the relationship between objective things in the real world. Accordingly, ANP reflects and describes decision-making issues more closely than AHP.

Super decision (SD) software provides powerful features that can calculate any ANP model and fully express the results of the calculations. The basic steps to make decisions are as follows:

1) Input. Decompose a complex problem into individual elements. There are three types of input: three-layers structure template, two-layers structure template or no template, self-designed.

2) Judge the relationship between elements. This step is to determine whether the internal independence exists, and whether there is dependency and feedback relationship exists. When the same layer of elements is independent of each other, it does not make comparison, and it is transformed into AHP model.
3) Calculate the analysis. According to the above input, SD software can construct a variety of matrix, the final available comprehensive advantage.

### 3 Identifying the factors and sub-factors of IPD risks

Based on the previous IPD research literature \(^{[4-11]}\), combined with the actual situation of the project and expert interviews, 26 factors were selected and classified into six first-level indicators, including organizational mechanism, early planning, risk sharing, operating system, collaborative mutual trust, and team communication.

#### A. Organizational mechanism

IPD model stakeholders include owners, designers, contractors, subcontractors, materials / equipment suppliers, consultants and so on. Different from the traditional organizational relationship, there are vague boundaries between the parties in IPD model, so it can achieve the depth of information exchange and resource sharing. The IPD contract breaks the boundaries of traditional contracts, expands the responsibilities of the members in the organizations and promote depth mutual communicate. But in the IPD contract, it has to define clearly the role of the various stakeholders and responsibilities, so that all parties have clear responsibility areas.

#### B. Early planning

In the IPD model, the division of the project phase stakeholder participated is very different from traditional organization. Under the owners' organization, the project team composed of stakeholders identified as early as possible. And the project team members' resource and experience are defined in the early stage of the project to define the project objectives and scopes to reduce the project uncertainty and deepen the team members' understanding of the project. Thus, the project is more likely to meet the requirements of the owners and meet the technical requirements, and ensure that the design program has a good implementation, thereby reducing the change and rework. In general, in the IPD model, the early intervention of the project stakeholders is more conducive to the project planning and project coordination control \(^{[9]}\).

#### C. Risk sharing

The biggest feature of IPD model is to establish a cooperative relationship between the owners, contractors and other stakeholders, so the interests of the parties tend to be unified, thereby reducing or even eliminate the risk of the project. According to the "shared risk, shared benefits", through the establishment of risk distribution matrix in IPD model, the proportion is determined according to the participants' responsibility of risk. As the participants abandoned the right to claim, in the event of a dispute, the organizers discussed the development of solutions. If the opinion is still unanimous, the IPD manager will be invited to consult the event; if it can not be resolved, they should consult the consultant. The IPD model could measure the working status of each participant by establishing a performance appraisal system.

#### D. Operating system

IPD model pursues mutual trust and cooperation to achieve smoothly communication, so it requires the use of advanced information tools to improve team collaboration. The BIM technology provides a technology platform for the integration of all parties in the life cycle, which pursue the maximum value of the project like reducing waste, improving efficiency, and making the key technologies built. The IPD model is the best operating system that can integrate BIM models and lean construction\(^{[5]}\). Undering IPD mode, many lean construction methods such as Target Design (TVD) and Last Planner System (LPS) can achieve continuous improvement of the
project, reduce waste and increase value.

E. Collaborative mutual trust

In the IPD model, the relationship among various stakeholders are equal, and the organizational relationship of project team is based on collaboration and trust. The trust between teams comes from relationships and commitments. When this form of trust arises, the individual is easy to understand the intention of others, and is naturally receptive to risk, and ready to control risk [12].

F. Team communication

Team internal communication is a key way to enhance team cohesion, resolve disputes and unify goals, and to convey information through formal and informal ways to correct information distortions.

Table 1 Risk Control Factor Set of IPD Projects

<table>
<thead>
<tr>
<th>Level 1 indicators</th>
<th>Secondary indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Organizational mechanism</td>
<td></td>
</tr>
<tr>
<td>S1 Team work can meet the interests of all stakeholders</td>
<td></td>
</tr>
<tr>
<td>S2 The role and responsibilities of the various stakeholders of the project can be clearly defined</td>
<td></td>
</tr>
<tr>
<td>S3 Team members are able to actively participate in and execute project directives</td>
<td></td>
</tr>
<tr>
<td>S4 Team members have a “together win” team spirit</td>
<td></td>
</tr>
<tr>
<td>S5 Able to determine the appropriate IPD organizational</td>
<td></td>
</tr>
<tr>
<td>S6 Team members have IPD or collaborative experience</td>
<td></td>
</tr>
<tr>
<td>S7 Team members are able to work efficiently and</td>
<td></td>
</tr>
<tr>
<td>S8 Stakeholders can be involved early</td>
<td></td>
</tr>
<tr>
<td>S9 The primary subcontractor can be identified early and included in the agreement</td>
<td></td>
</tr>
<tr>
<td>F2 Early planning</td>
<td></td>
</tr>
<tr>
<td>S10 Determine the project's sustainability goals early and develop a sound project plan</td>
<td></td>
</tr>
<tr>
<td>S11 Construct design and construction integration, and reduce engineering changes due to design errors</td>
<td></td>
</tr>
<tr>
<td>S12 Advanced professional skills</td>
<td></td>
</tr>
<tr>
<td>S13 Has a transparent financial structure</td>
<td></td>
</tr>
<tr>
<td>F3 Risk sharing</td>
<td></td>
</tr>
<tr>
<td>S14 The establishment of compensation incentive mechanism, the common benefit of stakeholders</td>
<td></td>
</tr>
<tr>
<td>S15 Stakeholders are able to take risks together</td>
<td></td>
</tr>
<tr>
<td>S16 Stakeholders are exempt from all claims</td>
<td></td>
</tr>
<tr>
<td>S17 Apply lean construction method</td>
<td></td>
</tr>
<tr>
<td>S18 The data structure is transparent and open, and is</td>
<td></td>
</tr>
<tr>
<td>F4 Operating system</td>
<td></td>
</tr>
<tr>
<td>S19 There are measures to ensure timely and real-time collection of data</td>
<td></td>
</tr>
<tr>
<td>S20 Has a highly efficient BIM cloud platform</td>
<td></td>
</tr>
</tbody>
</table>
Stakeholders have a transparent and open platform for business exchange

Team members can correctly understand the value of collaborative work

Stakeholders can complete project outputs based on mutual respect and trust

There is an open and direct communication between the various stakeholders

Collaborative teams have different levels of management team

The communication between the designer and the construction worker can be timely and complete

### 4 Building the measurement model of IPD risks

#### 4.1 Structuring the ANP model hierarchically

ANP system elements are divided into two parts: the first part is the control factor layer, including the problem objectives and decision criteria; the second part is the network layer, the control layer dominated by all the elements of the composition, which is the internal network structure. ANP model of risk control factors for IPD projects is shown in Figure 1.

![Figure 1 ANP model of risk control factors for IPD projects](image)

#### 4.2 Calculating the weights of the ANP

According to the principle of ANP method and the expert scoring, the relationship between the indicators in the above index system is analyzed synthetically, and the internal dependence and feedback relationship are determined. After determining the relative importance between the two indicators in the index system, the ANP judgment matrix was constructed, and then the super-matrix and the limit super-matrix were calculated, which can be the weight of the indicators. The window screenshots of ANP model of IPD projects risk control factor in the SD software is as shown in Figure 2 and Figure 3.
4.3 Comprehensive evaluation

With the help of SD software, the weight of all the risk control factors of the IPD projects were calculated, and the calculation results were as shown in Table 2.

<table>
<thead>
<tr>
<th>First-level indicators</th>
<th>Weights</th>
<th>Secondary indicators</th>
<th>Weights</th>
<th>Total weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Team work can meet the interests of all stakeholders</td>
<td>0.18173</td>
<td>0.07348</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>The role and responsibilities of the various stakeholders of the project can be clearly defined</td>
<td>0.02262</td>
<td>0.00915</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>Team members are able to actively participate in and execute project directives</td>
<td>0.17654</td>
<td>0.07138</td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>Team members have a “together win” team spirit</td>
<td>0.10853</td>
<td>0.04388</td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td>Able to determine the appropriate IPD organizational structure</td>
<td>0.00093</td>
<td>0.00038</td>
<td></td>
</tr>
</tbody>
</table>
According to the results of the first-level factors, it can be concluded that the relative importance of the first-level factors of risk control factors in the IPD projects is: organizational mechanism > operating system > early planning > collaborative mutual trust > risk sharing > team communication. Therefore, in the IPD projects management process, managers should focus on strengthening the organizational mechanisms, operating systems, and early planning. Among the organizational factors that affect the IPD projects, the team members can work efficiently and consistently (S7) is the largest weight. In the operating system factors influencing the IPD projects, the lean construction method (S1) is the largest weight. About the early planning factors that affect the IPD projects, the design and construction integration is constructed and the engineering change (S11) is the largest weight.

From the Table 2, risk control of IPD projects is the five key factors: the application of lean construction method (S17), the team members can work efficiently and consistently (S7), build
design and construction integration, reduce the design errors caused by engineering changes (S11),
the team members can correctly understand the value of collaborative work (S22), team work to
meet the interests of various stakeholders (S1). Therefore, in order to control the risks of IPD
projects, managers should focus on the above-identified key factors, do research about these
factors and analysis in order to develop appropriate prevention and control measures.

5 Conclusions

In this study, the key factors of risk control of IPD projects were measured by use of SD
software and through literature review and investigation. The results show that organizational
mechanisms, operating systems, and early planning are the core of controlling the risk of IPD
projects. The top five key factors are using the lean construction method (S17), team members can
work efficiently and efficiently (S7), is the IPD projects risk control (S11), the team members can
correctly understand the value of collaborative work (S22), team work to meet the interests of
various stakeholders (S1). Therefore, in the process of risk management of IPD projects, manager
should focus on strengthening the control of organizational mechanisms, operating systems and
delay planning. This study provides a reference for the IPD project manager to determine the risk
factors for controlling the IPD projects, avoiding the randomness and blindness of the IPD project
management to better promote the use of IPD model in China.

Acknowledgments

This study is supported by the National Natural Science Foundation of China (71640012), Natural
Science Foundation of Jiangxi, China (20161BAB211009, 20171BAB208012); Science and
Technology Research Project from Education Department of Jiangxi, China (GJJ150073), Chinese
Thirteen Five Planning Project of Social Science of Jiangxi, China (16GL30).

References

[1] Zhang Lianying, Luan Yan. Cost Control of Engineering Project under IPD Transaction Mode
[3] Peñamora F, Li M. Dynamic Planning and Control Methodology for Design/Build Fast-Track
Based on BIM in IPD Mode [J]. Science and Technology Management Research, 2013,33 (03):
219-223.(in Chinese)
[7] Wang Yujie, Su Zhenmin, She Xiaojie. Design and Analysis of Project Team Incentive
toward Integrated Project Delivery[J]. Journal of Construction Engineering & Management,


Causes of Delays in Iranian Gas and Combined Cycle Power Plant Projects

Derakhshanfar, H.1*, Elmualim, A.2, Ochoa J.J.3, Mayer, W.4, Gunawan, I.5

Abstract: Due to the current and potential shortage of Iran’s power generation capacity, the need of a systematic analysis of reasons of delays and developing a clear understanding among the industry professionals are highly crucial. Twenty-five main delay causes of Iranian gas and combined cycle power plant projects have been identified, and a questionnaire survey was conducted to solicit the importance of each cause from project engineers/managers. Data has been collected to rank the main causes of delays which include ineffective quality control/quality deficiencies; design changes/faults; mistakes during construction or procurement stage; frequent variation/change orders; unrealistic initial contract duration; late deliveries; sanctions and political conditions; and poor contract management. Some recommendations to avoid the delay causes or mitigate their impact have been provided. It is expected that the findings of this study will help the industry practitioners to improve the schedule planning and time performance of power plant projects.

Keywords: Causes of delays; Iranian Gas and combined cycle power plant projects; Project time management; Questionnaire survey

1* Derakhshanfar, H.
Corresponding author, School of Natural and Built Environments, University of South Australia
E-mail: hossein.derakhshanfar@mymail.unisa.edu.au

2 Elmualim, A.
School of Natural and Built Environments, University of South Australia

3 Ochoa J.J.
School of Natural and Built Environments, University of South Australia

4 Mayer, W.
School of Information Technology and Mathematical Sciences, University of South Australia

5 Gunawan, I.
Faculty of the Professions, University of Adelaide, Adelaide
1 Introduction

Power plant as a critical infrastructure plays a key role in economic development of any country and Iran is no different. It provides necessary infrastructure context to develop and promote the country economic, industrial, cultural, and social aspects [1].

The overall nominal capacity of Iran’s power plants has reached 73,152MW in 2015. From 1978 to 2014, the average annual growth of operational capacity and maximum power demand was 6.6 and 7.5 percent respectively [2]. The significance of the difference between supply and demand growth rates will become more highlighted by the fact that the annual operational capacity growth of 2013 and 2014 were only 1.9 and 3.9 percent [2]. Furthermore, the country has faced a shortage of 2000MW in power supply at peak demand during 2015 [1]. So, power plant projects delay should be considered as a decisive factor which must be minimized. Furthermore, the identification of the main delay causes in power plant projects is critical in providing the needed electricity supply to sustain the country development needs. Also, time is one of the most essential project constraints in variety of industries, as success of a project will often be measured in terms of completing the project within time as approved between the project managers and senior management [3]. Power plant projects are not exempted from this general statement.

The main objective of this study is to discriminate and rank the main causes of delays in Iranian gas and combined cycle power plant projects. Gas and combined cycle power plants constitute 36.1 and 25.3 percent of Iran’s total power capacity respectively (combined total of 61.4 percent) [1]. So, this study has focused on these two types of power plants. In this paper following a literature review, the research methodology has been set out. Then, 25 key delay causes have been determined from power plant projects’ lessons learned documented during last five years, previous studies, and some initial interviews with experts. A questionnaire has been employed to gather power plant project engineers and managers’ perspective on the effect of each delay causes on their projects. Finally, acquired responses have been utilized to rank the importance of each delay cause.

2 Literature Review

Many articles have studied and prioritized delay causes of construction projects in Iran [4], Indonesia [5], Kuwait [6], Lebanon [7], Malaysia [8] [9], United Arab Emirates [10], Hong Kong [11] [12], Jordan [13] [14] [15], Saudi Arabia [16] [17] [18], Nigeria [19] [20] [21] [22], Egypt [23], Turkey [24], and India [25]. Research on delay factors is not restricted to construction projects. Fallahnezhad [26] has identified and ranked the main delay factors of Iranian pipeline projects. Han et al. [27] discovered five major delay causes of Korea Train Express (KTX) project. Also, significant factors contributing to delay in Ghana groundwater construction projects has been analyzed by Frimpong et al. [28].

In addition to the mentioned articles, there are other studies which have analyzed causes of delays independent of project types. Sepehri’s study [29] declared that 60 percent of delay causes belong to organization factors, and environment and personal factors share is less than 40 percent. Marzouk et al. [30] examined Egyptian projects engineering phase delays and suggested a system to model engineering-related delay claims. Planning and design phases delay of construction projects in Taiwan were discerned and prioritized by Yang et al. [31]. Their study revealed that “changes in client’s requirement” are the main causes of delays in both planning and design phases. Olawale and Sun [32] concentrated their study on the obstacles to control projects time and cost. They also introduced 90 mitigation measures to confront the inhibiting factors. Contractor, consultant, and owner’s responsibility of delays in Saudi Arabian water and sewage construction projects has been scrutinized by Al-Khalil and Al-Ghaffly [33]. Their study found that owners/consultants and contractors point each other as the responsible of delays. There is a relationship between project’s time and cost. Abdul-Rahman et al. [34] studied financial causes contributing to project delays. The effects of delays in Nigerian construction projects were analyzed by Aibinu and Jagboro [35]. They also related that acceleration of site activities coupled with improved clients’ project management
procedures and inclusion of appropriate contingency allowance in pre-contract estimates can alleviate the negative effects of delay.

Although power generation is one of the key elements in world’s industries, the authors could not find any article reviewing delay causes of power plant projects neither in international nor domestic resources. So, it seems that there is a gap in research in this area.

3 Research Methodology

In this study, the literature and power plant projects’ lessons learned documented during last five years have been reviewed; experts’ feedbacks were documented simultaneously. Eventually, a questionnaire including 25 main delay causes was prepared by incorporating and tailoring the key delay attributes reported in the literature and lessons learned. The questionnaire has been employed to solicit project engineers and managers’ perspective on the main causes of delays. The finalized list is presented in Table 1.

Table 1: Questionnaire schematic including the list of main causes of delays in Iranian gas and combined cycle power plant projects

<table>
<thead>
<tr>
<th>No.</th>
<th>Cause Label</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1</td>
<td>Changes in the strategies and priorities of the organization</td>
</tr>
<tr>
<td>2</td>
<td>C2</td>
<td>Too much uncertainties in the project’s nature</td>
</tr>
<tr>
<td>3</td>
<td>C3</td>
<td>Frequent variation/change orders</td>
</tr>
<tr>
<td>4</td>
<td>C4</td>
<td>Lack of clarity in project scope</td>
</tr>
<tr>
<td>5</td>
<td>C5</td>
<td>Project's novelty</td>
</tr>
<tr>
<td>6</td>
<td>C6</td>
<td>Inadequate planning/Inaccurate estimating</td>
</tr>
<tr>
<td>7</td>
<td>C7</td>
<td>Unrealistic initial contract duration</td>
</tr>
<tr>
<td>8</td>
<td>C8</td>
<td>Late deliveries</td>
</tr>
<tr>
<td>9</td>
<td>C9</td>
<td>Inadequate sub-contractors experience</td>
</tr>
<tr>
<td>10</td>
<td>C10</td>
<td>Owner’s delays</td>
</tr>
<tr>
<td>11</td>
<td>C11</td>
<td>Weather condition</td>
</tr>
<tr>
<td>12</td>
<td>C12</td>
<td>Transportation and storage problems</td>
</tr>
<tr>
<td>13</td>
<td>C13</td>
<td>Sanctions and political conditions</td>
</tr>
<tr>
<td>14</td>
<td>C14</td>
<td>Financing and payments</td>
</tr>
<tr>
<td>15</td>
<td>C15</td>
<td>Inadequate documentation</td>
</tr>
<tr>
<td>16</td>
<td>C16</td>
<td>Inadequate/lack of communication between the parties</td>
</tr>
<tr>
<td>17</td>
<td>C17</td>
<td>Poor contract management</td>
</tr>
<tr>
<td>18</td>
<td>C18</td>
<td>Inspection and handover problems</td>
</tr>
<tr>
<td>19</td>
<td>C19</td>
<td>Skilled labor shortage</td>
</tr>
<tr>
<td>20</td>
<td>C20</td>
<td>Ineffective quality control/Quality deficiencies</td>
</tr>
<tr>
<td>21</td>
<td>C21</td>
<td>Mistakes during the construction or procurement stage</td>
</tr>
<tr>
<td>22</td>
<td>C22</td>
<td>Poor site management</td>
</tr>
<tr>
<td>23</td>
<td>C23</td>
<td>Design changes/faults</td>
</tr>
<tr>
<td>24</td>
<td>C24</td>
<td>Shortage in material</td>
</tr>
<tr>
<td>25</td>
<td>C25</td>
<td>Unexpected accidents during construction</td>
</tr>
</tbody>
</table>

60 sets of questionnaires were distributed to potential respondents working as project manager or project engineer in Iranian power plant projects. They were asked to evaluate each cause’s influence on their project. A six-point Likert scale ranging from 0 (no impact) to 5 (very high impact) was adopted to capture the effect of each cause on each project’s delay. Of the 60 questionnaires, 44 sets (73.3%) were returned. Also, of the 44 sets, 30 responses were related to gas, and the remaining 14 to combined cycle power plant projects.

Duration of a project was considered as the difference between last turbine synchronization and contract award dates. Planned and actual durations of each project were also determined from project control reports. The demographic characteristics of the respondents are presented in Table 2.

3.1 Data Analysis Approach

The collected data was analyzed using mean score [36], [8], [11]. The mean score was computed by the following formula:

\[ MS_i = \frac{\sum (f \times S)}{N} \]  (1)
where $MS$ is the mean score, $S$ is the score given to each cause of delay by the respondents (ranges from 0 to 5); $f$ is the frequency of responses to each score for each cause of delay; $N$ is the total number of responses for the respective cause of delay; and $i$ is respective cause of delay. The data has been analyzed for three cases including all projects (comprising both gas and combined cycle power plant projects), gas power plants, and combined cycle power plants.

4 Results

4.1 Concordance Analysis

In order to test the null hypothesis ($H_0$) that the sets of rankings are unrelated at 95% confidence interval, Kendall coefficient of concordance ($W$) was used [21]. According to concordance analysis results (Table 3), the low probability under the null hypothesis associated with the observed value of $W$ enables rejection of the null hypothesis that the respondents’ ratings are random and unrelated to each other. So, it can be concluded that there is a good degree of consistency among the respondents in prioritizing the causes of delays.

4.2 Comparative results of delay factors

The data collected from the respondents and project control reports have indicated that almost all the projects have experienced delay. The planned versus actual duration of the gas and combined cycle power plants are illustrated in Figure 1.

Table 2: Demographic characteristics of respondents

<table>
<thead>
<tr>
<th>Demographic characteristic</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30–35</td>
<td>25</td>
<td>57</td>
</tr>
<tr>
<td>36–39</td>
<td>19</td>
<td>43</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>44</td>
<td>100</td>
</tr>
<tr>
<td>Female</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.Sc.</td>
<td>28</td>
<td>64</td>
</tr>
<tr>
<td>M.Sc.</td>
<td>16</td>
<td>36</td>
</tr>
<tr>
<td>Occupational level in the project</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Executive</td>
<td>34</td>
<td>72</td>
</tr>
<tr>
<td>Managerial</td>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>Number of years working experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–10 years</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>More than 10 years</td>
<td>24</td>
<td>55</td>
</tr>
</tbody>
</table>

Table 3: Kendall Coefficient of Concordance Test

<table>
<thead>
<tr>
<th>Project Type</th>
<th>No. of Raters</th>
<th>$W$</th>
<th>Chi square</th>
<th>DF</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas &amp; Combined Cycle</td>
<td>44</td>
<td>0.080</td>
<td>84.86</td>
<td>24</td>
<td>1.00E-08</td>
</tr>
<tr>
<td>Gas</td>
<td>30</td>
<td>0.082</td>
<td>58.96</td>
<td>24</td>
<td>8.95E-05</td>
</tr>
<tr>
<td>Combined Cycle</td>
<td>14</td>
<td>0.129</td>
<td>43.26</td>
<td>24</td>
<td>9.29E-03</td>
</tr>
</tbody>
</table>

The mean score of formula (1) is used to rank the causes of delays. Figure 2 shows the mapping charts for the delay causes based on their mean scores. Based on the ranking, the five most important delay causes of gas power plant projects are: (1) Ineffective quality control/Quality deficiencies; (2) Design changes/faults; (3) Mistakes during the construction or procurement stage; (4) Frequent variation/change orders; (5) Unrealistic initial contract duration; and - Late deliveries.

The main causes of delays in combined cycle projects are slightly different which are: (1) Sanctions and political conditions; (2) Design changes/faults; (3) Mistakes during the construction or procurement stage; (4) Poor contract management; and (5) Late deliveries.

Considering the rankings for both gas and combined cycle projects, the overall main causes of delays determined as: (1) Design changes/faults; (2) Ineffective quality control/quality...
deficiencies; (3) Mistakes during the construction or procurement stage; (4) Frequent variation/change orders; and (5) Sanctions and political conditions.

![Mapping charts of delay factors based on mean score](image)

**Figure 2: Mapping charts of delay factors based on mean score**

5 **Discussion and Recommendations**

The main causes of delays in Iranian gas and combined cycle power plant projects have been identified and ranked. In this section, the authors have attempted to discuss and make some recommendations to project managers according to PMBOK Guide [3] to mitigate the negative impact of each delay cause.

In all the following cases, human error can be a potential root cause which can be decreased by suitable human resource management practices. Also, a project risk management system can help project managers to handle the effect of each delay cause.

5.1 **Ineffective quality control/ Quality deficiencies**

The root cause of quality deficiencies should be looked for in insufficient quality management practices. Quality requirements and/or standards for the project and its deliverables should be identified during quality planning and documented in “Quality Management Plan” which is a part of “Project management Plan”. In other words, quality should be planned, designed, and built into, not just inspected into the project’s management or the project’s deliverables.

Proper quality planning is not adequate by itself. A good quality management plan should be followed by suitable quality control mechanism. The results of executing should be examined to identify any variation between deliverables and their pre-defined requirements. Finally, quality control processes should be audited in regular intervals to ensure that quality standards are used.

5.2 **Design changes/faults**

Lack of clarity or insufficient knowledge of project scope can originate unnecessary design changes during project execution. To minimize unnecessary design changes, project scope statement should be prepared as clearly as possible to provide a shared understanding of project between all stakeholders. In addition, in case the knowledge about the project (or a part of the project) is insufficient, rolling wave planning which is a form of progressive elaboration can be exploited [3]. Furthermore, in order to reduce design uncertainties, a sequential relationship between the project’s phases can be used. It should be noted that this kind of relationship may eliminate options for reducing the overall schedule. In case of schedule compression by fast tracking, an appropriate risk management practice should be employed. Finally, a proper type of contract (e.g. cost reimbursable contract) and project lifecycle (e.g. adaptive lifecycle) should be intended to respond to an uncertain project scope.

5.3 **Mistakes during the construction or procurement stage**

In case a troublesome mistake comes through, seven basic quality tools should be used to identify the root causes of the mistake. As a result, a formal change request should be submitted, reviewed and accepted or rejected according to change management system. Accepted change requests will be implemented and finally, the effectiveness of the requested change should be examined in order to make sure that the problem has been solved.
Recurring mistakes or those problems which are not limited to the current project (e.g. procedures deficiencies) should be identified during quality audits, and appropriate change request should be considered to obviate the root cause.

5.4 Frequent variation/change orders

Poor scope management is a possible reason for frequent change orders. All the project’s requirements should be collected from all stakeholders during project planning. These requirements should be sorted and recorded within project scope statement, which is a part of scope baseline. Eventually scope baseline should be formally approved by key stakeholders to avoid unnecessary changes in requirements during project lifecycle.

Late identification and incorrect analysis of project stakeholders in line with ineffective communication with them is probably another potential explanation of excessive change orders.

5.5 Unrealistic initial contract duration

Initial contract duration is often one of the constraints included in project charter. A project manager should come up with her or his estimates and complete a sanity check of the estimates instead of just accepting the constraints from management. What-if scenario and Monte Carlo analyses are useful tools to determine more realistic estimates.

5.6 Late deliveries

Project team should document the possibility of late deliveries as a threat in project’s risk register and perform risk analysis to plan appropriate risk responses and formulate a reserve. Any new risks created by the implementation of selected risk responses (secondary risks) should also be analyzed as part of risk response planning. Risk reassessment and audit should be regularly performed.

5.7 Sanctions and political conditions

Sanctions and political conditions are enterprise environmental factors which are out of project control. Project manager should make sure that this delay cause has been registered as a threat in risk register and analyzed to formulate a proper response. Similar to other identified project’s risks, it should be monitored and controlled during project’s lifecycle.

5.8 Poor contract management

Incomplete or ambiguous procurement statement of work, inappropriate contract type, lack of documentation, and scant procurement control are the possible reasons which can result in poor contract management. The contract should contain all the scope of work and all the project management requirements. Procurement statement of work should be as clear as possible to avoid misinterpretations. Contract type should be suitable to the project type and risk level, and the contract should be tailored to the unique needs of the project. For example, a fixed-price contract should be used for acquiring goods, products, or services with well-defined specifications or requirements. In contradiction, a cost-reimbursable contract is used when the exact scope of work is uncertain and, therefore, project cannot be estimated accurately enough to effectively use a fixed-price contract [37].

Any correspondence, clarification, and notifications related to the contracts should be formal written communication. Project team should also implement procurement performance reviews throughout the contract duration and request changes as necessary. All procurements must be closed out and the lessons learned should be documented.

6 Conclusion

Many of Iranian gas and combined cycle power plant projects are experiencing delay. Delays in such projects can be catastrophic and cause black outs due to the current shortage and growing demand of electric power in Iran. 25 main factors causing delay in Iranian gas and combined cycle power plant projects discriminated. The experts’ judgement on each delay cause solicited through a questionnaire survey, and the causes sorted based on their mean score.
Ineffective quality control/quality deficiencies; design changes/faults; mistakes during the construction or procurement stage; frequent variation/change orders; unrealistic initial contract duration; late deliveries; sanctions and political conditions; and poor contract management introduced as the major causes of delays. Some mitigation strategies are presented for each main delay cause.

7 References


Projects Risk Management Using Artificial Neural Networks Based on Lessons Learned

Derakhshanfar, H.1*, Elmualim, A.2, Ochoa J.J.3, Mayer, W.4, Gunawan, I.5

Abstract: Even the simplest project involves some risk. Due to the complicated nature of contemporary projects, there should be an accurate and reliable risk management practice in place to face uncertainties and secure projects success. On the other hand, lessons learned and historical information are the most precious resources to identify and analyze project risks. This paper proposes a risk analysis tool using project risk management, lessons learned, and artificial neural network (ANN) concepts. The model utilizes the events happened in previous projects to predict the potential outcomes of future projects. Iranian gas power plant projects are considered as a case study. A questionnaire survey is used to solicit the project managers/engineers’ perspective about the impact of occurred events on their projects, and gathered data is used by the model to predict projects durations. Calculated Root Mean Square Error (RMSE) as a measure of the differences between values predicted by the ANN model and the actual values is 3.7 which means that the ANN’s prediction error is 3.7 months. It is expected that the findings of this study may be implemented in various types of industries with modifications to account for specific regional or national factors.

Keywords: Project risk management, Lessons learned, Artificial neural networks, Case study, Iranian gas power plants, Questionnaire survey
1 Introduction

Project risk is an uncertain event or condition that, if it occurs, has a positive (good risks, called opportunity) or negative (bad risks, called threat) effect on one or more project objectives such as scope, schedule, cost, and quality [1]. Without effective risk management, project managers would spend a considerable amount of the projects time and energy to confront problems which a prior response had not been planned for them. Poor risk management is one of the major reasons causing over budget, delay, or even failure of projects. Project risk has its roots in uncertainties which are the inseparable parts of every project, and the objective of project risk management is to increase the probability and impact of opportunities, and decrease the likelihood and effects of threats in a project.

There are various risk management models which some of them are summarized in Table 1. Although there are slight differences between the mentioned models, it can be asserted that almost all of them constitute four major processes including risk identification, analysis, response, and monitoring.

<table>
<thead>
<tr>
<th>No.</th>
<th>Model or Researcher</th>
<th>Risk Management Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Fairley [3]</td>
<td>Identify risk factors, Assess risk probabilities and effects on the project, Develop strategies to mitigate identified risks, Monitor risk factors, Invoke a contingency plan, Manage the crisis, Recover from a crisis</td>
</tr>
<tr>
<td>3</td>
<td>SEI [4]</td>
<td>Identify, Analyze, Plan, Track, Control, Communicate</td>
</tr>
<tr>
<td>6</td>
<td>Leach [7]</td>
<td>Identify potential risk events, Estimate the risk probability, Estimate the risk impact, Identify potential risk triggers, Analyze risks, Prevent risk event, Plan for mitigation, Insure against risk, Monitor for risk triggers</td>
</tr>
<tr>
<td>7</td>
<td>IRM [8]</td>
<td>Risk assessment, Risk reporting, Decision, Risk treatment, Residual risk reporting, Monitoring</td>
</tr>
<tr>
<td>8</td>
<td>SEI [9]</td>
<td>Prepare for risk management, Perform risk management activities (Assess risk, Plan for risk mitigation, Mitigate risk), Sustain and improve risk management</td>
</tr>
<tr>
<td>9</td>
<td>PMBOK [1]</td>
<td>Plan risk management, Identify risks, Perform qualitative risk analysis, Perform quantitative risk analysis, Plan risk responses, Control risks</td>
</tr>
</tbody>
</table>

Lessons learned and historical information are valuable resources to identify and analyze projects’ risks. Events from previous projects along with their effects on the projects’ performance can be perceived as risks and their possible impacts for future projects. One of the usual methods to identify project risks is “Checklist Analysis” in which the relevant risks will be selected from a checklist containing events happened in previous projects. It is obvious that the checklist should be continuously developed over time by the lessons learned documented in every closed project.

The main objective of this study is to propose an ANN model which utilizes the impact of each probable event taken place during preceding projects to predict the performance of an upcoming project. In other words, this research proposes a model which combines a risk checklist for risk identification and an ANN for risk analysis. In this paper, following a literature review in Section 2, the research methodology has been set out (Section 3). A case study and corresponding results are presented in Section 4 and 5 with the model obtained and the corresponding accuracy analysis. Finally, Section 6 and 7 conclude with a discussion on the significance of the results.

2 Literature Review

Many articles have studied the application of ANNs to project and portfolio management which are categorized based on PMI’s project and portfolio management knowledge areas [1], [10]. In Table 2, Tkáč & Verner [32] reviewed 412 articles published from 1994 to 2015 related to the application of ANNs in business. They classified the studies according to the year of publication, application area, type of neural network, learning algorithm, benchmarking method, citations and journal.

Some researchers have focused on the ANNs usage in portfolio management. Zhang et al. [13] have used ANNs for building an effective early warning system to recognize troubled projects. ANNs have been used by Han [11] to identify risky software projects. Costantino et al. [12] have
also utilized the project managers’ feedback on previous projects to develop an ANN contributing to project selection in a portfolio.

Table 2: Studies related to the application of ANNs to project and portfolio management and their knowledge area

<table>
<thead>
<tr>
<th>Category</th>
<th>Knowledge Area</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portfolio Management</td>
<td>Portfolio Strategic Management</td>
<td>[11], [12]</td>
</tr>
<tr>
<td></td>
<td>Portfolio Governance Management</td>
<td>[13]</td>
</tr>
<tr>
<td></td>
<td>Portfolio Performance Management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portfolio Communication Management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Portfolio Risk Management</td>
<td></td>
</tr>
<tr>
<td>Project Management</td>
<td>Project Integration Management</td>
<td>[14]</td>
</tr>
<tr>
<td></td>
<td>Project Scope Management</td>
<td>[15], [16], [17], [18], [19]</td>
</tr>
<tr>
<td></td>
<td>Project Time Management</td>
<td>[20], [21], [22], [23], [19]</td>
</tr>
<tr>
<td></td>
<td>Project Cost Management</td>
<td>[24], [25], [26], [27]</td>
</tr>
<tr>
<td></td>
<td>Project Risk Management</td>
<td>[28], [29], [30]</td>
</tr>
<tr>
<td></td>
<td>Project Human Resource Management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project Communication Management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project Procurement Management</td>
<td>[31]</td>
</tr>
<tr>
<td></td>
<td>Project Stakeholder Management</td>
<td>[32]</td>
</tr>
</tbody>
</table>

ANNs have also been utilized for scope management. HashemiGolpayegani & Emamizadeh [14] initiated an ANN able to suggest Work Breakdown Structure (WBS) for projects. They imported the words used in project activity titles as well as project attributes to their ANNs as the inputs.

The research by Tronto et al. [15] and Heiat [16] are the ANN’s application in resource and effort estimation of software projects. They compared the results of their created ANN to the results from regression analysis in two separate studies. They concluded that the neural network produces improved performance over conventional regression analysis in non-linear and complicated cases. Kim et al. [17] employed ANN to discern major project delay factors from a pool of possible factors. Agarwal et al. [18] have merged ANN and Genetic Algorithm concepts for resource constrained project scheduling. They measured the result of their hybrid model against the results from autonomous application of each concept.

Project cost management is another application of ANNs. Cheng et al. [20] have created hybrid models combining Genetic Algorithm, Fuzzy Logic, and ANN to predict project cost and cash flow. Key project management factors affecting project cost are extracted through an ANN by Chua & Loh [23], and the project budget performance was estimated based on these factors. Ling & Liu [19] determined project budget and schedule influencing factors as well. Furthermore, their ANN was able to predict budget and schedule performance on the basis of the influencing factors.

ANNs have also employed to calculate Comprehensive Risk Factor by Zhu et al. [24], Li & Chen [25], Zuogong et al. [26], and Chenyun [27]. Procurement management is another knowledge area that is targeted by ANNs. Jin & Zhang [28] studied risk allocation strategies in public–private partnership projects by ANN. The ANN’s ability to calculate projects’ economic future value has examined by Badiru & Sieger [29]. Chou et al. [30] tried to forecast bid award amounts for bridge construction projects in Taiwan by synthesizing ANN and Genetic Algorithm. Finally, ANN has also been applied to stakeholder management. Baets et al. [31] utilized ANN to visualize stakeholder perceptions and to monitor changes in these perceptions.

3 Research Methodology

3.1 Introduction to Artificial Neural Network

Composed of many simple computational elements, Artificial Neural Networks (ANNs) are inspired from human brain structure to reflect the ability to learn and employ the earned knowledge to solve variety of problem including prediction and classification [33].

An ANN consists of many processing elements (PE) known as artificial neurons typically arranged into few layers based on the problem and application (Figure 1). An artificial neuron can process some inputs to create one or several outputs to other processing elements or outside the network using an activation function. The weight of each input is adjusted in order to reach the
appropriate output during the learning phase; then uses the weights to predict results from similar sets of inputs [34].

![Diagram of a typical artificial neuron and artificial neural network](image)

**Figure 1:** A typical neuron and artificial neural network

### 3.2 ANN Risk Management Model

Lessons learned and historical information are reliable resources to find the events happened during previous projects provided the lessons have been documented as complete as possible. In this case, the events can be used to develop a risk checklist. Each project’s events associated with their subjective impact (e.g. on a Likert Scale) and project actual duration (or cost) are used to build the required training, validation, and test data set (Table 3). Events and project attributes (e.g. project size, type, etc.) are contemplated as the ANN’s inputs, and project actual duration (or cost) is considered as the model’s output (see Figure 2). After trained, validated and tested, the ANN can be employed as a risk management and decision-making tool to predict future projects’ actual duration (or cost) based on the experts’ judgement about the potential events (risks).

<table>
<thead>
<tr>
<th>Project</th>
<th>Event n-1</th>
<th>Project n’s Actual Duration (or Cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project n</td>
<td>event n-2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>event n-N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Project n’s attributes</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3:** Typical data set required to develop the ANN

![Diagram of a typical feed forward ANN](image)

**Figure 2:** Risk management ANN model for data set n

### 4 Case Study

Iranian gas power plant projects were exploited in order to examine the proposed approach on a case study. 25 key delay causes of Iranian gas power plant projects have been determined from the projects’ lessons learned documented during last five years, previous studies, and some initial interviews with experts (Table 4). These delay causes (events) were considered as identified risks. A questionnaire has been employed to gather gas power plant project engineers and managers’ perspective on the impact of each delay cause on their projects. The questionnaires were distributed to potential respondents working as project manager or project engineer in Iranian power plant projects. They were asked to evaluate each cause’s influence on their project. A six-
A point Likert scale ranging from 0 (no impact) to 5 (very high impact) was adopted to capture the effect of each cause on each project’s delay. By means of circulated questionnaires, the experts’ feedback on 24 gas power plant projects was gathered. Actual durations of each project and the project size (number of gas turbine-generator units) were also determined from project control reports. The results of the questionnaire survey along with the projects size were inputted to train, validate, and test the ANN, and projects actual duration was contemplated as the ANN’s output. A feed-forward back propagation (BP) network is developed using MATLAB neural network toolbox function (newff). The ANN parameters are presented in Table 5.

<table>
<thead>
<tr>
<th>No.</th>
<th>Event Label</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E1</td>
<td>Changes in the strategies and priorities of the organization</td>
</tr>
<tr>
<td>2</td>
<td>E2</td>
<td>Too much uncertainties in the project's nature</td>
</tr>
<tr>
<td>3</td>
<td>E3</td>
<td>Frequent variation/change orders</td>
</tr>
<tr>
<td>4</td>
<td>E4</td>
<td>Lack of clarity in project scope</td>
</tr>
<tr>
<td>5</td>
<td>E5</td>
<td>Project's novelty</td>
</tr>
<tr>
<td>6</td>
<td>E6</td>
<td>Inadequate planning/Inaccurate estimating</td>
</tr>
<tr>
<td>7</td>
<td>E7</td>
<td>Unrealistic initial contract duration</td>
</tr>
<tr>
<td>8</td>
<td>E8</td>
<td>Late deliveries</td>
</tr>
<tr>
<td>9</td>
<td>E9</td>
<td>Inadequate sub-contractors experience</td>
</tr>
<tr>
<td>10</td>
<td>E10</td>
<td>Owner's delays</td>
</tr>
<tr>
<td>11</td>
<td>E11</td>
<td>Weather condition</td>
</tr>
<tr>
<td>12</td>
<td>E12</td>
<td>Transportation and storage problems</td>
</tr>
<tr>
<td>13</td>
<td>E13</td>
<td>Sanctions and political conditions</td>
</tr>
<tr>
<td>14</td>
<td>E14</td>
<td>Financing and payments</td>
</tr>
<tr>
<td>15</td>
<td>E15</td>
<td>Inadequate documentation</td>
</tr>
<tr>
<td>16</td>
<td>E16</td>
<td>Inadequate/lack of communication between the parties</td>
</tr>
<tr>
<td>17</td>
<td>E17</td>
<td>Poor contract management</td>
</tr>
<tr>
<td>18</td>
<td>E18</td>
<td>Inspection and handover problems</td>
</tr>
<tr>
<td>19</td>
<td>E19</td>
<td>Skilled labor shortage</td>
</tr>
<tr>
<td>20</td>
<td>E20</td>
<td>Ineffective quality control/Quality deficiencies</td>
</tr>
<tr>
<td>21</td>
<td>E21</td>
<td>Mistakes during the construction or procurement stage</td>
</tr>
<tr>
<td>22</td>
<td>E22</td>
<td>Poor site management</td>
</tr>
<tr>
<td>23</td>
<td>E23</td>
<td>Design changes/faults</td>
</tr>
<tr>
<td>24</td>
<td>E24</td>
<td>Shortage in material</td>
</tr>
<tr>
<td>25</td>
<td>E25</td>
<td>Unexpected accidents during construction</td>
</tr>
</tbody>
</table>

Table 5: the ANN parameters

<table>
<thead>
<tr>
<th>ANN Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>The total number of layers</td>
<td>4</td>
</tr>
<tr>
<td>Hidden layers</td>
<td>2</td>
</tr>
<tr>
<td>Input layer nodes</td>
<td>26</td>
</tr>
<tr>
<td>Hidden layer 1 nodes</td>
<td>10</td>
</tr>
<tr>
<td>Hidden layer 2 nodes</td>
<td>2</td>
</tr>
<tr>
<td>Output layer nodes</td>
<td>1</td>
</tr>
<tr>
<td>The number of training samples</td>
<td>16</td>
</tr>
<tr>
<td>The number of validating samples</td>
<td>4</td>
</tr>
<tr>
<td>The number of test samples</td>
<td>4</td>
</tr>
<tr>
<td>BP Training function</td>
<td>Levenberg-Marquardt</td>
</tr>
<tr>
<td>Hidden layer 1 transfer function</td>
<td>tansig</td>
</tr>
<tr>
<td>Hidden layer 2 transfer function</td>
<td>tansig</td>
</tr>
<tr>
<td>Output layer transfer function</td>
<td>purelin</td>
</tr>
</tbody>
</table>

5 Results

Plots comparing the actual projects duration to neural network predictions are presented in Figure 3, Figure 4, and Figure 5 for training, validating and test cases respectively. The Root Mean Square Error (RMSE) is used as a measure of the differences between values predicted by the ANN and the actual values observed. The RMSE is computed by the following formula:
\[
RMSE = \sqrt{\frac{\sum_{i=1}^{n} (d_{\text{pred}} - d_{\text{act}})^2}{n}}
\]  

(1)

where \(d_{\text{pred}}\) represents ANN predicted duration, \(d_{\text{act}}\) is project actual duration, and \(n\) is the number of cases. The calculated RMSE for test cases is 3.7 which is satisfactory. It can be interpreted as the magnitude of the difference between forecasted durations by the ANN and actual project durations. In other words, the ANN’s prediction error is 3.7 months.

6 Discussion

The results show that there is reasonable conformity between the ANN predictions and actual project durations. It should be noted that the more extensive documented lessons learned and events, the more ANN’s prediction capability.

The proposed model has some advantages over traditional risk management tools like Monte Carlo analysis. First, Monte Carlo requires to set an activity network diagram and make three (optimistic, pessimistic, and most likely) estimates for each activity which is almost impossible in the early stages of a project, while the proposed approach can be exploited to estimate (or to cross check of estimates) when only some major attributes of the project are known.

In addition, although the probability and impact of a single risk can be considered in traditional risk management approaches, the inter-relation between risks and the effect of each risk on
probability and impact of other risks cannot be encompassed by conventional methods. In contradiction, the suggested tool can analyze the aggregated effects of all risks and their interactions on the project. On the other hand, the proposed ANN requires a comprehensive lesson learned documentation and more computational efforts which are its drawbacks.

7 Conclusion

This paper presents an ANN model combining risk management, knowledge management, and artificial neural network concepts to estimate project duration (or cost) during the early stage of projects in order to improve the ability of project managers, customers, or owners to make decisions and enhance the chances of project success. The model utilizes the events happened in previous projects to predict the potential performance of future projects based on the experts’ judgement on the probability of occurrence and impact of each event. To examine the proposed approach, Iranian gas power plant projects were considered as a case study. A questionnaire survey was employed to elicit the events occurred in previous projects and their subjective impact on the projects’ duration. An ANN constructed based on the gathered information which is able to predict projects duration with the RSME of 3.7.

Results show that model is relevant and applicable to project risk management and may be implemented in various types of industries with modifications to account for specific regional or national factors.

8 References


Sustainable Construction Project Management Critical Success Factors for Developing Countries

M. Reza Hosseini¹*, Saeed Banihashemi², Igor Martek³, Amir Tabadkani⁴ and Asheem Shrestha⁵

Abstract: In the quest for rapid economic growth in developing countries, the demand for construction projects have faltered in its attempts to deliver projects in a sustainable manner. This lack of progress, at times stems from the absence of Project Management Critical Success Factors (PM-CSFs). A review of literature reveals a scarcity of studies concerning PM-CSFs for sustainable delivery of construction projects in developing countries. In order to bridge this knowledge gap, this paper provides a framework for PM-CSFs to integrate sustainability into project management practices on construction projects for developing countries. Through a review of literature, a list of 56 CSFs was created, considering the three criteria: (1) applicability for developing countries, (2) applicability for construction projects and (3) relevance with project management practices. To modify and contextualize the list, semi-structured interviews were conducted with 16 project managers experienced in managing sustainable construction projects in Iran, a developing country. The findings suggest a final list of 43 PM-CSFs, which was subsequently used to develop a framework for outlining PM-CSFs based on the International Competence Baseline (ICB) Version 3.0 categories. This study contributes to the field by presenting a framework that outlines CSFs for integrating sustainability into project management practices, applicable to and customized for developing countries from a competency-based perspective.

Keywords: Critical success factors (CSFs), Developing countries, Project management, Sustainable construction, Construction industry.

¹* Hosseini, M.R.
Corresponding author, School of Architecture and Built Environment, Deakin University, Australia
E-mail: reza.hosseini@deakin.edu.au

² Banihashemi, S.
School of Building and Construction Management, University of Canberra, Australia
Email: Saeed.Banihashemi@canberra.edu.au

³ Martek, I.
School of Architecture and Built Environment, Deakin University, Australia
Email: igor.martek@deakin.edu.au

⁴ Tabadkani, A.
Department of building and architectural engineering, Politecnico di Milano, Italy
Email: amirtabadkani@yahoo.com

⁵ Shrestha, A.
School of Architecture and Built Environment, Deakin University, Australia
Email: asheem.shrestha@deakin.edu.au
1 Introduction

Sustainability concerns have become requisite to delivery of construction projects in advanced economies (Marcelino-Sádaba et al., 2015). Yet, developing countries are still lagging in integrating sustainability into core practices of managing projects (Xia et al., 2016). The challenges confronting construction project managers in developing countries transcend delivering projects on time and within budget. That is, they are also expected to deliver projects in a sustainable manner (Du Plessis, 2007). To address such a challenge, previous studies have delineated 6 principles to be integrated into practices of project management to redefine delivery of projects from the perspective of sustainability (Silvius et al., 2012). These include harmonizing social, environmental, economic interests, short term and long-term orientation, local and global orientation, consuming income rather than capital, transparency and personal ethics and values. Despite awareness of these principles, their level of implementation in developing countries is still far from satisfactory. To facilitate this, critical success factors (CSFs) need to be identified and considered, yet there remains a conspicuous lack of studies directly targeting CSFs for integration of sustainability into project management practices on construction projects in developing countries. This study addresses this gap in the body of knowledge. The reminder of the paper is organized as follow. First, a brief background, followed by describing the methods deployed to extract the information from the literature, and details of conducting interviews. The framework developed based on the findings is presented next. The study concludes with acknowledging the limitations and suggesting several areas for future research.

2 Background

Identification of CSFs for successful project management has been an active field of research. A holistic review on previous works shows that they cover both developed and developing countries such as the UK (Opoku et al., 2015), Australia (Siew, 2014), China (Gan et al., 2015), South Africa (Du Plessis, 2007), India (Patil et al., 2016), Sri Lanka (Karunasena et al., 2016), and Malaysia (Yong and Mustaffa, 2013). These CSFs cover a wide range of projects, including residential, transportation and public-private-partnerships. Additionally, studies in this category target various aspects associated with project management (Pullen et al., 2010), and involvement of all stakeholders (Duy Nguyen et al., 2004). These CSFs, however, just partially target sustainability and place priority over other objectives (Banihashemi et al., 2017). In essence, current literature does not define the CSFs that focus on an integration of sustainability into project management practices, a point argued by Banihashemi et al. (2017). Yet, these studies, outlining CSFs for project managers along with the studies that provide guidelines to promote sustainable construction, can be seen as a sound basis to prepare a list of CSFs for integration of sustainability into project management practices. A comprehensive review of literature on available studies, including those that presented guidelines for making generic projects sustainable and studies presenting CSFs for successful project management was conducted. This resulted in creation of a list of 332 CSFs, as illustrated in Appendix 1. Nevertheless, sustainability-based critical success factors are highly context-specific and have to be adapted in view of their corresponding context (Yalegama et al., 2016). Therefore, such a list has to be customized and contextualized to become applicable within the context of developing countries, as discussed next.
3 Research Method

To develop a framework of PM-CSFs for delivery of sustainable construction projects, a two-staged qualitative approach was deployed. This entailed a qualitative meta-analysis followed by conducting semi-structured interviews as illustrated in Figure 1.

<table>
<thead>
<tr>
<th>Sequential Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Approach</strong></td>
</tr>
<tr>
<td>Stage 1</td>
</tr>
<tr>
<td>Stage 2</td>
</tr>
</tbody>
</table>

Figure 1. Schematic of the Research Design

3.1 Stage 1 (Qualitative meta-analysis)

In order to conceptualize and synthesize the existing body of the knowledge of CSFs for the construction industry, a qualitative meta-analysis approach was deployed. The meta-analysis approach was applied to a collection of appropriate publications, relevant research pieces and professional standards. The keywords were limited to critical success factors, construction industry, project management practices, sustainable construction, sustainable project management, sustainable development and developed and developing countries. A list of relevant publications was retrieved throughout the ‘title/abstract/keyword’ of the major databases such as ScienceDirect®, ASCE®, Taylor & Francis®, EBSCO®, ICE® and Google Scholar®. The abstract and introduction sections of the identified publications were subsequently analyzed and those items fitting clearly with at least two keywords were kept. More than 30 relevant publications, checklists and standards were recorded to be used as the foundation to create the initial pool of CSFs and their further refinement. The next stage of this study is termed by Levy and Ellis (2006) as evaluating “the applicability of literature”. Testing for applicability of literature entails assessing the outcome collated from previous studies and retaining only the pieces of information which are applicable to the objective of the study and support the theoretical arguments (Levy and Ellis, 2006). Hence, the 332 CSFs (Appendix 1) were thoroughly reviewed by the research team. A list of 56 factors (see Appendix 2) was found to contain the CSFs that met the following criteria: (1) Applicability to developing countries; (2) Applicability to Triple Bottom Line (TBL) of sustainability; and (3) Relevance to project management practices.

3.2 Stage 2 (Semi-structured interviews)

This stage covered the customization of the list of 56 identified CSFs (see Appendix 2) within the
natural context of developing countries (matched with TBL of sustainability) through conducting semi-structured interviews with experts. A total of 27 experts were invited, drawn from managers with vast experiences in managing projects, where sustainability practices were adopted, as well as academics. Of these, 16 interviewees provided full and acceptable responses that formed the basis of this study. Various sizes of companies, project types, sizes, and different levels of experience were represented in the sample, to ensure the applicability of views across a broad area of the construction sector.

The Iranian construction industry was deemed an appropriate context for exploring the CSFs for integration of sustainability into the construction project management practices for developing countries. The annual turnover of the Iranian construction industry was accounted for US$38.4 billion, with the estimated growth rate of 4.4% over a four-year period of 2008-2012 (Pournader et al., 2015). Forecasts indicate 1.4% year-on-year growth in delivery of construction projects for 2015, and an average of 3.1% over the next five years. According to Pournader et al. (2015), the amount of investment, and the size of the construction industry in Iran, makes it an ideal sample for developing countries.

4 Study Findings

4.1 Interviews

The interviewees were first provided with two important documents. These included the Agenda 21 for sustainable construction in developing countries (Du Plessis, 2002) and six principles of sustainability (Silvius et al., 2012) for being considered during their stage-wise development. The former is the document approved and advised by the United Nations Environmental Program (UNEP) to promote sustainability in developing countries and the latter is the core concept of project management integration with sustainability. These documents were utilized in assisting the interviewees to acquire an accurate understanding of the concepts investigated in this study. This was to make sure all the respondents have a common comprehensive understanding of the topic of the study and their appreciations of the meanings of terms, concepts and requirements are analogous. Interviewees were provided with the list of CSFs and were asked to think loudly about the items. They were asked to express their views about each item in three levels being agree, disagree or detailed modification advice including; add, delete or combine. This process gradually modified the list, and the process was carried forward until all of the experts reached a consensus. In the end, the initial list of 56 CSFs was distilled into 43 items, to be used in the next step.

4.2 PM-CSFs Framework

Integration of sustainability into project management practices of construction projects requires a systematic change in the business model, processes, reporting and activities (Silvius et al., 2012). This requires a conceptual framework to reflect which competencies are required for facilitating essential changes. In essence, the PM-CSFs identified in this study could be viewed through the lenses of project management competencies. International Project Management Association (IPMA) launched its International Competence Baseline (ICB) to standardize the project management practices and harmonize its implementation in light of the different principles. Currently, the ICB Version 3.0 is one of the most extensively used frameworks by companies to assess and develop project management competencies (IPMA, 2006). ICB V.3.0 breaks project
management competencies down into 3 categories: (1) Technical Competences (TC) covering the project management processes; (2) Behavioral Competences (BC) dealing with the personal skills of the project manager and their relationships with the projects stakeholders; and (3) Contextual Competences (CC) including the interaction of the project with its context (projects, programs, portfolios and the permanent organization).

Therefore, considering these definitions and their practical implications, the final list of identified CSFs was linked to the competencies outlined by ICB V.3.0. As such, the CSFs were classified into three categories of technical, behavioral and contextual competencies as illustrated in Table 1.

Table 1. The PM-CSFs framework

<table>
<thead>
<tr>
<th>No.</th>
<th>CSF</th>
<th>CSFs’ categorization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A high degree of trust within the Project Management Team (PMT)</td>
<td>✓ TC</td>
</tr>
<tr>
<td>2</td>
<td>Commitment to systematic methodologies of project management</td>
<td>✓ BC</td>
</tr>
<tr>
<td>3</td>
<td>Enacting required policies in supporting sustainability principles establishment in construction projects by governmental and professional bodies</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>Clearly defined goals and priorities of all stakeholders</td>
<td>✓ BC</td>
</tr>
<tr>
<td>5</td>
<td>Well-defined scope of work and project constraints</td>
<td>✓ BC</td>
</tr>
<tr>
<td>6</td>
<td>Client’s commitment to the needs of the other stakeholders</td>
<td>✓ BC</td>
</tr>
<tr>
<td>7</td>
<td>Compliance with anti-corruption rules and regulations in the decision-making process</td>
<td>✓</td>
</tr>
<tr>
<td>8</td>
<td>Implementing an effective strategic planning regime</td>
<td>✓ BC</td>
</tr>
<tr>
<td>9</td>
<td>Effective and open share of knowledge among PMT</td>
<td>✓ BC</td>
</tr>
<tr>
<td>10</td>
<td>Knowledge and awareness of sustainable project delivery in the PMT</td>
<td>✓ BC</td>
</tr>
<tr>
<td>11</td>
<td>Public acceptance towards the project</td>
<td>✓ BC</td>
</tr>
<tr>
<td>12</td>
<td>Economic and political stability</td>
<td>✓ BC</td>
</tr>
<tr>
<td>13</td>
<td>Positive organizational culture in support of sustainable project management</td>
<td>✓</td>
</tr>
<tr>
<td>14</td>
<td>Strategic alignment of stakeholders’ needs with project sustainability goals</td>
<td>✓</td>
</tr>
<tr>
<td>15</td>
<td>Dominance of constructive relationships within project stakeholders</td>
<td>✓ BC</td>
</tr>
<tr>
<td>16</td>
<td>Needs assessment of people</td>
<td>✓ BC</td>
</tr>
<tr>
<td>17</td>
<td>Implementing an effective decision making process by the PMT</td>
<td>✓ BC</td>
</tr>
<tr>
<td>18</td>
<td>Availability of resources (fund, machinery, materials, etc.) as planned throughout the project</td>
<td>✓ BC</td>
</tr>
<tr>
<td>19</td>
<td>PMT’s adaptability to amendment in project scope and plan</td>
<td>✓ BC</td>
</tr>
<tr>
<td>20</td>
<td>Support and cooperation of PMT in delivering a sustainable project</td>
<td>✓ BC</td>
</tr>
<tr>
<td>21</td>
<td>Effective allocation of resources by the PMT</td>
<td>✓ BC</td>
</tr>
<tr>
<td>22</td>
<td>Strong commitment to sustainable project delivery from project stakeholders</td>
<td>✓ BC</td>
</tr>
<tr>
<td>23</td>
<td>Emphasis on high quality workmanship</td>
<td>✓ BC</td>
</tr>
<tr>
<td>24</td>
<td>Transparent and competitive procurement process</td>
<td>✓ BC</td>
</tr>
<tr>
<td>25</td>
<td>Creating accountabilities, expectations, roles and responsibilities for the organization</td>
<td>✓ BC</td>
</tr>
<tr>
<td>26</td>
<td>Comprehensive contract and specification documentation</td>
<td>✓ BC</td>
</tr>
<tr>
<td>27</td>
<td>Effective pre-tendering and tendering investigations</td>
<td>✓ BC</td>
</tr>
</tbody>
</table>
Implementing effective health and safety protocols √
Project Manager’s experience and competence √
PMT formation based on competency and transparency √
Tenure of project managers √
Implementing an effective quality control and quality assurance regime by the PMT √
Deploying updated and realistic project cost and time estimates by the PMT √
Implementing an effective project risk management by the PMT √
Implementing an effective change management system during design and construction by the PMT √
Implementing effective communication and data exchange protocols at all levels of decision-making within the PMT √
Use of lessons learnt in previous projects by the PMT √
Comprehensive contractors portfolio investigation in terms of their level of awareness of the sustainability concept and their previous records of sustainable projects implementation √
Use of up to date construction technology and methods for execution of the project √
Environmental impacts management by the PMT √
Water and noise pollutions minimization during execution √
Effective management of waste during execution phase √
Implementing a particular project monitoring and feedback methodology to evaluate the current state of sustainability and rectify any discrepancy and/or deviation √

Total 4 15 24

Notes: *The CSFs are not ranked in any particular order; *BC=Behavioral Competencies; TC=Technical Competencies; and CC= Contextual Competencies

5 Discussion of the Findings

As seen in Table 1, the majority (55.81%) of CSFs were contextual competencies in nature. That is, problems such as corruption and economic and political stability are inherently major predicaments affecting construction projects in developing countries (Gan et al., 2015, Karunasena et al., 2016). This shows that integration of sustainability into construction project management practices in developing countries relies largely on overcoming such unfavorable contextual factors. Hence, such integration depends on the level of commitment given to sustainability concerns by policy makers and clients as well as the community as asserted in previous studies on the topic (Karunasena et al., 2016).

The second group is the technical competencies comprising 15 CSFs. Holistically, this category falls to managing the technical processes of construction projects such as time, cost, quality, scope and risk, communication, information and feedback platforms and waste, noise and environmental impacts management. Due to the socioeconomic and political issues dominating in developing countries, these competencies have been given the top priority. As such, sustainability principles have been overlooked (Gan et al., 2015). This highlights the necessity of redefining the priority of technical competencies in developing countries. That is, these competencies play a role in integration of sustainability, yet the priority given to them against sustainability concerns has to
be optimized in delivering construction projects.

The last category includes the behavioral competencies that tries to address the standards of trust, commitment and cooperation among the project management team to incorporate sustainability into the construction project management practices through its four CSFs. This category was not found to be substantial, compared against technical and contextual competencies. However, as asserted by (Opoku et al., 2015) behavioral competencies are influential in driving stakeholders and the project team towards implementing sustainability practices in delivering construction projects.

6 Conclusion

The study contributes to the body of knowledge in several ways. First, through a qualitative meta-analysis entailing an exhaustive review of literature, applicable studies containing guidelines for integration of sustainability into project management alongside studies outlining CSFs for project management were identified. Second, the list was contextualized and customized within the context of a developing country, and for construction projects. As such, another contribution of this paper lies in targeting the context of developing countries as an underrepresented, yet important area when it comes to sustainable construction. In addition, the CSFs were translated into necessary competencies for project management through grounding the CSFs into a framework (check list) for project management competency. This is a point of departure from previous studies as while previous findings outline generic guidelines and basic concepts, this study points to specific competencies to facilitate the integration of sustainability into project management practices for construction projects.

While the study makes meaningful contributions, several limitations are to be acknowledged. The findings are based on the interviewees drawn from project management practitioners in Iran. In direct application and generalizations to other developing countries, the discrepancies between Iran and the context at hand should be taken into account. Besides, the framework remains tentative, prior to being validated in exposure to empirical data. This points to new opportunities for further investigation into the topic. That is, the field will benefit from future studies that target validation of the model through conducting case studies in various countries and show the implications of the framework from a practical viewpoint.

Appendices

Appendices are available at https://figshare.com/s/7842f8836c33ef858482.

References


A REVIEW ON INTERNATIONAL ECOLOGICAL LEGISLATIONS ON LIFE-CYCLE ENERGY CONSUMPTION, GREENHOUSE-GAS EMISSIONS AND COSTING ASSESSMENT

Vivian W. Y. Tam 1, Khoa N. Le1 and Cuong N. N. Tran 1

Abstract: One of several reasons that lead to global warming appears to be due to the large contribution of greenhouse-gas (GHG) emissions. Organization for Economic Co-operation and Development (OECD) contributes about 39% of global greenhouse-gas emissions. Although OECD already has a legal environmental framework for its members, the regulations is still based on its members self-awareness rather than mandatory. Simultaneously, each country also has a legal system for the protection and preservation of the environment for each country. Consequently, the unification of the environmental law system for the whole organization is needed to reduce anthropogenic GHG emissions. The paper reviews international legal and regulation system of ten countries in OECD that have the largest amount of GHG emissions. Then based on the analysis, the paper provides recommendations for improving environmental mandatory regulations for the organization.

Keywords: Australia, Greenhouse-gas emissions, renewable energy, environmental legislation

1. Introduction
One of the most significant factors involving with the global warming phenomenon is the increase of GHG emissions into the atmosphere (Cheung, 2013; Wang and Wang, 2015; Villoria-Sez et al., 2016; Alvarez Herrnz et al., 2017). Anthropogenic GHG emissions include about 82% of carbon dioxide (CO2), 9% of methane gas (CH4), 6% of nitrous oxide (N2O) and 3% of other fluorinated gases (IPCC, 2014; United States Environmental Protection Agency (EPA), 2015). With the effort to protect the environment worldwide, some top emitter countries have deployed a variety of energy efficiency improving methods which help to reverse the uptrend of global GHG emissions releasing since 2012. These methods of GHG reduction should be continuously implemented in both legal as well as technical approaches to enhance the synchronous effects to stall the climate change and austerity (Olivier et al., 2016). To deal with the tremendous impacts of rapid global warming, governments should synchronize laws, standards and tools to protect the environment against public nuisances as well as private interference (Cheung, 2013; Wong et al., 2013; Percival et al., 2013). Global CO2 emissions were 32,310 million metric tons in 2012, approximately 1.3 times more in comparison with 2003 and Organisation for Economic Co-Operation and Development (OECD), which is the forum where 35 member countries cooperate to stimulate economic, social and environmental issues of globalization, are responsible for 39% of this amount (World Bank, 2015; Paramati et al., 2017). Although Estonia was the country has the data of total GHG per capita in the first ranking and Luxembourg was the first one with data of total GHG emissions per unit of GDP in OECD during the period of 2004-2014, they have contributed average 19,451.74 and 12,086.25 thousand tonnes CO2 equivalent of GHG emissions to atmosphere respectively. This amount is much smaller than data of top ten GHG emitting countries as shown in Table 1 (OECD, 2015, 2017). Hence, this paper discovers issues related with green building laws and regulations in ten countries with the biggest data of GHG emissions releasing in the table only.

1 School of Computing, Engineering and Mathematics, Western Sydney University, Locked Bag 1797, Penrith, NSW 2751, Australia.
2 College of Civil Engineering, Shenzhen University, Shenzhen, China
* Corresponding author: Email: vivianwytam@gmail.com; Tel: 61-02-4736-0105; Fax: 61-02-4736-0833.
### TABLE 1: Average data of top ten countries with CO2 per capita, CO2 per 1000 dollar GDP and total greenhouse-gas GHG emissions in the period of 2004-2014

<table>
<thead>
<tr>
<th>Country</th>
<th>Total GHG Tonnes of CO₂</th>
<th>Country</th>
<th>Total GHG per capita Kg per capita</th>
<th>Country</th>
<th>Total GHG per unit of GDP Kg per 1000 US dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>7,058,550.04</td>
<td>Luxembourg</td>
<td>24.49</td>
<td>Estonia</td>
<td>0.639</td>
</tr>
<tr>
<td>Japan</td>
<td>1,361,557.12</td>
<td>Australia</td>
<td>24.46</td>
<td>New Zealand</td>
<td>0.597</td>
</tr>
<tr>
<td>Germany</td>
<td>952,487.17</td>
<td>United States</td>
<td>23.08</td>
<td>Australia</td>
<td>0.576</td>
</tr>
<tr>
<td>Canada</td>
<td>730,357.44</td>
<td>Canada</td>
<td>21.68</td>
<td>Canada</td>
<td>0.536</td>
</tr>
<tr>
<td>Mexico</td>
<td>657,835.81</td>
<td>New Zealand</td>
<td>18.84</td>
<td>Poland</td>
<td>0.532</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>625,761.90</td>
<td>Estonia</td>
<td>14.55</td>
<td>Czech Republic</td>
<td>0.505</td>
</tr>
<tr>
<td>Korea</td>
<td>614,511.70</td>
<td>Ireland</td>
<td>14.55</td>
<td>United States</td>
<td>0.471</td>
</tr>
<tr>
<td>Australia</td>
<td>528,106.28</td>
<td>Iceland</td>
<td>14.48</td>
<td>Korea</td>
<td>0.433</td>
</tr>
<tr>
<td>France</td>
<td>517,857.61</td>
<td>Czech Republic</td>
<td>13.36</td>
<td>Mexico</td>
<td>0.393</td>
</tr>
<tr>
<td>Italy</td>
<td>515,234.18</td>
<td>Finland</td>
<td>13.25</td>
<td>Greece</td>
<td>0.390</td>
</tr>
</tbody>
</table>

The International Organization for Standardization (ISO) 14000 family of environmental standards have currently been applied in about 171 countries around the world to set up their environmental management system’s principles and frameworks (ISO, 2017a, 2015). Currently, all countries listed in Table 1 have adopted ISO 14000 in their environmental regulations system as one of the signals of solving environmental issues (Wiengarten et al., 2013). Accordingly, the paper first exposes the issues of environmental legislation of top ten greenhouse-gas emitting countries: United States, Japan, Canada, Mexico, Australia, Korea and four European countries mentioned in Table 1. Then, the development of the legislative framework in Australia has also been reviewed along with the effectiveness and future prospects of green building rating tools in Australian scheme. This country is chosen to analyzed due to the reason that combining with standing in 8th ranking in the top ten GHG emitting countries, it has also been ranked in second place of ten countries have the most considerable data of total GHG emissions releasing per capita and third position for total greenhouse-gas per 1000 dollar GDP aspect correspondingly.

### 2. INTERNATIONAL ENVIRONMENTAL LAWS AND REGULATIONS

In the context of developing equally three sustainable pillars: environmental, social, and economic pillars, choosing soft or hard laws to confront with environmental issues is always the question for any government all over the world (Abbott and Snidal, 2000; Sindico, 2006). While hard laws, as known as binding laws, refer to lawful obligations that are defined and implemented by authority, the state of ‘soft law’ launches to practical when at least one of these aspects of legalization: obligation, precision, and delegation are violated (Abbott et al., 2000; Shaffer and Pollack, 2009). Many hard and soft international instruments have been applied such as Stockholm Declaration (1972); Geneva Convention (1979); Vienna Convention (1987); Montreal Protocol (1990); United Nations Framework Convention (1992). To apply these climate instruments effectively and successfully into one individual state’s specific circumstance, the country which plays the role as a member of United Nations Framework Convention should put its environmental protection into priority status rather than other aspects of its society (Barrett, 2013; United Nations Framework Convention, 2017). Table 2 is divided environmental legislation of these ten OECD countries into nine criteria: Basic Environmental protection; Climate change; Air and sound pollution; Water protection and management; Waste management; Soil protection; Habitat protection; Energy; Heritage properties protection (United Nations Framework Convention, 1992; OECD, 2017). Until 2011, OECD has 75 environmental acts which become the keystone for its members’ mandatory policies on the environment (Gurra, 2011).
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Country</th>
<th>Japan</th>
<th>Korea</th>
<th>Australia</th>
<th>European Union</th>
<th>United Kingdom</th>
<th>Germany</th>
<th>France</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic Environmental Protection</strong></td>
<td>- Basic Environmental Law, Environmental Impact Assessment Law, Law for Enhancing Motivation on Environmental Conservation and Promoting of Environmental Education</td>
<td>- Basic Environmental Policy Act, 1990</td>
<td>- Environmental Protection Act, 1994</td>
<td>- Protection and Biodiversity Conservation Act, 1999</td>
<td>- Framework Act on Environmental Policy, 2008</td>
<td>- Environmental Protection Convention on Climate Change (UNFCCC) and the Kyoto Protocol; &quot;EU 20-20-20&quot; targets set out in the EU Integrated Energy and Climate Change Package (IECCP); &quot;EU 20-20-20&quot; targets set out in the EU Integrated Energy and Climate Change Package (IECCP); Alkali Act 1863; Environmental Protection Act 1995</td>
<td>- United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol; &quot;EU 20-20-20&quot; targets set out in the EU Integrated Energy and Climate Change Package (IECCP); Law on Conservation and Environmental Care</td>
<td>- United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol; &quot;EU 20-20-20&quot; targets set out in the EU Integrated Energy and Climate Change Package (IECCP); Law No. 221 of December 28, 2015, Provisions on the Environment to Promote the Green Economy and to Restrict the Excessive Use of Natural Resources; Legislative Decree 152/2006 (Environmental Protection Code),</td>
<td></td>
</tr>
</tbody>
</table>
2.1. European countries regulations
Four of top ten GHG emitting OECD countries are in European zone in the period of 2004-2014 (shown as in Table 1). They are Germany, United Kingdom, France, Italy. Hundreds of environmental legal acts have been intertwined both in the regional and national policies (Cherp, 2001). There were about 268 comitology committees divided in 29 policy sectors in 2011, for instance (Selin and VanDeveer, 2015). As can be seen in Table 2, the environmental legislation framework for these countries is covered with all nine criteria. However, some countries do not break up their laws into sections according to categories, but enact laws that cover those categories such as Italy or France for habitat, soil preservation, etc. And in addition, for example of renewable energy poly, Italy has just adopted directly legislative decrees (Legislative Decrees 387/2003 and 28/2011) to implement the European Union’s Renewable Energy Directive 2009/28/EC (Michelle and Guido, 2011; Scarica Comuni Rinnovabili, 2015).

2.2. American region’s eco-law systems
A diversity of laws and regulations serve as the foundation of United States Environmental Protection Agency to protecting the natural habitats (United States Environmental Protection Agency (EPA), 2017). The National Environmental Policy Act of 1969 (NEPA) is a United States environmental law put into practice since 1970 that changes the game of the environment protection in this country (Anderson, 2013). Since then, many major environmental policy have been translated from laws, such as Code of Federal Regulations (CFR), Title 40 (Regulations of the Environmental Protection Agency) and some other significant CFRs (Harjo, 2016). Although the United States legislation system is a complex combination of rules to form a fragmented laws structures, punitive approach has been applied to increase the Environmental Protection Agency’s enforcement powers under the Clean Air Act of 1963 (Murchison, 1995; Robert, 2013).

As a neighbor of United States, Canada has similar direction in the fighting with climate preservation. Its label of ‘Canada’s Environmental Choice’ was introduced first time in 1988 (Tews et al., 2003). Three core Canadian acts that protecting and assessing environmental impacts are the Environment Act 1987, Environmental Assessment Act 1992 and Environmental Protection Act 1999 (Environment Canada, 2012). Along with these acts, in term of climate change prevention and energy efficiency, Canada has enacted the Greenhouse Gas Reduction Targets Act in Federal states, Specified Gas Emitters Regulation, Energy Administration Act, Energy Efficiency Act in 2007, or other related environmental management legal such as Clean Air Act, Water Act, Soil Conservation Act, etc (CANLii, 2014; Doern et al., 2015).

In Mexico, the General Law on Climate change has been developed by the Environmental Law Institute via the USAID/Mexico Competitiveness Program, and approved by the Senate of Mexico in 2012. By this law, Mexico is the country right after United Kingdom to set up a ecological scheme with multi-sector as well as multi-stakeholder approach to deal with climate change (Senate of Mexico, 2012; IDLO, 2012). Certainly, Mexico has not recently concerned about the environment. This country has also issued a variety of legislation that protects and preserves air, water and other ecological resources, which can be seen in Table 2.

2.3. Asia-Pacific environmental legislation systems
In contrasting to United States, Australia utilizes a practicability-based approach in designing its environmental regulations (Murchison, 1995). The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is an Act of the Parliament of Australia, replaced the National Parks and Wildlife Conservation Act 1975, that designs a Australian environmental protection scheme (Australian Government, 1999). Due to the particularity of Australian legal structures, which is lack of distinctive constitutional functions for environmental matters that leading to the dispute of which governmental level will resolve ecological issues, only until 2011, the Clean Energy Bill was introduced and then revoked in 2014 (Peel, 2008). Currently in Australia, Standards Australia is a non-for-profit as non-government organisation that is recognised as a member of ISO (ISO, 2017b).

Although standards are voluntary by their own meaning, they can become compulsory when State and
Commonwealth governments introduce them into legislation (Standards Australia, 2017). Fig. 1 shows the development of environmental law in Japan. Based on the Basic Environment Law in 1993 and the Environmental Impact Assessment Law in 1997, initial and final steps in the whole process of assessment have been revised in the Amendment of Environmental Impact Assessment Law in 2011 (Ministry of Environment Japan (MOEJ), 2012; Schumacher, 2017). Prior to that primary environmental legislation, many laws related to forest, land, and other ecosystems have been released during the period from 1948 to 1972. These law instruments aim to the large-scale projects in Japan to assess their environmental impacts as well as to strengthen the Japanese eco-legislation system in the fighting with climate change (Kurasaka, 2001; Ministry of Environment Japan (MOEJ), 2012).

With the boom of industrial development in South Korea, the country has paid its attention to the environmental issues by enacting Framework Act on Environmental policy in 2008, Framework Act on Low carbon, green growth in 2010, Act on promotion of the development, use and diffusion of new and renewable energy in 2011, and Sustainable development Act in 2015 (Norbert et al., 2015; Korea Ministry of Government Legislation, 2017). These acts provide the approach to preserve the environment by promoting sustainable development such as motivating the industry of innovative and renewable energy, endorsing the stable supply of energy, eco-friendly adaptation of the energy structure and the greenhouse gas emissions reduction (Korea Ministry of Government Legislation, 2017).

3. AUSTRALIA, A CLEANER ENVIRONMENTAL LEGISLATION SYSTEM
Since the National Environmental Protection Council Act was enacted in 1994, the amount of greenhouse gas emissions has been seen gradually increasing (OECD, 2015). As can be seen in Table 3, this amount fluctuated between the period of 2008 and 2012, and begins to decline in 2013. The acts that involved with renewable energy in large-scale generation shortfall charge and small-scale technology shortfall charge generation was introduced in 2000 and 2010, respectively. And the acts that managing the minimum greenhouse and energy standards are regulated in 2012, which are getting effectively along with the Clean Energy Legislation act in 2014. In the period from 1994 to 2014, the amount of greenhouse-gas emissions reached the highest level of 537,889.89 (thousand tonnes CO₂-eq) in 2009, and then reduced to 522,397.09 (thousand tonnes CO₂-eq) in 2014 (OECD, 2015). This means from the time the regulations came into effect to their effectiveness in life is a long and complicated process. It needs a synchronization of the acts to bring the most effective in protecting the environment.

### Table 3: Chronological relationship between Australian total GHG emissions and environmental legislation in the period of 1994-2014

<table>
<thead>
<tr>
<th>Year</th>
<th>Total GHG emissions</th>
<th>Environmental legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Total GHG emissions</td>
<td>Environmental legislation</td>
</tr>
<tr>
<td>------</td>
<td>---------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>2001</td>
<td>491,441.70</td>
<td>Australian Heritage Council Act 2003</td>
</tr>
<tr>
<td>2007</td>
<td>529,842.87</td>
<td>Renewable Energy (Electricity) (Small-scale Technology Shortfall Charge) Act 2010; Building Energy Efficiency Disclosure Act 2010</td>
</tr>
</tbody>
</table>

4. RECOMMENDATION AND CONCLUSION
The promulgation of a common environmental legislation for OECD members aims to slow down the climate change process is necessary. Due to the specific constitutionality of each country, the overlapping of national environmental acts of member countries and the OECD’s legal instruments is inevitable. With the current quite complicated, or even complex legislation acts relevant to environment of these aforementioned countries, member states will have to adjust their legal framework to match with the organization’s and to fulfil their responsibility to implement the organization’s legal decisions as well as recommendations (Gurra, 2011). As analysis in the above parts, this is a long process from the laws were passed until they come to effect. Although the environmental legislation system have specific and particular regulations for measuring and management, the ecological results have been taken a while to be in a positive trend for environment protection. Therefore, mandatory as well as voluntary standards for environment protection implementation, monitoring and management should be synced along with each OECD’s country’s constitution system. The paper suggests some measures as follows: (1) Governments should consider to focus laws that can regulate sustainable economic growth as well as greener environmental development in order to prevent any sudden crashes which would happen same as in 2009. This would help the economic growth has a steady, consistent sustainable trend with environment. (2) Beside issuing mandatory regulations on sustainable development, voluntary tools should be utilised to support these legislation requirements in industries. These tools will help governments shape their law systems flexibly and enterprises volunteer to contribute their efforts to control of environmental pollution.

5. ACKNOWLEDGMENT
The authors wish to acknowledge the financial support from the Australian Research Council (ARC) Discovery Project under grant number DP150101015.

6. REFERENCES


Senate of Mexico (2012). “General law on climate change Mexico,” <https://www.inef.org/media/workshops/2015/15hghgtadingeworkshop/GeneralClimateChangeLaw>


Public Housing as Method:
Upgrading the Urbanisation Model of Chongqing through a Mega Urban Project

Hu, Weijie.¹* and Wang, Yiting.²

Abstract: By analysing its mechanism and rationale, the author explains how the mega urban project of public rental housing in Chongqing functions as a method to upgrade the urbanisation model in China. However, the author critically argues that uneven distribution and financial debt in public rental housing may damage this urbanisation model. Over the past three decades, China has been experiencing rapid urbanisation, including in the city of Chongqing. Public rental housing has been adopted as the core urbanisation mega-project in Chongqing. There are three main generators of urbanisation in Chongqing: 1. the securitised land-exchange system (dipiao 地票); 2. a massive distribution of urban household registration (hukou 户口); and 3. construction of over 40 million square metres of public rental housing. As part of the ‘troika’ urbanisation generators and policies, Chongqing’s public rental housing has become a government-led strategy for promoting urbanisation. Thus, the nature of the mechanisms and contestations associated with public rental housing in Chongqing is selected as the research target. Due to the emphasis on the government’s role in this mega urban project, public rental housing in Chongqing stands out as a prominent case among other pilot programs across the country. The author’s criticism is given that uneven residential distribution and financial debts in public rental housing may lead to potential problems, or even damage Chongqing’s urbanisation model. It is hoped that the findings here can contribute to adding a new dimension of understanding to the issue of rapid urbanisation and urban sustainability in western China.

Keywords: Chongqing public rental housing; Public housing; Urbanisation model; Mega urban project.

¹ Hu, Weijie.
Corresponding author, School of Architecture, Design and Planning, the University of Sydney, Australia
E-mail: weijie.hu@sydney.edu.au

² Wang, Yiting.
Department of Urban Planning, School of Geography and Tourism, Chongqing Normal University, China
1 Introduction

Over the past three decades, China has been experiencing rapid urbanisation, including in the city of Chongqing. In 1998, Chongqing and its immediate rural hinterland were carved out of Sichuan Province and made a direct-controlled municipality (zhixia shi 直辖市) reporting directly to the central government in Beijing. The intention of the central government was obviously to set Chongqing as an aggressive target for urbanisation and economic growth in the backward south-west of China[1]. Since then, Chongqing has been experiencing a significant urban boom over the last 20 years. However, the urban-rural dichotomy in Chongqing has not been fundamentally changed. Although the urban-to-rural income ratio in Chongqing was 4.01:1 in 2006[2] and had been narrowed to 2.56:1 by 2016, structural differentiation in society continues to proceed faster than structural and norm integration due to a lack of long-term mechanisms for rural-urban conversion[3].

In recent years, public rental housing (hereafter PRH) has been adopted as the core urbanisation mega-project in Chongqing. There are three main generators of urbanisation in Chongqing: 1. the securitised land-exchange system (dipiao 地票); 2. a massive distribution of urban household registration (hukou 户口); and 3. construction of over 40 million square metres of PRH. As part of the ‘troika’ urban generators and policies, Chongqing’s PRH has become a government-led strategy for promoting urbanisation (see Figure 1). Thus, the nature of the mechanisms and contestations associated with PRH in Chongqing is selected as the research target. Due to the emphasis on the government’s role in this mega urban project, PRH in Chongqing stands out as a prominent case among other pilot programs across the country. However, uneven residential distribution and financial debt in PRH may lead to potential problems.

![Figure 1. three generators in the urbanisation in Chongqing](image)

2 Public Rental Housing in Chongqing

2.1 Mega urban projects as method

Mega urban projects are arguably the symbol par excellence of entrepreneurial urbanism, and it is not a coincidence that they have become a familiar part of the urban scene throughout the world, especially in East Asia[4]. Mega urban projects of varying sizes have commenced around the leading urban centres of China, including in the rapidly growing megalopolis of Chongqing. Since 2009, over 40 million square metres of PRH has been built, three-quarters of which was completed in the first three years[5][6]. By the end of 2016, there were a total of 39 PRH communities, of which seven
communities were completed and 32 sites were still under construction, with 692,000 apartments having been built. Currently, around 400,000 people are living in the seven completed sites and about 100,000 people are living in the other six semi-completed sites. This PRH mega urban project is strictly monitored from start to finish by government, including in relation to land distribution, housing allocation, and housing ownership. For example, Chongqing Municipality has allocated a total of over 2000 hectares of land for building PRH. In addition, the ‘eight giant state-owned investment firms (badatou 八大投)’ have been appointed to oversee the construction of PRH, to assist in infrastructural development and to ensure the provision of public utilities and services. Furthermore, the allocation of PRH has been controlled to ensure that PRH are not resold or sublet for profit.

The construction of PRH is a contested set of spatial practices in uniquely socio-economic contexts on the periphery of Chongqing. Furthermore, PRH has attracted public debate about urbanisation and its financial sustainability.

2.2 A mega urban project for upgrading the urbanisation model

In the urbanisation model of other Chinese cities, informal housing is widely used to accommodate migrant workers, such as underground living in Beijing[7] and ‘village in the city’ in Shenzhen[8] and Guangzhou[9]. By contrast, migrant workers can live in formal PRH in Chongqing’s urbanisation model. From the perspective of the housing demand-supply relationship, Chongqing PRH is totally different from informal housing in other cities because Chongqing PRH balances its housing demand by increasing housing supply, while other locations stabilise housing supply by curbing housing demand. Furthermore, the availability of Chongqing PRH in contrast to the factory dormitory, such as Foxconn factory campus in Zhengzhou, provides a place for family life. Chongqing PRH is more family-oriented to accommodate the needs of family life, by contrast to factory dormitories.

But what makes Chongqing’s urbanisation model most outstanding is that it officially allows rural migrants to possess urban assets and to share in the benefits of urban growth. From this point of view, PRH not only provides a stable housing supply for rural migrants, but also upgrades the urbanisation model by narrowing the social wealth gap.

Extensive research has been undertaken on how to achieve income equality, and it is largely agreed that this goal is beyond the scope of urbanisation. However, it would appear to be possible to effectively solve income inequality through urbanisation in China as a result of land ownership practices in history. Due to the legacy of Socialist China, land in China is all state-owned, which means local governments are the actual manipulators of all urban land. Thus, the role of government is far greater in China than it is in other countries. As a result, the task of narrowing the social wealth gap there can be effectively achieved through urbanisation.

Considering China’s example, the most feasible means to create more legal taxpayers with urban assets would seem to be the massive and equal provision of PRH for the whole society[10]. Housing ownership became transferable to individuals at a low price after the monetisation of housing distribution in China in 1998. As long as public services in a city are increasingly improved, urban real estate in that city will appreciate. Those who possess urban real estate will automatically come to share in increased social wealth[11]. As a result, the ability to own urban real estate has become a vital factor in the distribution of social wealth. Because the monetisation of housing ownership has led to much faster wealth gains than job-salary increases, the wealth gap between
people with urban real estate and people without urban property has widened. In other words, housing ownership can directly affect social stratification. Therefore, Chongqing government should be clearly aware that enabling rural migrants to own urban property is the primary method of narrowing the wealth gap in Chongqing’s urbanisation process.

Land and real estate cannot automatically generate wealth, but possession of land or real estate is a means of sharing social wealth. Local government’s provision of public housing with corresponding equal public services is probably the most appropriate way to redistribute social wealth via urbanisation. Therefore, the PRH mega urban project is the core urbanisation method used in Chongqing.

However, this mega urban project does not form a complete urbanisation system, which may lead to potential problems, such as spatial marginalisation, social segregation and financial deficit.

3 Criticism of Public Rental Housing in Chongqing

3.1 Uneven distribution

Mega urban projects in China are likely to use space on the urban fringe because plentiful land on the outskirts of cities can be lent to land developers at a relatively low price. Thus, the urban edge of Chongqing has attracted the attention of entrepreneurial local governments that see mega urban projects as the driving force of urbanisation.
Given that the Chongqing government seeks a maximum return in affordability on land revenue, PRH is often located in spatially marginal areas. As shown in Figure 2, at urban scale, a total of 39 sites of PRH in Chongqing are presently mostly located between the inner-city ring and the outer-city ring, which means locations are far away from the city centre and important urban facilities. From the seven completed sites, the distance to the city centre is between 14.5 kilometres to 50.9 kilometres; while the distance to sub-centres is between 4.3 kilometres and 38.3 kilometres, as shown in Table 1.

### Table 1. Information of site distribution of PRH in Chongqing

<table>
<thead>
<tr>
<th>Communities of PRH</th>
<th>Distance to the center (km)</th>
<th>Distance to sub-centers (km)</th>
<th>Distance to the metro (m)</th>
<th>Number of available PRH apartments</th>
<th>Number of applicants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minxin Jiayuan (民心佳园)</td>
<td>14.5</td>
<td>11.4</td>
<td>600</td>
<td>488</td>
<td>5945</td>
</tr>
<tr>
<td>Kangzhuang Meidi (康庄美地)</td>
<td>16.5</td>
<td>7.0</td>
<td>150</td>
<td>374</td>
<td>9205</td>
</tr>
<tr>
<td>Kangju Xicheng (康居西城)</td>
<td>40.0</td>
<td>12.1</td>
<td>3500</td>
<td>2044</td>
<td>609</td>
</tr>
<tr>
<td>Min’an Huafu (民安华福)</td>
<td>26.5</td>
<td>15.2</td>
<td>4000</td>
<td>1028</td>
<td>104</td>
</tr>
<tr>
<td>Liangjiang Mingju (两江名居)</td>
<td>33.5</td>
<td>26.0</td>
<td>1100</td>
<td>394</td>
<td>623</td>
</tr>
<tr>
<td>Chengnan Jiayuan (城南家园)</td>
<td>16.7</td>
<td>4.3</td>
<td>500</td>
<td>427</td>
<td>7124</td>
</tr>
<tr>
<td>Yunzhuang Shanshui (云篆山水)</td>
<td>28.3</td>
<td>19.8</td>
<td>900</td>
<td>180</td>
<td>368</td>
</tr>
<tr>
<td>Bandao Yijing Leyuan (半岛逸景乐园)</td>
<td>22.9</td>
<td>11.4</td>
<td>1500</td>
<td>3626</td>
<td>637</td>
</tr>
<tr>
<td>Konggang Leyuan (空港乐园)</td>
<td>31.1</td>
<td>31.1</td>
<td>980</td>
<td>3531</td>
<td>1450</td>
</tr>
<tr>
<td>Qiaoping Renjia (樵坪人家)</td>
<td>25.1</td>
<td>21.9</td>
<td>11000</td>
<td>4581</td>
<td>90</td>
</tr>
<tr>
<td>Chengxi Jiayuan (城西家园)</td>
<td>50.9</td>
<td>38.3</td>
<td>37500</td>
<td>4079</td>
<td>48</td>
</tr>
<tr>
<td>Juulong Xiyuan (九龙西苑)</td>
<td>35.2</td>
<td>25.0</td>
<td>17300</td>
<td>4067</td>
<td>47</td>
</tr>
<tr>
<td>Meili Yangguang Jiayuan (美丽阳光家园)</td>
<td>23.6</td>
<td>12.8</td>
<td>4300</td>
<td>3063</td>
<td>1248</td>
</tr>
</tbody>
</table>

At settlement scale, as well as marginal location, clustered distribution also contributes to the uneven distribution of PRH in Chongqing. The PRH sites are mainly located in several regions, showing a clustered site distribution. Of 39 sites, there are 18 sites within the Liangjiang New Zone. This site distribution strategy easily results in segregating communities of PRH from other commercial housing communities. If this situation worsens, it will further result in spatial and social differentiation that goes against the social sustainability goals of public rental housing and...
creates significant hidden social dangers, such as community degradation.

According to the *Urban-Rural Master Plan of Chongqing 2007-2020*, the urban regional scope of Chongqing will increase to 2737 square kilometres in 2020. This means an average urban land area of 91.2 square kilometres will be allocated to just one PRH community, which is obviously too uneven a distribution. The uneven distribution of PRH has resulted in forming migrant’s residential preferences for different PRH communities. Some PRH communities are more popular, such as the Kangzhuang Meidi community, while other PRH communities enjoy less favour, such as the Jiulong Xiyuan community and the Chengxi Renjia community. In the case of Chongqing’s urbanisation, the uneven distribution of PRH will further result in spatial and social differentiation that is not conducive to the redistribution of social wealth in Chongqing.

For a proposed solution, existing practice and implementation in Tianjin could possibly be consulted. Tianjin Municipality clearly stipulates that every year at least one piece of land should be reserved for affordable housing from the demolition plots in the city centre in order to avoid spatial and social differentiation[12].

### 3.2 Financial sustainability

In addition to the debate on uneven distribution, scholars have raised questions over the financial sustainability of the construction of PRH in Chongqing, especially given the huge amount of investment and financial debt required.

At the economic level, the direct investment of PRH is mainly composed of three parts, land investment, construction investment and loan interest.

<table>
<thead>
<tr>
<th>Table 2. information of direct investment of PRH in Chongqing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land investment</td>
</tr>
<tr>
<td>60 billion CNY</td>
</tr>
<tr>
<td>The direct investment of PRH is 169 billion CNY in total</td>
</tr>
</tbody>
</table>

As shown in Table 2, the land investment is estimated to be comprised as follows. The need for land is calculated to be 2000 hectares. Official data from Chongqing Municipality shows that the land investment per hectare is around 30 million CNY[13]. Thus, a total of 60 billion CNY is needed for land investment.

The estimated construction investment is around 104 billion CNY. Due to the higher construction standards of Chongqing’s PRH, the construction cost per square metre is about 2500-2700 CNY[14]. For example, the average construction price per square metre is about 2,600 CNY in the Minxin Jiayuan community. On the basis of these planning and construction standards, the estimated construction investment required for 40 million square metres of PRH is about 104 billion CNY.

The loan interest is estimated to be 5 billion CNY. The loan interest rate of commercial banks is roughly 6.90% over 3-5 years. According to the Chongqing government’s financing plan and budget, loan financing comprises 70% of financial investment, and the annual loan interest is estimated to be around 104 × 70% × 6.9% = 5 billion CNY.

Judging from the estimation above, the total direct investment required for PRH in Chongqing could reach up to 169 billion CNY. The Chongqing government is responsible for repaying the entire investment of 169 billion CNY, as it is the only investment subject of PRH.

According to the Chongqing government’s previous financing plan and budget, the direct
financial investment of PRH would be covered by fiscal investment and a financing loan at a ratio of 3:7. Fiscal investment would consist primarily of the central government’s specialty fund, the local government’s fiscal budget, and a reduction of fees and taxes. The financing loan component would mainly be collected from bank loans, non-bank financial agencies, housing accumulated fund loans, and marketing channels, such as issue bonds[15]. Specifically speaking, the Chongqing government intends to repay the financial debt through two channels, rent of PRH, and sales of PRH and its commercial stores.

Table 3. Information of income of PRH in Chongqing

<table>
<thead>
<tr>
<th>Rent of PRH</th>
<th>Sales of PRH and its commercial stores</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 4.4 billion</td>
<td>Sales of half of PRH</td>
</tr>
<tr>
<td></td>
<td>60 billion CNY</td>
</tr>
</tbody>
</table>

The income of PRH is 104.4 billion CNY in total

In terms of PRH rent, Chongqing Municipality intends to balance the annual loan interest through the rental income of PRH. At present, the standard PRH rent is 9-11 CNY per square metre. The total annual income of PRH rent is only around 3.6-4.4 billion. However, PRH cannot achieve a 100% occupancy rate in reality. As shown in the Table 3, the estimated PRH rent is thus less than 4.4 billion, meaning it cannot fully repay the previously estimated loan interest of 5 billion CNY per year.

In terms of the sales of PRH and its commercial stores, it is said that housing ownership can be sold to tenants after they have rented for five years. However, there is not yet a sound policy on housing sales. If half of PRH can be sold, the income from housing sales is estimated to be around 60 billion CNY. Based on estimates, the income from commercial store sales could be about 40 billion CNY[16]. Thus, Chongqing Municipality can speed up the reflow of funds in a relatively short time by selling PRH. However, while selling PRH can ease a small amount of short-term financial pressure, the income generated cannot make up for expenditure.

4 Conclusion

It is particularly interesting that in the logic of Chongqing government, it attempts to use mega urban projects to actively generate the market and obtain profits for the sake of its urbanisation and development, despite that parts of the profits are also re-assigned to the public via administrative means and macro-economic readjustment. Obviously, the massive construction of PRH is part of this logic described above. As the most important urbanisation mega-project in Chongqing, PRH not only gives access to addressing housing issues for low-income residents and rural migrants, but also upgrades the urbanisation model in Chongqing by narrowing the social wealth gap. However, the uneven residential distribution of PRH and the financial debt associated with PRH may lead to a failure to narrow the social wealth gap, which may damage Chongqing’s urbanisation model.

In addition, PRH as a method to upgrade the urbanisation model inevitably needs to rely on a powerful political authority. Without a strong administrative diktat, it may be difficult for other cities to replicate this urbanisation model. In fact, Chongqing, as the only direct-controlled municipality in western China, has received substantial policy support from the central government, such as in the form of raising financial aid and investment, adopting experimental
innovation policies, etc. The advantaged predominance of Chongqing as a direct controlled municipality has thus extensively benefited its urbanisation model, meaning the model may not be directly replicable in other Chinese regions.

**Acknowledge**

The authors gratefully acknowledge the financial fund (CSC Graduate Research Students Support Grant) from China Studies Center, the University of Sydney.

**References**


Exploring the Causes of the Policy Failure of China's Real Estate Regulation Policy from the Perspective of the Inner Problems of the Policy

Yang, D.L.¹, Huang, Y.D.²*, Wang Chang³, Hu, Y.Q.⁴

Abstract: In recent years China has promulgated a large number of real estate regulation policies to ensure the stability of the real estate market, prevent financial risks, balance the supply and demand and promote social security. But whether from the perspective of the efficiency of public policy or the effectiveness of public policy, it can be found that there are policy failures in China’s real estate market. The emergence of policy failures is not only due to the behaviour of the government, developers and the public, but also due to the inner problems and shortcomings of China's real estate regulation policies. On the basis of the study of the China’s real estate regulation policy’s failure, this paper analyzes the four main problems existing in current China's real estate regulation policies, and puts forward some countermeasures and suggestions to improve China’s real estate regulation policies.

Keywords: Real estate; Real estate regulation; Public policy; Policy failure.

¹ Yang, D.L.
Corresponding author, Department of Public Administration, Xi’an Jiaotong University, China
E-mail: yangdl@mail.xjtu.edu.cn

²* Huang, Y.D.
Corresponding author, Department of Public Administration, Xi’an Jiaotong University, China
E-mail: anniedir@126.com

³ Wang Chang
Department of Public Administration, Xi’an Jiaotong University, China

⁴ Hu Y.Q.
Department of Public Administration, Xi’an Jiaotong University, China
1 Research on the Failure of China's Real Estate Regulation Policy

1.1 Theoretical research on the failure of real estate regulation policy

1.1.1 The theory of real estate regulation policy

The real estate regulation policy refers to a series of policies that made by the government to supervise, regulate and control the real estate industry, to promote the balance of the supply-demand structure of the real estate market, and to promote the coordination of the real estate industry and the national economy through various means.

China's real estate regulation policy has the following necessities and importance: First of all, because China implements the socialist system, the essence of socialism requires us to carry out macro controls to the real estate market; secondly, the real estate market has the defects of spontaneity, hysteretic nature and blindness which are common in any market and must be regulated by macro-regulation policies; thirdly, the real estate market itself is faced with the problems of the high prices, the incompleteness of the market, the single mode of financing, structural imbalance, land finance and adverse social effects, the implementing of the real estate regulation policies is conducive to solving these problems.

China's real estate regulation policy contains the following four policy instruments: Financial policy, tax policy, land policy and other policies.

The objective of China's real estate regulation policy is to ensure the stability of the real estate market, prevent financial risks, balance the supply and demand and promote social security.

1.1.2 The theory of policy failure

From the point of view of system theory, public policy can be divided into three stages: "input", "transformation" and "output". The policy failure refers to the validity of public policy, and examining the validity of public policy should not only consider the efficiency-the input&output ratio of public policy, but also should consider the effectiveness of public policy, which refers to the sustainable impact on the whole society. Therefore, the policy failure of public policy can be divided into two cases: One is the public policy did not reach the expected goal, or reached the expected goal but the input is greater than the output; the other is the public policy had an unexpected negative impact on society during the process of transformation and output.

1.2 The embodiment of the policy failure of China's real estate regulation policy

1.2.1 From the angle of efficiency of public policy

From the perspective of efficiency of policy, the policy failure refers to the phenomenon that public policy did not reach the expected goal, or the policy reached the expected goal but the input is greater than the output. Nowadays the expected goals haven't been achieved yet, and there are still many problems:

(1) Over-high house price and precipitous rise of house price
Although starts late, China’s real estate market grows up quickly. From 1987 to 2016, China's house price has risen nearly 20 times in 29 years.

In addition, the house-price-income ratio of the big city of China can reach up to 10-20, which means ordinary wage earners need to use 10 years or even 20 years of wages to buy a suite.

(2) The imperfection and chaos of the market
China's real estate market is a typical incomplete market. Firstly, the real estate market lacks the openness and transparency; secondly, there are many irregularities in the real estate industry; finally, the real estate market lacks all kinds of fair mechanism and supervision mechanism.

(3) Inflexible ways of raising funds for real estate construction
At present, China's real estate industry relies heavily on the support of banks. About 30%-40% of the real estate development fund comes from bank loans; and the number of consumers buying house through loans is more than 70%.

(4) Structural imbalance
First of all, in terms of supply and demand structure, because of the large profit margins, real estate developers prefer the high-end housing construction but often neglect ordinary commercial housing, economic housing, as well as low-rent housing. But fortunately, this situation has improved in recent years. The data of the three key years 2005, 2009 and 2013 shows that in this three years the investment ratio of high-end housing is 6.6%, 5.7% and 4.2% respectively, which means the situation has improved.

Secondly, in terms of regional structure, the development of China's real estate industry in different regions is still uneven at present. For example, the eastern region's real estate added value accounted for the highest proportion of GDP, which is far beyond the Midwest, and this gap continues to grow.

(5) Land Finance
After the reform of the tax sharing system in 1994, the local government has experienced a shortfall of nearly 30%; and coupled with the unique Chinese land system, local government performance appraisal system and promotion mechanism, the degree of dependence of local government revenue on Land Finance is increasing year by year.

Since 2003, the central government has promulgated a large number of real estate regulation policies, the intensity of which is obvious to all of us. However, the above problems show that the implementation of the series of regulation policy did not really solve the existing problems of China's real estate industry and did not achieve the expected goal—ensuring the stability of the real estate market, preventing financial risks, balancing the supply and demand and promoting social security, which proves the policy failure of China’s real estate regulation policies.

1.2.2 From the angle of effectiveness of public policy
From the angle of effectiveness of public policy, the policy failure refers to the phenomenon that the public policy had an unexpected negative impact on society during the process of
transformation and output.

At present, the implementation process of China's real estate regulation policy does cause a lot of social problems:

In order to obtain land transfer fees, local governments collect land from the peasants at a low price, which encroaches upon the vital interests of the peasants and aggravates the contradiction between urban and rural areas; high prices make the newly graduated young people become the "ant tribe" and "house slaves"; with the change of real estate regulation policies, there appears "false divorce" behavior, which seriously damaged the social atmosphere and normal social order; many real economy groups have moved into the real estate industry, which leads to the decline of the real economy and so on.

Therefore, from the point of view of the effectiveness of public policy, the policy failure of China’s real estate regulation policies also can be proved.

2 Analysis of the Reason of China’s Real Estate Regulation Policy’s Failure

2.1 The factors leading to the failure of China's real estate regulation policy

The failure of China's real estate regulation policy has four main factors: government behavior, real estate developers behavior, social public behavior and the inner problems of regulation policy itself. Local governments do not actively implement the central government's policies for their own economic interests; real estate developers monopolize market information and slip through the laws and policies' fingers; the public always make irrational decision when they are playing irrational game with the developers. As a tool to make up the market failure, the real estate regulation policy should have considered and prevented possible irrational behaviors in advance to avoid the failure of China’s real estate regulation policy. This shows that China's real estate regulation policy itself still has some problems, which is also an important reason for the policy failure. Therefore, we will discuss the main problems of China's real estate regulation policy below.

2.2 The main problems of China's current real estate regulation policy

2.2.1 The discretionary and short-term characters of the regulation policy

The current regulation policy adopts the method of discretionary choice, which is a kind of anti-economic-performing behavior. The discretionary choice is to regulate the problems after a round of macro control. This approach seems to be timely and targeted, but in fact it foreshadows the failure of policy early.

First of all, the discretionary character determines the short-term and temporary nature of real estate regulation policies. For example, in 2016, house prices in some cities soared. By the end of the year, local governments proclaimed house purchase restriction policies one after another. This
kind of short-term policy only meets to solve the problems of the present stage but makes no long-term mechanism to control these problems from the sources.

Secondly, the discretionary character determines the passive and hysteretic nature of real estate regulation policies. Real estate regulation policy can only changes following the changes of market rather than take preventive measures, which leads to frequent fluctuations in the market.

Thirdly, the discretionary character will also make the market expectations increasingly unstable. Frequently changing policies make consumers lost, which results in the retaliatory rebound of real estate market and the situation of "the more regulation the more price rise".

2.2.2 The imbalance of the regulation policy

First of all, during the process of formulating, China's real estate regulation policy does not balance well between economic and social functions, that is, efficiency and fairness. For a long time, China's real estate regulation policy pays more attention to economic function than social function, trying to stimulate economic growth through the development of real estate but ignoring the original nature of housing is for people to live and its function of guaranteeing people's livelihood.

Secondly, the use of policy tools is unbalanced. According to the experience of developed countries, these countries always follow the laws of the market, they pay more attention to the use of financial policies to protect the freedom and activity of the market. At present, China's real estate regulation policy is overly dependent on the coercive force of the administrative policy tools, which easily leads to the situation of policy conflict.

Thirdly, the regulation policy is also unbalanced in the distribution of benefits. Because of the related interests, the regulation policy is always in the maintenance of the interests of local government and real estate developers but ignores the interests of the residents.

Finally, China's real estate regulation policy doesn't balance the new housing market and the secondary housing market well. For example, after the "9 • 30" policy in 2016, the government imposed price limits on new houses, but the price of the second-hand house is still fixed by the owner. Therefore, there has been a "house prices upside down"phenomenon.

2.2.3 Lack of diversity and flexibility of the regulation policy

First of all, the regional difference in the real estate market is very significant, this difference is reflected in the demand of real estate, the amount of real estate, the quality of real estate, real estate structure, real estate prices and so on. Before 2010, China's real estate regulation policy ignored the regional differences and only after 2010 did we begin to pay attention to this.

Secondly, China's real estate regulation policy is also lack of flexibility. For example, some policies aim at curbing speculation actually also inhibit the needs for improving living conditions. Some "emergency brake" policy curbs housing prices in a short time but often leads to retaliatory rebound, and the policy usually cannot adjust timely and flexibly.
2.2.4 The ambiguity of the regulation policy

First of all, the real estate regulation policy is usually formulated by many government departments, the power and responsibility is ambiguous, which is likely to cause "multiple management" and "bureaucracy".

Secondly, the real estate regulation policy also has semantic ambiguity. The content and objectives of the policy are often vague and leave a lot of room for interpretation and speculation. For example, a policy's title contains "to suppress the excessive rising housing prices" often makes people misread that the prices will rise continually, which not only fails to restrain the demand, but stimulated purchase intentions and developers' confidence; and "restriction policy" has often been interpreted as "hunger marketing", which often has the opposite effect.

3 Suggestions on improving China’s real estate regulation policy

3.1 Raise the awareness to improve the inner problems of China's real estate regulation policy

In order to promote the healthy development of the real estate industry, in the past we usually seek solutions mostly from the perspective of government, developers and the public, but lack the attention to the regulation policy itself. But many inner problems of current regulation policy are seriously affecting the implementation effect of the real estate regulation policy, therefore, we should enhance the initiative awareness to improve the regulation policy's inner problems, so as to ensure the validity of the regulation policies, in order to help to achieve the expected goals.

3.2 Make up for the discretionary and short-term characters of the regulation policy

(1) Pay attention to the formulation of long-term development policy with high feasibility, and pay attention to the continuity and compatibility of the policy

The market expectation has great influence on the effect of the policy. But because of the discretionary and short-term characters of regulation policy, the expectations are easily disrupted. Therefore, the long-term development plan can be made to make up for the short-term regulation policies, which can stabilize market expectations and inject confidence into the market. But long-term planning policies must be feasible and stable.

(2) Establish a long-term regulation mechanism

A set of long-term regulation mechanism should be set up, which will help stabilize the market expectation and reduce the influence of uncertain factors. Recently, the Department of housing construction also proposed to establish a long-term regulation mechanism, which means that China will introduce a series of supporting policies to strengthen the intensity of regulation.

The long-term regulation mechanism must be a stable system. Here is the suggestion of the components of the long-term regulation mechanism: real estate early warning system, real estate
transaction supervision system, real estate information disclosure system, real estate risk control system and real estate policy feedback system. From the stage of early warning and assessment, to the stage of implementation and supervision, and to the stage of the effect feedback, this whole process should be settled as a complete system. If so, we can strengthen the enforcement of the policy, track the implementation of the policy and make adjustments according to changes timely, which helps to make up for the discretionary character and ensure the validity of the policy.

3.3 Improve the imbalance of real estate regulation policy

(1) Balance the economic function and social function

We should first safeguard the social function of the policy and then consider the economic function, first ensure fairness and then promote efficiency. For example, through a variety of means, with the help of social forces, further improving the construction of affordable housing.

(2) Balance the interests of policy objects

The land finance is largely due to the reduction of the local government's financial power. So we should reduce the financial pressure on local governments through giving part of administrative powers to the society, thus the local government will not be much partial to the real estate developers and disregardful to the interests of the residents to get more revenue.

(3) Balance the use of policy tools

Use more fiscal and monetary policies to regulate the real estate market and reduce administrative orders appropriately. Balance the use of policy tools to maintain the activity of the real estate market.

(4) Balance the regulation of new housing market and second-hand housing market

Regulation should both focus on the new housing market and the secondary housing market. Only the balance between the two can maintain the stability of the real estate market's order and improve market expectations.

3.4 Pay attention to the diversity and flexibility of the regulation policy

(1) Pay attention to the difference of different cities

Realize "different city different governance pattern". Different cities have different characteristics, the problems appeared during theirs development processes are also different. So the regulation policies should differ among cities, to prevent the emergence of "somewhere sick, everywhere takes drugs" phenomenon. In doing so, it can not only restrain the irrational phenomena in one place, but also prevent the adverse effects on other cities.

(2) Pay attention to the difference of different regions of the city

Pay attention to the coordinated development of all regions and the average distribution of various resources. The regulation should also pay attention to the characteristics of different regions, for
example, the majority of demand is rigid demand or investment need? After mastering the
difference, we can treat differently in the formulation of regulation policy, which not only prevents
to damage the needs of ordinary property buyers, but also suppresses speculation. It is beneficial
to prevent the extreme phenomenon of "different prices in the city", and promote the stable
development of the market.

(3) Improve the flexibility of regulation policy

Track the implementation of the policy in time and adjust flexibly according to the changes after
the establishment of the policy feedback system; combine macro regulation and micro regulation,
solve newly-presented problems by micro control; make full use of the Internet and other new
media, grasp the response timely to improve the implementation of regulation policies.

3.5 Improve the ambiguity of regulation policy

(1) Define the power and responsibility relationship of the policy makers

Avoid multiple management and clarify the power and responsibility relationship between the
administrators. This will help prevent conflicts and contradictions in policies and clear up the
management ideas.

(2) Avoid the semantic ambiguity of the regulation policy

Firstly, Deal with every policy in terms of detailed explanation to explicit its objectives and
content during the formulation stage, take strict precautions against giving the outlaws an opening;
secondly, adjust in time after identifying problems to avoid the spread of the plague of harmful
effect.

References

Herald, 2017-1(B01).
University.
45-46.
in China, Hunan: Central South University: Industrial Economics.


Gupta, M.1*, Hasan, A.2, Jain, A.K.3 and Jha, K.N.4

Abstract: The construction projects are usually labour intensive and consequently, manpower is an important factor which drives productivity and governs or controls most of the other resources in a construction project. Labour productivity has a significant influence on project performance. Although considerable research has been devoted to identification of various factors affecting labour productivity, rather less attention has been paid to the factors related to site amenities and labour welfare schemes. The present study was conducted to identify various productivity factors which directly affect the morale and well-being of construction labour force. A questionnaire survey was conducted amongst site engineers and foremen to evaluate 38 attributes. A total of 151 completed questionnaires were received and analysed further to reveal that the top five attributes affecting the labour productivity are: hazardous jobs without proper safety considerations, unavailability of safe drinking water, inadequate lighting arrangements, lack of accommodation/labour camps, and low daily wages. Using the factor analysis, the identified attributes were categorized into 8 factors: health and medical provisions, site services, labour camp facilities, hygiene and sanitation, leave and benefits, social welfare and employment policies, remuneration, and accommodation. It is believed that the finding of this paper will provide useful insights into various site amenities which affect the labour productivity in construction projects, especially in developing countries such as India.

Keywords: Labour productivity, site amenities, labour welfare, construction projects.

1* Gupta, M.
Corresponding author, M.Tech Student (Construction Technology and Management), Department of Civil Engineering, IIT Delhi, India.
Email: mayank1673@gmail.com

2 Hasan, A.
PhD Candidate (Construction Management), School of Natural and Built Environments, University of South Australia, Adelaide, Australia.
Email: abid.hasan@mymail.unisa.edu.au

3 Jain, A.K.
Professor, Department of Civil Engineering, IIT Delhi, India.
Email: akjain@civil.iitd.ac.in

4 Jha, K.N.
Associate Professor, Department of Civil Engineering, IIT Delhi, India.
Email: knjha@civil.iitd.ac.in
1 Introduction

The construction sector is one of the world’s largest and challenging sectors. It makes significant contributions to both Gross Domestic Product (GDP) and employment. On an average, it contributes around 9 percent to the world’s GDP\[1\]. Since the construction industry is project-oriented, labour productivity holds a key place in ensuring profitability and competitiveness of the construction organisations. Consequently, it has remained one of the most widely researched area in the field of construction management.

Previous studies have found that productivity rates in other industries are better as compared to the construction sector \[2\]. Since labour costs comprise of around 30-50 percent of the total cost of the project in many countries \[3\], low labour productivity often causes project delays and cost overruns. While a considerable amount of research has been performed towards identification of factors affecting productivity in construction projects, issues related to labour welfare and site amenities have been largely ignored by the previous researchers. As a result, poor productivity of construction workers has remained one of the major causes of cost overruns and delays in construction projects.

The construction project sites generally have temporary facilities to cater to the various day-to-day needs of the labour workforce. The arrangement of these facilities such as provision of sanitation, drainage, canteen, power, and medical facilities at both construction site and labour camps could have a significant impact on productivity and morale of the workforce. Moreover, lack of hygiene and proper sanitation facilities also lead to more absenteeism due to increased occurrence of diseases or medical conditions. The productivity on construction sites is adversely affected by the unsatisfactory site conditions and poor quality of life \[4\]. In a study based on 15 construction projects across the six Indian states, it was revealed that lack of basic facilities was among the highest responded factors for causing absenteeism and turnover in construction projects\[5\]. However, the authors did not consider various important and mandatory site provisions such as provision of labour accommodation, sanitary facilities, drinking water, and labour welfare schemes in sufficient detail.

Previous researchers have found several factors such as material unavailability, rework, lack of equipment, poor communication, and inadequate supervision as the top ranked factors affecting labour productivity in construction projects across the globe. However, most of these studies have not covered the site services and labour welfare policies while examining the productivity factors. Few studies have identified working conditions as one of the motivation factors but did not discuss it in sufficient depth \[6\]. There has been a lack of research on examining the effects of various site amenities on low construction productivity. As a result, corrective measures to improve the condition of site amenities have also not been emphasized and discussed in sufficient depth. Therefore, there is a need to identify and examine various site amenities in context to labour productivity.

The quality of site facilities affects labour productivity both directly and indirectly. The objective of the present research is to identify various site amenities which affect the labour productivity in the construction projects in developing countries. Since the uncertainties associated with the factors related to site amenities are less as compared to that of other productivity factors, it is believed that the labour productivity can be significantly improved if more research is conducted in this direction.
2 Data Collection

The various factors relating to the site amenities were identified from the literature review and preliminary site surveys. A total of 38 factors were identified and finalised for the questionnaire survey. The responses were obtained on a five-point Likert scale in which ‘1’ represents ‘strong disagreement’ while ‘5’ represents ‘strong agreement’. The responses were stored and analysed using Statistical Package for Social Sciences (SPSS) software.

The organisations accounted for the sample survey comprised of the members of the Construction Industry Development Council (CIDC), India. To ensure that the chosen sample accurately represents the entire population, following formulae was used to calculate the sample size (SS) [7].

\[
SS = \frac{(Z^2 \cdot P \cdot (1-P))}{C^2}
\]  

(1)

Putting \(Z = 1.96\) for 95 percent confidence level; \(P = 0.5\) used for sample size needed; \(C\) or confidence interval = 0.5 in equation (1), SS turns out to be 384 for an infinite population.

Correction for finite population,

\[
\text{New SS} = \frac{SS}{1+\left(\frac{(SS-1)}{\text{pop}}\right)}
\]  

(2)

Where \(\text{pop}\) represents the number of construction firm members of CIDC which is 113. Using equation (2), the value of new SS is calculated as 80. Accordingly, questionnaires were distributed among 80 companies and finally, after two months of follow-up, 151 completed questionnaires were received. The respondents included 81 construction engineers and 70 foreman. The reason behind choosing engineers and foremen as potential respondents was their familiarity with the actual site conditions and direct interactions with the labour workforce. The average experience of the respondents was 7 years.

3 Data Analysis and Discussions

Each of the attributes affecting labour productivity was ranked on the basis of relative importance index (RII) using the following expression:

\[
\sum \frac{w}{A \times N}
\]  

(3)

where ‘w’ is the weight assigned to each attribute by the respondents and ranges from 1 to 5, ‘A’ is the highest weight (i.e. 5 in this case) and ‘N’ is the total number of respondents. The highest RII indicates the most critical factor with rank ‘1’, the next RII indicates the second most critical factor with rank ‘2’ and so on. Using the RII, the rank orders of different attributes were obtained for three categories of responses: all responses, and those of engineers and foremen separately. The results are presented in Table 1. Due to space limitations, Table 1 shows the top ten attributes only.

The initial tests were conducted to ascertain the significance of the data before performing factor analysis. The standard errors of skewness and kurtosis obtained were 0.197 and 0.392 respectively. These tests confirmed the normality of the data since the values fall into the range of (-1.96 to +1.96). Cronbach’s alpha test value obtained was 0.953 (closer to 1) sufficing the criteria for the internal consistency reliability. The closer the value of Cronbach alpha to 1, greater is the
internal consistency reliability [8] and therefore, the Cronbach alpha value of 0.953 in this survey was considered to be good. All the diagonal values in anti-image correlation matrix were found to be greater than 0.5.

The Kaiser-Meyer-Olkin (KMO) value of 0.907 (>0.5) proved the suitability of data for factor analysis. For analysing the multivariate normality and correlations between the factors, the Bartlett’s test of sphericity was conducted. The value of significance obtained was 0.000 (<0.005) representing the suitability of data for factor analysis.

Table 1. Ten most important attributes affecting labour productivity in construction projects

<table>
<thead>
<tr>
<th>Factors affecting labour productivity</th>
<th>All responses</th>
<th>Engineer</th>
<th>Foreman/ Supervisor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RII</td>
<td>Rank</td>
<td>RII</td>
</tr>
<tr>
<td>Hazardous jobs without proper safety considerations</td>
<td>0.800</td>
<td>1</td>
<td>0.793</td>
</tr>
<tr>
<td>Unavailability of safe drinking water</td>
<td>0.784</td>
<td>2</td>
<td>0.778</td>
</tr>
<tr>
<td>Inadequate lighting arrangements</td>
<td>0.775</td>
<td>3</td>
<td>0.793</td>
</tr>
<tr>
<td>Lack of accommodation/labour camps</td>
<td>0.770</td>
<td>4</td>
<td>0.763</td>
</tr>
<tr>
<td>Low daily wages</td>
<td>0.770</td>
<td>5</td>
<td>0.812</td>
</tr>
<tr>
<td>Improper safety arrangements</td>
<td>0.755</td>
<td>6</td>
<td>0.736</td>
</tr>
<tr>
<td>Low job security</td>
<td>0.722</td>
<td>7</td>
<td>0.728</td>
</tr>
<tr>
<td>High chances of epidemic at labour camps</td>
<td>0.715</td>
<td>8</td>
<td>0.746</td>
</tr>
<tr>
<td>No power supply at labour camps</td>
<td>0.709</td>
<td>9</td>
<td>0.741</td>
</tr>
<tr>
<td>Congested sites/poor site layout</td>
<td>0.703</td>
<td>10</td>
<td>0.728</td>
</tr>
</tbody>
</table>

The eight factors extracted on the basis of their Eigen value greater than 1 have been shown in Figure 1. The total attributes extracted after factor loading greater than 0.45 were 33 out of the original set of 38 attributes. The cumulative percentage of variance for the extracted eight components was 64.920 % of the total variance.

3.1 Health and medical provisions

The labour productivity is directly affected by the health and medical conditions of workers in a construction project. This necessitates the importance of adequate medical facilities at or near the construction site. It will take considerably less time in consulting an on-site doctor as compared to visiting a medical facility at a distant location. Many workers take a full day leave even when a minor medical conditions arise. The percentage of construction and industrial workers found to be responsible for reduced work productivity due to health problems were in the range of 5 to 12 percent with a mean loss of productivity of the order of 12 to 28 percent [9], which is quite significant. Therefore, any injury or medical condition must be timely and properly attended by providing adequate medical facilities on site. Provision of vaccination against seasonal and chronic diseases along with regular medical check-ups will keep the workers physically fit and will also help in preventing the spread of communicable diseases.

Improper arrangement of basic facilities on site can result in enormous wastage of productive time. For instance, wrong positioning of toilets can lead to a loss of 20 man hours a day considering 3 trips per day for 100 craftsmen taking 2 minutes each way [10]. Unavailability of temporary sheds presents enormous health threats to the workers, especially when the temperature goes above 40°C during summer in the northern states of India.
<table>
<thead>
<tr>
<th>Principal Components</th>
<th>Factors affecting labour productivity in construction projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health and medical provisions</td>
<td>No health cover/ insurance policies for labourers in case of any accident or disease (0.727)</td>
</tr>
<tr>
<td></td>
<td>Lack of medical facilities at/near the site (0.723)</td>
</tr>
<tr>
<td></td>
<td>No provision of regular medical check-up/vaccination for the labourers (0.718)</td>
</tr>
<tr>
<td></td>
<td>No provision of emergency vehicles at site in case of any medical issues or accidents (0.692)</td>
</tr>
<tr>
<td></td>
<td>Unavailability of temporary sheds at site (for rest, lunch, protection against bad weather) (0.505)</td>
</tr>
<tr>
<td></td>
<td>Improper arrangement of toilets for labourers at site (0.495)</td>
</tr>
<tr>
<td>Site services</td>
<td>Inadequate lighting arrangements (0.758)</td>
</tr>
<tr>
<td></td>
<td>Lack of transportation facilities between labour camps and site (0.671)</td>
</tr>
<tr>
<td></td>
<td>Lack of training programs for workers (0.635)</td>
</tr>
<tr>
<td></td>
<td>Congested sites/poor site layout (0.613)</td>
</tr>
<tr>
<td></td>
<td>Hazardous jobs without proper safety considerations (0.518)</td>
</tr>
<tr>
<td></td>
<td>Absence of canteen facilities for labourers at site (0.467)</td>
</tr>
<tr>
<td></td>
<td>Non-availability of safe drinking water at site (0.443)</td>
</tr>
<tr>
<td>Labour camp facilities</td>
<td>No power supply at labour camps (0.752)</td>
</tr>
<tr>
<td></td>
<td>Inadequate provision of bathing and washing facilities at labour camps (0.696)</td>
</tr>
<tr>
<td></td>
<td>Non-availability of proper cooking facilities at labour camps (0.655)</td>
</tr>
<tr>
<td></td>
<td>No power back-up at labour camps especially during the night-hours (0.571)</td>
</tr>
<tr>
<td></td>
<td>Labour accommodation/labour camps at a large distance from the site (0.570)</td>
</tr>
<tr>
<td></td>
<td>Low upkeep/maintenance of labour camps (0.478)</td>
</tr>
<tr>
<td>Site Amenities</td>
<td>Hygiene and sanitation</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leave and benefits</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Social welfare and employment policies</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remuneration</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accommodation</td>
</tr>
</tbody>
</table>

**Figure 1. Factors affecting labour productivity in construction projects**

Note: (1) Figure in percent shows the variance explained by a component (2) Factor loading of an attribute is given in parenthesis adjacent to that attribute.
3.2 Site services

The adequate lighting arrangements not only improves labour productivity but also enhances quality and safety, especially during night shifts. Lack of proper transportation facilities for workers to commute from their homes to the site forces the workers to waste a considerable amount of time in travelling and thereby, results in fatigue\(^{[11]}\). The travel distance from site was found to be one of the major reasons for absenteeism among the workers\(^{[5]}\). Absence of training programs negatively affects the skill upgradation in workers. Proper training is considered as the second best option after experience under the manpower driver for productivity enhancement\(^{[12]}\). Proper safety equipment help in the prevention of accidents and injuries in construction projects. Previous studies have found that congested sites have a negative impact on productivity and workers’ morale\(^{[3]}\)[13][14].

3.3 Labour camp facilities

Inadequate provisions for facilities concerning basic human needs such as inappropriate bathing and washing facilities and non-availability of cooking facilities in labour camps have a psychological effect on workers and their families. In the absence of regular power supply, the workers do not get proper sleep or rest which increases their fatigue and leads to higher absenteeism. Due to negligence of the employer and lack of detailed welfare policies, the quality of life of construction labours was rated between poor and near poor and the working conditions were identified between poor and average\(^{[4]}\).

3.4 Hygiene and sanitation

The burden created by the group of water, sanitation and hygiene exceeds many major diseases and is the major contributor to the mortality and disability rates\(^{[15]}\). Poor sanitation and absence of preventive measures such as bleaching and fogging create unhygienic conditions for the workers and their families and thereby, increase the chances of epidemics in labour camps. Unavailability of safe drinking water also creates major health problems. Improper sanitary facilities and poor quality of water cause several health issues amongst the workers\(^{[5]}\).

3.5 Leave and benefits

Paid maternity leaves for female workers and provision of basic educational facilities for children could have a positive psychological impact on workers. However, due to unorganised nature of the construction industry in developing countries, workers do not receive many employment benefits which are available to the workers of other sectors. In a recent report commissioned by Qatar’s Supreme Committee for Delivery and Legacy (SCDL), workers on the Qatar World Cup stadiums were found to be working 18-hour every day, more than twice the amount permitted by the local law\(^{[16]}\).

3.6 Social welfare and employment policies

The nature of the employment of construction workers is temporary and it is dependent on the future projects of the construction firm\(^{[14]}\)[17][18]. As a result, low job security often forces the workers to quit the work before completion of the project in order to search for a new job. Consequently, frequent changes in crew negatively affects the labour productivity and diminishes the positive effects of training programs and the learning curve. The construction workers in India and other developing countries are generally migrant workers from different parts of the country and hence,
a provision of resettlement allowance could be a major factor if the construction firms want to keep their workforce engaged till completion of the project. Moreover, there are no provisions of pension or superannuation benefits for the construction workers.

3.7 Remuneration

The workers receive daily wages which ranges from US$5-10 in most of the projects. The labour productivity can be significantly improved by offering performance-based incentives, fixed wages, and timely payment of wages. The importance of performance-based incentives has also been emphasized by the previous researchers [18][19]. Low remuneration was found as the major source of discontent among the construction workers [18]. Moreover, lower wages force the workmen to continuously look for better employment prospects in other sectors.

3.8 Accommodation

Due to low wages and location of the project, the construction workers often find it difficult to find a suitable accommodation for themselves and their families, especially when they are involved in projects in the urban areas where the rent is very high. In order to prevent turnover and absenteeism, accommodation should be provided by the employer near the construction sites at an affordable rate.

4 Conclusion

In developing countries such as India, the construction workers are considered as inexpensive resources. Consequently, the factors associated with their well-being and health are often neglected by the contractors. However, improper site amenities and absence of labour welfare schemes have detrimental effects on worker's productivity and morale. The past studies have mainly looked into productivity factors from the construction and management perspectives. There has been a lack of sincere research efforts to examine the services directly related to the construction workers. The first essential step in this direction is the identification of important attributes and factors. To fill this gap in the literature, the present study examined various attributes which are related to site amenities and labour welfare and have a direct relationship with the workers' performance and motivation.

The findings based on 151 completed questionnaires, received from engineers and the foremen, revealed that 8 factors that affect the labour productivity are: 1) health and medical provisions, 2) site services, 3) labour camp facilities, 4) hygiene and sanitation, 5) leave and benefits, 6) social welfare and employment policies, 7) remuneration, and 8) accommodation. These factors need to be considered by the construction organisations to improve the working conditions in the construction industry and thereby, improving labour productivity.

References


PROPERTIES OF CARBON-CONDITIONED RECYCLED AGGREGATE

Vivian W. Y. Tam\textsuperscript{1,2}\textsuperscript{*}
Anthony Butera\textsuperscript{1}
Khoa N. Le\textsuperscript{1}

ABSTRACT

The process of carbon-conditioning refers to the pressurised exposure of recycled aggregate to carbon dioxide (CO\textsubscript{2}) for a certain period of time before concrete mixing. The entraining of CO\textsubscript{2} assists to facilitate the negative properties of recycled aggregate that produces a deprived final recycled concrete as well as providing a superior calcium carbonate chemical reaction. Carbon-conditioning reduces porosity and water absorbency of recycled aggregate. In addition to improve recycled aggregate quality, CO\textsubscript{2} emissions from the aggregate also help filling openings in the concrete composition, generating an improved bond matrix from the formation of calcium carbonates (Zhan et al. 2014). These two traits assist in enhancing the recycled concrete properties. This paper demonstrates a great potential in the use of RA\textsuperscript{CO2} and provides insight for effective use of recycled aggregate for concrete production. The effective use of recycled aggregate can reduce the amount of landfill that is utilised for construction and demolition waste.

**Keywords:** Carbon-conditioned recycled aggregate, recycled concrete.

\textsuperscript{1}School of Computing, Engineering and Mathematics, Western Sydney University, Locked Bag 1797, Penrith, NSW 2751, Australia.
\textsuperscript{2}College of Civil Engineering, Shenzhen University, Shenzhen, China.
\textsuperscript{*} Corresponding author: Email: vivianwytam@gmail.com; Tel: 61-02-4736-0105; Fax: 61-02-4736-0833.
INTRODUCTION
Construction and demolition waste is attributed with a very large portion of landfill space in both Australia and the world (Pacheco-Torgal 2013). The recycling of construction waste has been heavily researched in order to discover a solution to reduce landfill space occupied by the unwanted materials. The application of construction waste as aggregate within concrete serves as a solution with outstanding potential to decrease landfill volume. Conversely, recycled aggregate concrete, as it is known, is characterised by large mechanical shortcomings (Liu 2008).

Typically, natural aggregate concrete performs superiorly to recycled aggregate concrete (Kou et al. 2012). The deficiency of strength exhibited by recycled aggregate concrete does not permit it to surpass natural aggregate in terms of mainstream practical usage. To achieve a recycled aggregate concrete which challenges natural aggregate concrete, it must undertake additional strengthening processes. However, these supplementary procedures must closely equal practicality and monetary expenditure of natural concrete. The following literature review analysis the property enrichment processes currently and close to being researched.

The process of carbon conditioning of recycled aggregates proposes an abundance of potential and must continue to be investigated. (Kou et al. 2012) experiment delivered outstanding results and creates a necessity for further experimentation.

This paper investigates the properties of carbon-conditioned recycled aggregate and provide insights of its potential contribution to the environment.

RECYCLED AGGREGATE PROPERTIES
Recycled aggregate samples collected from a south-eastern Australia centralised recycling plant was adopted for the production of concrete. Particle size distribution is of importance as it affects workability and strength (Neville 1995). As regards the sample collected was fulfilling the particle size distribution of 10mm and 20mm aggregate as stated in Australian standard (see Figure 1) (AS 1141.11 2014).

![Particle size distribution](image)

Figure 1: Particle size distribution of recycled aggregate: (a) 10mm; and (b) 20mm
The water absorption of the recycled aggregate sample is about 5.02% for 10mm and 5.63% for 20mm with particle density on oven-dried basis of about 1.44t/m³ for 10mm and 1.30t/m³ for 20mm, particle density on saturated and surface-dried basis of about 1.51t/m³ for 10mm and 1.37t/m³ for 20mm, apparent particle density of about 1.55t/m³ for 10mm and 1.40t/m³ for 20mm, aggregate crushing value of about 34%, about 2% contaminant, flakiness index of about 15.12 for 10mm and 9.78 for 20mm, and misshapen particle of about 0.88%. The properties of natural aggregate are also compared with the recycled aggregate as shown in Table 1.

Table 1 Properties of natural aggregate and recycled aggregate

<table>
<thead>
<tr>
<th>Source</th>
<th>Natural aggregate</th>
<th>Recycled aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Water absorption (%)</td>
<td>1.02 (10mm); 0.42 (20mm)</td>
<td>5.02 (10mm); 5.63 (20mm)</td>
</tr>
<tr>
<td>Particle density on oven-dried basis (t/m³)</td>
<td>2.59 (10mm); 2.47 (20mm)</td>
<td>1.44 (10mm); 1.30 (20mm)</td>
</tr>
<tr>
<td>Particle density on saturated and surface-dried basis (t/m³)</td>
<td>2.61 (10mm); 2.48 (20mm)</td>
<td>1.51 (10mm); 1.37 (20mm)</td>
</tr>
<tr>
<td>Apparent particle density (t/m³)</td>
<td>2.66 (10mm); 2.50 (20mm)</td>
<td>1.55 (10mm); 1.40 (20mm)</td>
</tr>
<tr>
<td>Aggregate crushing value (%)</td>
<td>21</td>
<td>34</td>
</tr>
<tr>
<td>Contaminant (%)</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Flakiness index</td>
<td>28.27 (10mm); 22.52 (20mm)</td>
<td>15.12 (10mm); 9.78 (20mm)</td>
</tr>
<tr>
<td>Misshapen particle (%)</td>
<td>3.02</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Carbonation Chamber
For carbon-conditioning recycled aggregate, a carbonation chamber was designed and built, including a translucent polyvinyl chloride pressure pipe with a screw top lid connecting to a CO₂ tank, brandishing a regulator in controlling pressure. CO₂ was introduced to the chamber for the experimented pressure and duration. Figure 2 illustrates the carbonation chamber used.
Carbon dioxide release trends
The recycled aggregate is first weighed to gain an initial reading before, similar as all other aggregate experiments, exposure to CO$_2$ for 2 hours at 200 kPa. On average, the 20mm recycled aggregate gains about 6 grams of weight over approximately 1,300 grams of aggregate. 10 mm recycled aggregate accumulated about 4 additional grams over 1,400 grams of aggregate after the carbon-conditioning process. This illustrates the slow 9-day dissipation of CO$_2$ from the carbon-conditioned recycled aggregate.

The lethargic CO$_2$ release is favourable to the commercial sector. Primarily, aggregate which has undergone CO$_2$ treatment can effectively be utilised in concrete several hours or even days after carbon-conditioning. Secondly, the carbon-conditioned recycled aggregate can provide concrete well into hydration. Calcium carbonates can continue to be added many days after pouring. Consequently, the carbon-conditioning process does not have to occur, although preferred, moments before mixing into concrete, suggesting that the process is flexible and can fit within complicated schedules without inconvenience. The relatively low cost, practicality and sluggish CO$_2$ dissipation are all desirable traits which can lend themselves to commercial utilisation.

CONCLUSION
Carbon-conditioning is an effective process for improving the mechanical quality of both recycled aggregates and recycled aggregate concrete. The CO$_2$ entrainment of aggregate greatly contributes to the reduction of aggregate water absorbency, improves density and derives a superior crushing value created by additional calcium carbonates. The slow release of CO$_2$ after conditioning also allows for flexibility and thus an acceptable practicality for commercial usage. Carbon-conditioning also provides a recycled concrete that has an excellent compressive, tensile and flexural strength. The modulus of elasticity does, however, require a greater amount of troubleshooting in order to achieve strengths akin to that of natural concrete. Raising the pressure within the carbon chamber does also create, in general, an inferior concrete when compared to low pressure concrete. Overall, this paper proved that carbon-conditioning is a very practical method for improve the mechanical quality of recycled aggregate and recycled concrete.

ACKNOWLEDGEMENTS
The authors wish to acknowledgement the support from the Innovyz Waste and Recycling Technologies Program.

REFERENCES
A China’s residential energy saving estimation model based on IPAT equation and LMDI decomposition

Ran Yan1, Pengcheng Xiang1*, Minda Ma1
1. School of Construction Management and Real Estate, Chongqing University, Chongqing, 400045, PR China
*Corresponding author: Pengcheng Xiang, Email: pcxiang@cqu.edu.cn

ABSTRACT: China’s residential energy savings (CRES) is an essential reference to be evaluated in China’s building energy–efficiency (BEE) work. One missing possibility along this direction is that there is currently no effective method to estimate CRES data by summarizing all its quantifiable and unquantifiable impact factors. To arrive at a solution, an effective CRES estimation method based on IPAT equation (Human Impact = Population * Affluence * Technology) and LMDI decomposition (Logarithmic Mean Divisia Index) was put forward in this study to fill up the blankness in this research direction. The calculation results reflect that CRES data in the periods of 2001–2005, 2006–2010, and 2011–2015 is 118, 79, and 96 million tce, respectively. Furthermore, the comparison between the calculated CRES data and the official planned CRES data in the said periods proves that China had surpassed its BEE targets in the field of residential building sector and the recent China’s BEE work (2006–2015) obtained good implementation effects. To a certain extent, the results of our pioneering CRES data estimation method would help the government formulate and implement more suitable and targeted BEE goals and policies with China’s special national condition.

Key Words: China’s residential energy savings (CRES); China’s residential energy consumption (CREC); Building energy–efficiency (BEE) policy; IPAT equation; LMDI decomposition

1 Introduction

Building sector is one of the top three fields in total national energy consumption (TNEC), which creates an incredible energy demand explosion. Due to China becomes the largest emitter of Greenhouse Gas worldwide (IEA, 2016), it has resulted in strict challenges for China’s building energy efficiency (BEE) work since China’s national building energy consumption (NBEC) is becoming the second largest sector in TNEC. Thereinto China’s residential energy consumption (CREC) is a typical type of building energy consumption accounting for over 80% of China’s NBEC in the current stage (MOHURD_of_PRC, 2016). If the growth trend of CREC continues, CREC will exceed 1.2 billion tons of standard coal equivalent (tce) in 2030 (Delmastro et al., 2015) which would lead to a more severe environmental pollution and hinder China’s sustainable development strategy. Therefore, China’s residential energy savings (CRES) have aroused public concern involving China’s urban residential energy savings (CURES) and China’s rural residential energy savings (CRRES). CRES reflects the building energy–saving benefits which come from the operation stage of China’s existing residential buildings nationwide under the influence of numerous relevant impact factors such as policy, technological progress and users’ behavior, etc.

However, the quantification work of CREC/CRES data lags behind significantly which seriously affects the conduct of China’s BEE work since building energy consumption data is an essential reference to be evaluated (Ma et al., 2017b). Besides, reliable and accurate CREC data is the prerequisite for achieving CRES data. Although China’s BEE work has exhibited great progress in several respects, such as laws, incentive policies, and BEE technology, several shortages still exist in CREC/CRES data quantification work (MOHURD_of_PRC, 2016). The main reasons are as follows. (i) The statistical system of CREC data is still a work in process. In China’s energy
consumption statistical system, CREC has not been considered separately as an independent division of energy consumption but scattered in different energy consumption statistics of various societal divisions. This is the root cause of the missing CREC data. (ii) Given the reliable data supporting of CREC is still missing, studies on the accurate calculation of CRES is still inadequate seriously namely CRES data remains lacking at the current stage.

CRES should be regarded as a non–ignored reference to quantitatively verify how far the BEE goals in residential building sector achieved and to evaluate the completion of relevant policies. For example, the government established the goal of the official planned CRES during the period of 2011–2015 is 93 million tce (MOHURD_of_PRC, 2012). Necessarily, the actual CRES in the said period should be figured out and compared with the official planned one. This examination would help the government formulate and implement more targeted goals and policies for the upcoming stage of China’s BEE work. In a word, it is an urgent and significant work to establish a method to estimate CRES and launch an operation of performance appraisal based on the goal examination of CRES.

Based on the above analysis, this study aims to establish an effective method to estimate CRES through relatively mature and credible CREC data. Subsequently, CRES data from 2001 to 2015 is figured out and a CRES goal examination is also involved.

2 Literature Review

As a prerequisite for estimating CRES, numerous published works have documented varied approaches to assess CREC data since China’s BEC supervision system is hard to completely realize nationwide namely the statistical system of China’s BEC data at the national level is a work in progress. Thus, official data on CREC are still missing at the current stage (MOHURD_of_PRC, 2016). However, the results of these methods are significantly different. Initially, the vast majority of scholars focused on primary CREC data estimation methods. Thereinto, to simplify the complex calculation process, some works directly replaced CREC approximation as living energy consumption of China’s households since the data source of living energy consumption of China’s households was clearly published in China Energy Statistical Yearbook (Lin and Liu, 2015; Liu and Zhao, 2015; Lu, 2017; Wang and Yang, 2016; Zhang et al., 2016). However, the rationality and accuracy of the data estimation approach is disputable since CREC and living energy consumption of China’s households are definitely two different concepts. Given that CREC is a typical sector of China’s NBEC, it is necessary to review the approaches focused on China’s NBEC data estimation. A small percentage of research teams established relatively systematic and sustainable NBEC data estimation models to improve the accuracy of China’s NBEC data in the last ten years. Notably, these methods have been widely accepted and referenced by numerous relevant studies. Thereinto as the first systematic NBEC data estimation approach in China, Building Energy Conservation Research Center of Tsinghua University built China Building Energy Model (CBEM) in 2007 and the data of CBEM have been updated to 2014 which indicated a NBEC value of 819 million tce, accounting for 21.06% of TNEC (THUBECRC, 2016). Contrastively, based on relevant data promulgated by China Energy Statistical Yearbook, Chongqing University built the China Macroscopic Building Energy Consumption Statistical System (CMBECSS) in 2010. CMBECSS implemented weight combination and error correction to integrate the distributed energy consumption related to NBEC and effectively estimated the NBEC from 1985 to 2009 (Cai et al., 2014). Thereafter with the technological supporting from China Association of Building Energy
Efficiency (CABEE) and Lawrence Berkeley National Laboratory (LBNL), the calculation framework of CMBECCSS has been further improved and the data of CMBECCSS V2.0 have been updated to 2014 which indicated a NBEC value of 814 million tce, accounting for 19.12% of TNEC in the said year. Thereinto the value of China’s urban residential energy consumption (CUREC) is 326 million tce accounting for 40.05% of NBEC, compared to a China’s rural residential energy consumption (CRREC) value of 201 million tce accounting for 24.69% of NBEC (CABEE, 2016).

As we indicated in Introduction, due to the reliable data supporting of CREC is still missing, studies on the accurate calculation of CRES is still inadequate seriously namely CRES data remains lacking at the current stage. In this regard, the main focus of this study is aiming to establish an effective approach to estimate CRES data.

The studies mentioned above reflect that an effective method to estimate CRES is an urgent task. The overall innovation and contribution of this study are as follows. (i) An important new concept is established. Modified REC per unit area reflects the changes in the actual residential building energy–efficiency level, which is recalculated based on a constant residential building service level. This new concept is utilized to measure the changes in residential building energy–efficiency level and further estimate CRES. (ii) An effective CRES estimation method is put forward. We established equations of CREC to estimate CRES based on modified REC per unit area through an extended version of IPAT equation (Human Impact = Population * Affluence * Technology). Then with LMDI decomposition (Logarithmic Mean Divisia Index), we put forward an effective method to estimate CRES and successfully obtained the said data from 2001 to 2015.

The reminder of this study is organized as follows: Section 3 introduces the principles of IPAT equation and LMDI decomposition. Subsequently, the effective CRES estimation method is put forward. Then the model variables are explained. Furthermore, the sources of corresponding data are also introduced. Section 4 provides the results of CRES estimation model and a further discussion based on these results. Section 5 presents the conclusions.

3 Methodology

3.1 IPAT Equation and LMDI Decomposition

The approach to achieve CRES data estimations required IPAT equation and LMDI decomposition in this study. A number of previous studies have proved the development of the two methods as shown below. Ehrlich and Holdren (1971) established a famous method named IPAT equation aiming to uncover the influence among population growth, economic development, and technological advancements, as shown in Eq. (1).

\[ I \ (Human \ Impact) = P \ (Population) \ast A \ (Affluence) \ast T \ (Technology) \]  (1)

IPAT equation has been widely appreciated and applied in energy economics, environmental science, and many relevant fields since it was put forward (Tan et al., 2016; Wang et al., 2013). Notably, it is still one of the most important research tools in the above research fields.

As for the LMDI method, Ang and Choi (1997) designed the prototype of the LMDI on the basis of Divisia Index Method. As one of the most well-known forms of index decomposition analysis, LMDI owns simple decomposition process, and effective outputs without any residual value (Wang et al., 2017; Wang et al., 2015). Through LMDI decomposition analysis, an explained variable is decomposed into a bunch of driving factors. Subsequently, an analysis about the contribution of the factors can be conducted at a quantitative level, and the key driving factors can be marked for further exploration (Ang, 2015; Ang, 2004; Ma et al., 2017b). Eq. (2) indicates the
general framework of the LMDI decomposition analysis.

\[
\Delta V_{x_i} = \sum_{i=1}^{n} \frac{V_{i|t} - V_{i|0}}{\ln \left( \frac{x_{i|t}}{x_{i|0}} \right)} \ln \left( \frac{x_{i|t}}{x_{i|0}} \right) \quad (i = 1, 2, 3, ..., n)
\]  

(2)

Notice:
- \(x_i\) – The explanatory variable;
- \(x_{i|t}\) – The value of \(x\) in reporting period;
- \(x_{i|0}\) – The value of \(x\) in baseline period;
- \(V\) – The explained variable;
- \(V_{i|t}\) – The value of \(V\) in reporting period;
- \(V_{i|0}\) – The value of \(V\) in baseline period;
- \(\Delta V_{x_i}\) – The contribution of \(x_i\) to \(V\).

3.2 CRES Estimation Model

The combination of IPAT equation and LMDI decomposition enables researchers to conduct quantitative analyses of how much the relevant impact factors contribute to rise in carbon emissions (Wang and Li, 2016). IPAT equation and LMDI decomposition are mostly applicable to carbon emissions and energy consumption analyses (Ma et al., 2017c). Given that CREC is a typical energy consumption, the two methods apply equally to the CREC field.

Fig. 1 Schematic of REC per unit area with residential building service level and residential building energy–efficiency level

Notice:
- Curve A – the curve under the influence of residential building service level
- Curve B – the curve under the influence of residential building energy–efficiency level

Fig. 1 indicates that REC per unit area is influenced by residential building energy–efficiency level and residential building service level (Ma et al., 2017a). REC per unit area decreases with the increase in residential building energy–efficiency level and increases with the increase in residential building service level. In short, under the influence of the two factors, REC per unit area increases yearly. In view of the analysis above, we obtained a feasible method to estimate CRES. We assumed that the residential building service level in baseline and reporting periods remains unchanged and then we recalculated the modified REC per unit area. Modified REC per unit area is an important index to measure the actual residential building energy–efficiency level and a crucial prerequisite for achieving CRES data estimation. Modified REC per unit area reflects the changes of REC per unit area in the actual residential building energy–efficiency level, which is calculated from a constant residential building service level.

\[
re_m = \frac{re}{I_{rs}}
\]

(3)
In this case, \( r_{em} \) is modified REC per unit area, \( re \) is REC per unit area, and \( I_{rs} \) is residential building service level index reflecting the changing value of residential building service level of all existing residential buildings in urban / rural regions at a national and provincial level over a period. Since residential building service level is an abstract concept and is difficult to measure quantitatively, resulting in the difficulty to quantify \( I_{rs} \). Thus, we applied mathematical processing under the assumption that a functional relation exists between \( I_{rs} \) and REC per capita index, as shown in Eq. (4).

\[
I_{rs} = \alpha I_{rp} \tag{4}
\]

In this case, \( I_{rp} \) is REC per capita index and \( \alpha \) is an unknown coefficient \((\alpha > 0)\). Given that \( \alpha \) is unquantifiable and we could not calculate \( r_{em} \) directly, through further research, we finally established an effective CRES estimation method based on IPAT equation and LMDI decomposition.

As shown in Eq. (5), based on an extended version of IPAT equation, we put forward an equation of CUREC \((RE_1)\) and CRREC \((RE_2)\) by summing up its comprehensive impact factors, respectively.

\[
RE_i = P_1 \times A_1 \times I_{rs} \times r_{em_i} \quad (i=1,2) \tag{5}
\]

In this case, \( P_1 \) and \( P_2 \) are China’s urban and rural population, respectively. \( A_1 \) and \( A_2 \) are building area of China’s existing urban and rural residential buildings, respectively. \( I_{rs} \) and \( r_{em_i} \) have been introduced as shown above. Based on Eq. (5), we employed LMDI decomposition to decompose CUREC and CRREC. In a period about \([0, t]\), CUREC/CRREC changes from \( RE_i|_{t=0} \) to \( RE_i|_{t} \) and \( \Delta RE_i \) can be defined as a sum of comprehensive effect factors as follows:

\[
\Delta RE_i = RE_i|_{t}-RE_i|_{0} = \Delta RE_{P_1} + \Delta RE_{A_1} + \Delta RE_{I_{rs1}} + \Delta RE_{r_{em1}} \quad (i=1,2) \tag{6}
\]

In this case, \( \Delta RE_{P_1}, \Delta RE_{A_1}, \Delta RE_{I_{rs1}} \) and \( \Delta RE_{r_{em1}} \) are defined as the contribution of \( P_1, A_1, I_{rs} \) and \( r_{em} \) to CUREC changes and CRREC changes, respectively.

Eqs. (8) to (11) reveal the contributions of each driving factor for CUREC and CRREC through LMDI decomposition, as shown below.

\[
\Delta RE_{P_1} = \frac{RE_i|_{t}-RE_i|_{0}}{ln(RE_i|_{t}-ln(RE_i|_{0})} \times \ln\left(\frac{P_{1t}}{P_{10}}\right) \tag{7}
\]

\[
\Delta RE_{A_1} = \frac{RE_i|_{t}-RE_i|_{0}}{ln(RE_i|_{t}-ln(RE_i|_{0})} \times \ln\left(\frac{A_{1t}}{A_{10}}\right) \tag{8}
\]

\[
\Delta RE_{I_{rs1}} = \frac{RE_i|_{t}-RE_i|_{0}}{ln(RE_i|_{t}-ln(RE_i|_{0})} \times \ln\left(\frac{I_{rs|_{t}}}{I_{rs|_{0}}}\right) = \frac{RE_i|_{t}-RE_i|_{0}}{ln(RE_i|_{t}-ln(RE_i|_{0})} \times \ln\left(\frac{I_{rs|_{t}}}{I_{rs|_{0}}\times I_{rp|_{0}}}\right) \tag{9}
\]

\[
\Delta RE_{r_{em1}} = \frac{RE_i|_{t}-RE_i|_{0}}{ln(RE_i|_{t}-ln(RE_i|_{0})} \times \ln\left(\frac{r_{em|_{t}}}{r_{em|_{0}}\times r_{em|_{0}}}\right) = \frac{RE_i|_{t}-RE_i|_{0}}{ln(RE_i|_{t}-ln(RE_i|_{0})} \times \ln\left(\frac{r_{em|_{t}}}{r_{em|_{0}}}\right) \tag{10}
\]

\[
CURES = \sum |\Delta RE_{1x}| \quad \langle \Delta RE_{1x} \in \{ \Delta RE_{P_1}, \Delta RE_{A_1}, \Delta RE_{I_{rs1}}, \Delta RE_{r_{em1}} \} \rangle, \Delta RE_{1x} < 0 \tag{11}
\]

\[
CRRES = \sum |\Delta RE_{2x}| \quad \langle \Delta RE_{2x} \in \{ \Delta RE_{P_2}, \Delta RE_{A_2}, \Delta RE_{I_{rs2}}, \Delta RE_{r_{em2}} \} \rangle, \Delta RE_{2x} < 0 \tag{12}
\]

### 3.3 Variables and Data Sources

Eqs. (7) to (10) involve five main variables, as shown in Table 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Unit</th>
<th>Declaration</th>
</tr>
</thead>
<tbody>
<tr>
<td>China’s urban residential energy consumption (CUREC)</td>
<td>( RE_1 )</td>
<td>( 10^4 ) tce</td>
<td>–</td>
</tr>
<tr>
<td>China’s rural residential energy consumption (CRREC)</td>
<td>( RE_2 )</td>
<td>( 10^4 ) tce</td>
<td>–</td>
</tr>
<tr>
<td>China’s urban population</td>
<td>( P_1 )</td>
<td>( 10^6 ) persons</td>
<td>–</td>
</tr>
</tbody>
</table>
China’s rural population

Building area of China’s existing urban residential buildings

Building area of China’s existing rural residential buildings

REC per capita index

CUREC intensity

CRREC intensity

All data used in this study were obtained from China Statistical Yearbook for the period 2000–2015, except for the data of CREC. Given that the statistical system of China’s BEC is still a work in progress, official data on CREC are missing. Hence, we referred to our former studies that were relatively mature and credible (CABEE, 2016). The data of the main variables are shown in Tables 2 to 4.

### Table 2 Data involved in CRES estimation method in 2001–2005

<table>
<thead>
<tr>
<th>Variable</th>
<th>Year</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_1 ) (10^4 \text{ tce})</td>
<td>13,777.22</td>
<td>15,126.87</td>
<td>17,018.80</td>
<td>18,863.28</td>
<td>20,435.36</td>
<td>22,424.63</td>
<td></td>
</tr>
<tr>
<td>( R_2 ) (10^4 \text{ tce})</td>
<td>8,734.30</td>
<td>9,046.85</td>
<td>9,821.09</td>
<td>11,064.21</td>
<td>12,400.20</td>
<td>13,386.92</td>
<td></td>
</tr>
<tr>
<td>( P_1 ) (10^6 Persons)</td>
<td>459.06</td>
<td>480.64</td>
<td>502.12</td>
<td>523.76</td>
<td>542.83</td>
<td>562.12</td>
<td></td>
</tr>
<tr>
<td>( P_2 ) (10^6 Persons)</td>
<td>808.37</td>
<td>795.63</td>
<td>782.41</td>
<td>768.51</td>
<td>757.05</td>
<td>745.44</td>
<td></td>
</tr>
<tr>
<td>( A_1 ) (10^6 \text{ m}^2)</td>
<td>5,722.48</td>
<td>6,651.92</td>
<td>8,184.61</td>
<td>8,911.15</td>
<td>9,616.15</td>
<td>10,769.00</td>
<td></td>
</tr>
<tr>
<td>( A_2 ) (10^6 \text{ m}^2)</td>
<td>20,134.91</td>
<td>20,447.69</td>
<td>20,733.87</td>
<td>20,903.47</td>
<td>21,121.70</td>
<td>22,139.57</td>
<td></td>
</tr>
<tr>
<td>( I_{rp} )</td>
<td>1.000</td>
<td>1.085</td>
<td>1.199</td>
<td>1.349</td>
<td>1.463</td>
<td>1.584</td>
<td></td>
</tr>
<tr>
<td>( r_{e1} ) (tce/100m²)</td>
<td>2.408</td>
<td>2.274</td>
<td>2.079</td>
<td>2.117</td>
<td>2.125</td>
<td>2.082</td>
<td></td>
</tr>
<tr>
<td>( r_{e2} ) (tce/100m²)</td>
<td>0.434</td>
<td>0.442</td>
<td>0.474</td>
<td>0.529</td>
<td>0.587</td>
<td>0.605</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3 Data involved in CRES estimation method in 2006–2010

<table>
<thead>
<tr>
<th>Variable</th>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_1 ) (10^4 \text{ tce})</td>
<td>22,424.63</td>
<td>24,090.24</td>
<td>25,944.63</td>
<td>27,073.53</td>
<td>28,128.31</td>
<td>29,213.11</td>
<td></td>
</tr>
<tr>
<td>( R_2 ) (10^4 \text{ tce})</td>
<td>13,386.92</td>
<td>14,153.25</td>
<td>15,085.64</td>
<td>15,477.83</td>
<td>16,157.25</td>
<td>17,538.44</td>
<td></td>
</tr>
<tr>
<td>( P_1 ) (10^6 Persons)</td>
<td>562.12</td>
<td>577.06</td>
<td>593.79</td>
<td>606.64</td>
<td>621.74</td>
<td>636.93</td>
<td></td>
</tr>
<tr>
<td>( P_2 ) (10^6 Persons)</td>
<td>745.44</td>
<td>737.42</td>
<td>727.50</td>
<td>721.38</td>
<td>712.76</td>
<td>703.98</td>
<td></td>
</tr>
<tr>
<td>( A_1 ) (10^6 \text{ m}^2)</td>
<td>10,769.00</td>
<td>11,289.12</td>
<td>11,971.43</td>
<td>12,496.79</td>
<td>13,241.41</td>
<td>14,082.16</td>
<td></td>
</tr>
<tr>
<td>( A_2 ) (10^6 \text{ m}^2)</td>
<td>20,134.91</td>
<td>22,460.12</td>
<td>22,592.74</td>
<td>22,809.28</td>
<td>23,163.17</td>
<td>22,885.53</td>
<td></td>
</tr>
<tr>
<td>( I_{rp} )</td>
<td>1.000</td>
<td>1.085</td>
<td>1.199</td>
<td>1.349</td>
<td>1.463</td>
<td>1.584</td>
<td></td>
</tr>
<tr>
<td>( r_{e1} ) (tce/100m²)</td>
<td>2.408</td>
<td>2.274</td>
<td>2.079</td>
<td>2.117</td>
<td>2.125</td>
<td>2.082</td>
<td></td>
</tr>
<tr>
<td>( r_{e2} ) (tce/100m²)</td>
<td>0.434</td>
<td>0.442</td>
<td>0.474</td>
<td>0.529</td>
<td>0.587</td>
<td>0.605</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4 Data involved in CRES estimation method in 2011–2015

<table>
<thead>
<tr>
<th>Variable</th>
<th>Year</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_1 ) (10^4 \text{ tce})</td>
<td>29,213.11</td>
<td>29,413.70</td>
<td>31,121.66</td>
<td>33,309.67</td>
<td>34,385.35</td>
<td>35,964.51</td>
<td></td>
</tr>
<tr>
<td>( R_2 ) (10^4 \text{ tce})</td>
<td>17,538.44</td>
<td>18,685.50</td>
<td>19,782.61</td>
<td>21,221.22</td>
<td>21,457.83</td>
<td>22,146.53</td>
<td></td>
</tr>
<tr>
<td>( P_1 ) (10^6 Persons)</td>
<td>636.93</td>
<td>690.79</td>
<td>711.82</td>
<td>730.71</td>
<td>749.16</td>
<td>771.16</td>
<td></td>
</tr>
</tbody>
</table>
4 Results Analysis and Discussion

4.1 The Estimation Results of CRES

With MATLAB R2014a, the time-series data involved in the five types of variables in Section 3.3 were introduced to Eqs. (7) to (10). The results prove that only $\Delta R_{e_{ri}}$ is less than 0, which reflects the contributions of $r_{ei}$ to CUREC and CRREC are definitely negative. In this regard, $|\Delta R_{e_{ri}}|$ can be regarded as the values of CURES and CRRES. Table 5 indicates the estimation results about CRES during the period of 2001–2015.

Table 5 The estimation results of CRES in 2001–2015

<table>
<thead>
<tr>
<th>Year</th>
<th>CRES (10^4 tce)</th>
<th>RES (10^4 tce)</th>
<th>CRES (10^4 tce)</th>
<th>RES (10^4 tce)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>11,786.92</td>
<td>1,999.41</td>
<td>7,909.26</td>
<td>847.14</td>
</tr>
<tr>
<td>2002</td>
<td>10,487.75</td>
<td>3,038.37</td>
<td>7,421.17</td>
<td>1,041.89</td>
</tr>
<tr>
<td>2003</td>
<td>1,299.17</td>
<td>1,795.49</td>
<td>488.09</td>
<td>1,199.43</td>
</tr>
<tr>
<td>2004</td>
<td>2,139.94</td>
<td>1,514.54</td>
<td>2,589.58</td>
<td>1,743.14</td>
</tr>
<tr>
<td>2005</td>
<td>548.11</td>
<td>2,139.94</td>
<td>2,589.58</td>
<td>1,743.14</td>
</tr>
</tbody>
</table>

4.2 The Root Cause about the Considerable Achievement of CRES

Fig. 2 shows that the calculated CRES is more than the official planned CRES in the period of 2006–2010 (The State Council of PRC, 2007) and in the period of 2011–2015 (MOHURD of PRC, 2012). It should be noticed that China did not publish the official planned CRES in the period of 2001–2005, so we could not compare the calculated CRES with the official planned CRES in this period.
Based on the above comparison, we believed that in the third stage of China’s BEE work (2006–2015), the BEE policies obtained a good implementation effect in the field of residential building sector. In this period, the government deepened the BEE policy system in a series of ways, such as laws and regulations, technical standards, propaganda and training, market mechanism, economic incentives, and technological innovation (MOHURD_of_PRC, 2016). Furthermore, based on variety of official published information (MOHURD_of_PRC, 2012, 2014, 2016), we summarized the completion status of main targets and main relevant BEE policies in the third stage of China’s BEE work (2006–2015), as shown in Table 6.

### Table 6: Main targets’ completion status and relevant policies of China’s BEE work in 2006–2015

<table>
<thead>
<tr>
<th>Project</th>
<th>Target requirements</th>
<th>Completion status</th>
<th>Main relevant BEE policies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Newly built buildings</strong></td>
<td>(1) The new mandatory BEE design standards should be fully implemented in northern severe cold zone, cold zone and hot–summer–cold–winter zone, and the implementation rate should be above 95% during the construction stage. (2) Northern mega cities (i.e., Beijing, Tianjin) should perform higher BEE design standards. (3) A bunch of low/ultra–low BEC demonstration buildings should be built.</td>
<td>(1) The implementation rate of mandatory BEE design standards during the construction stage of newly built buildings reached 97.19% at the national level. (2) The said rate was 100% in northern mega cities. (3) 1017 low/ultra–low BEC demonstration buildings at the national level have been built.</td>
<td>(1) The Law of PR China on Promoting Clean Production (2003) (2) The Law of PR China on Energy Conservation (1998, 2008) (3) Regulation on Energy Conservation in Civil Buildings (2008)</td>
</tr>
</tbody>
</table>
Table 6 reflects that the tasks related to China’s BEE work achieved significant results, and these achievements impelled our calculated CRES to exceed the official planned CRES in the third stage of China’s BEE work. As we mentioned in Introduction, CRES data is one of the foundation of China’s BEE work. Given that effective CRES estimation method is deficient, the government have to launch an operation of performance appraisal based on BEE load such as checking the building area of BEE retrofit of existing buildings. It may force the government to concentrate on one–side pursuit for more building area of BEE retrofit, instead of increased RES, which seriously reduces the actual energy–saving benefits. Thus, it is an urgent and significant task to establish a method to assess CRES and launch an operation of performance appraisal based on the goal checking of RES nationwide. It is of great significance for the development of China’s BEE work. To a certain extent, the results of our CRES data estimation would help the government formulate and implement suitable BEE policies with China’s special national condition.

5 Conclusions

Given that studies on effective estimation method of CRES remain lacking, we conducted a study on CRES estimation and proposed an effective CRES estimation method based on IPAT equation and LMDI decomposition which perform well in CRES estimation. We used CREC data and economic and social development related data in China for the period 2000–2015. With this effective CRES estimation method, we obtained CURES and CRRES from 2001 to 2015 successfully. The calculation results showed CRES in the periods of 2001–2005, 2006–2010, and 2011–2015 was 118, 79, and 96 million tce, respectively. Furthermore, the comparison between the calculated CRES data and the official planned CRES data in the said periods proves that China had surpassed its BEE targets in the field of residential building sector and the recent China’s BEE work (2006–2015) obtained good implementation effects. To a certain extent, this study filled up the blankness in this research direction about CRES estimation and the results of our pioneering CRES data estimation method would help the government formulate and implement more suitable and targeted BEE goals and policies with China’s special national condition. It should be noticed that some other relevant impact factors not involving in this study such as energy consumption structures and energy consumption costs in different residential buildings in different regions, also reflect non–ignorable effects on CRES. On the basis of the IPAT equation about CRES estimation, these said relevant impact factors have the possibility to be added to further improve the accuracy of CRES estimation in the upcoming study.

References


Selection of Most Suitable Pipe Material for Water Supply Projects

Sood, A.1*, Hasan, A.2 and Jha, K.N.3

Abstract: Pipelines are an integral and major component of the water supply and distribution network. Due to their high importance in water supply projects, both investment-wise and hydraulically, the selection of pipe material plays a crucial role in the success of the project. Consequently, a wrong selection of the pipe material can have major implications not only for project cost and duration but also for the post-commissioning operations and maintenance phases. Therefore, it is essential to devise a methodology in order to ensure that the selection of the most appropriate pipe material in a water supply project is based on key project and pipe characteristics. The present study proposes a framework based on Analytical Hierarchy Process (AHP) using the data from a water supply project in India. The results demonstrated mild steel pipes as the most preferred choice for the given project. It is believed that the suggested approach will assist the organisations in making a right decision while selecting pipe material in their water supply projects.

Keywords: pipeline, pipe material, water supply projects, analytical hierarchy process.

1* Sood, A. 
Corresponding author, M.Tech Student (Construction Technology and Management), Department of Civil Engineering, IIT Delhi, India.
Email: ashish.sood91@gmail.com

2 Hasan, A.
PhD Candidate (Construction Management), School of Natural and Built Environments, University of South Australia, Adelaide, Australia.
Email: abid.hasan@mymail.unisa.edu.au

3 Jha, K.N.
Associate Professor, Department of Civil Engineering, IIT Delhi, India.
Email: knjha@civil.iitd.ac.in
1 Introduction

Pipelines form the most essential part of a water distribution network. It has been observed that pipelines cost could be as high as 60 percent of the total project cost in the water supply projects. Moreover, they are an important consideration in the hydraulic design of the supply network such as pump size and capacity. Therefore, right selection of pipe material is critical for successful construction, efficient operation and proper maintenance of the entire supply system.

The type of pipe selected must take into consideration various performance criteria such as durability, hydraulics, cost-effective installation, operation, and maintenance. A framework based on a case study of a proposed water supply project has been devised to select the appropriate pipeline material. This proposed project consists of a system of twin pipelines of diameter 1300 mm each along the K-M-P (Kundli-Manesar-Palwal) highway in the state of Haryana in India. The project is taken up by the Irrigation department of the state government to pump water from one canal to other through a pipeline for further distribution for drinking and irrigation purposes. The selected case will help us in identifying the decision criteria for material selection of the pipe to be used in this project.

The different types of commercially available pipes can be classified into two broad categories: metallic and non-metallic.

1.1 Metallic pipes

The main advantage of metallic pipe is their ability to bear both external loads as well as internal pressures due to their high strength and excellent mechanical properties. Different pipe materials under this category along with their respective advantages and disadvantages have been discussed briefly in the following paragraphs.

Cast Iron (CI) pipes come in three varieties based on their process of manufacturing: vertically cast, horizontally cast and centrifugally cast, with centrifugally cast pipes being most popular these days. The requirements for centrifugally cast CI pipes are outlined in IS1536:2001. A coating is needed to protect these pipes from corrosion. However, the coating material should not affect the quality of water being transported through the pipeline. The major advantages are ease in manufacturing, laying and jointing, and ability to withstand higher external loads due to more thickness as compared to steel pipes. Whereas, the major disadvantages of using CI pipes is that they are heavy and thus, transportation and handling are difficult. These are manufactured in shorter spans to ease out handling and transportation but it increases the cost for jointing. Further, they often have casting defects and therefore, low tensile strength.

Centrifugally cast Ductile Iron (DI) pipes are commonly used in water supply projects. The molten metal is treated with magnesium to improve the properties of the pipe. The requirements for DI pipes are covered in IS8329:2000. These pipes are 30 percent lighter than conventional CI pipes due to lesser thickness. These have higher mechanical strength, better resistance to impact and lesser wear and tear than CI pipes.

Mild Steel (MS) pipes are ideal for welding and possess excellent mechanical properties. Consequently, these are the preferred choice for transmission of high pressure liquid over a long distance. Being light in weight, they are of great advantage when the pipe diameter is greater than 900mm. The requirements for MS pipes are specified in IS3589:2001. Steel pipes maintain their mechanical properties in case of large variations in temperature. Moreover, these are flexible and
thereby, best suited for dynamic loads. Galvanised Iron (GI) pipes are MS pipe coated with zinc and offer better corrosion resistance.

1.2 Non-metallic pipes

The non-metallic pipes such as cement concrete (CC) pipes have a major advantage over metallic pipes because they offer much better corrosion resistance. However, CC pipes are bulky and require utmost care during handing and transportation. Also, these cannot be used where sulphates are present in the soil to low resistance against sulphate attack. Since these pipes are rigid, they require sand bedding before laying to avoids cracks under loading. These are more suitable for low to medium pressure handling.

Reinforced Concrete (RC) pipes are produced by centrifugal spinning or vibratory processes or both. The requirements for CC and RC pipes are given in IS458:2003[4]. RC pipes cater to working pressure of up to 0.3 MPa in the pumping mains and 0.4 MPa in the gravity mains.

Pre-stressed Concrete (PSC) pipes are manufactured by helically binding steel wire (in tension) around a concrete core (in compression). The PSC pipes will always be under compression as stresses induced in the pipe will reduce the compressive stress due to pre-stressing. Thus, they offer better impermeability. They are of two types: cylinder type and non-cylinder type. The requirements for PSC pipes are described in IS784:2001[5]. They offer combination of durability of concrete, high strength of steel, and economy of raw materials. These pipes are ideally suited for water supply with pressure between 0.6 to 2 MPa. They are most competitive economically for diameters above 600mm. However, their installation requires skilled personnel because pipes cannot be cut to arrange desired shorter segments. Moreover, their production requires specialised plants and skilled labour and consequently, transportation cost from the factory to the actual site could be very high if the site is not located in the vicinity of the production plant.

Bar Wrapped Steel Cylinder (BWSC) pipes are made of steel cylinder welded with steel joint rings and lined centrifugally with mortar. MS bar is helically wrapped with steel cylinder and then coated with cement mortar. This composite construction technique greatly enhances impact resistance, rigidity, and strength of the pipe. The thickness of steel plate is comparatively lesser and they are more economic than the CI, DI or MS pipes. In addition, both bar and cylinder thickness can be adjusted to alter design and economics to serve different requirements.

Asbestos Cement (AC) pipes are in use for more than six decades. These pipes are made from asbestos fiber and cement, and compressed by rollers to form laminated material. These pipes are jointed by CI joints or AC collar joints. The requirements for AC pressure pipes are discussed in IS1592:1989[6]. They are lighter than RC or PSC pipes. These are not affected by electrolytic corrosion and can cater to pressures of up to 1.5 MPa. However, holes can be easily drilled in these pipes which make tapping or pilferage easier.

Un-plasticized polyvinyl chloride (uPVC) pipes are light weight, tough, resistant to chemical attacks and incur low transportation and handling costs due to their light weight. They have good elastic properties and offer better adaptability to earth movements. However, ultraviolet (UV) radiation causes de-coloration of uPVC pipes, leading to cracking and brittleness.

Polyethylene (PE) pipes are flexible and possess high chemical resistance. Moreover, these can be easily bend for installation and do not require additional efforts at pipe bends and elbows. Consequently, installation cost is relatively lower. They are available both in coils as well as pipes and are usually jointed by thermal fusion welding. Two grades are manufactured: Low-
density polyethylene (LDPE) and High-density polyethylene (HDPE). Due to high flexibility, LDPE are recommended for water temperatures up to 38°C. HDPE are less flexible, tougher, and possess more flexural strength and resilience under traffic loads.

Glass Reinforced Plastic (GRP) pipes are made of two materials. A binder and reinforcing material, they are made up of glass fiber or resin. Their molecules do not react chemically but form a composite by boundary layer. These are very light and deliver high performance. Due to relatively inert nature, these are considered highly durable. Moreover, their flexibility makes them easier to install.

As can be seen from above discussions, a wide variety of pipes having different properties are commercially available in the market to suit specific project requirements. The aim of this paper is to propose a framework to assist a decision maker in the selection of the most suitable and economic pipe material for water supply projects.

## 2 Methodology

The Analytical Hierarchy Process (AHP) was used to develop a framework for the selection process based on relative merits of alternative solutions in a Multi-Criteria Decision Making (MCDM) problem. The main advantage of AHP lies in the fact that it gives a good overall picture of the performance of all the alternatives by evaluating them using the hierarchy of the criteria.

The important factors for analyzing the performance of the different pipeline materials rehabilitation technologies are identified based on literature review and expert opinions. The most typical factors that affect the selection of pipe material are: size and pressure capacity. In the present case, the proposed pipeline is pumping into rising mains and consequently, RC, AC, Prestressed Concrete, PVC and LDPE are not suitable to cater to the pressure requirements of the system. On the other hand, based on the size criteria, GI pipes become increasingly less advantageous based on economic and corrosion considerations as compared to CM lined MS pipes in larger sizes and thereby, they are also not considered for further evaluation.

CPHEEO Manual by the Ministry of Urban Development, Government of India gives a comprehensive list of 21 criteria and a scoring system that can be used to arrive at a decision. The same criteria along with inputs from the experts in the field of water supply and distribution projects have been used to identify the most suitable option. The important factors for analyzing the performance of the different pipeline materials are described as follows:

1) **Strength characteristics:** The hydraulic loads due to water flowing at pressure increase drastically at joints and bends. The pipe also has to sustain the heat loads if the pipeline is laid at or above the ground level. In addition, dynamic loads and impact due to movement of traffic along with the dead load of backfilled soil also need to be considered.

2) **Hydraulic characteristics:** The main requirement of the water supply system is that water reaches the highest delivery point with a minimum set head (usually 7m). The head losses in the pipeline system will increase the head requirement of the pump and related equipment.

3) **Economy:** Economy is one of the most essential criteria in any construction project. Economy not only includes the costs involved during the installation or construction phase, but also the costs incurred during the operation and maintenance phases. The designed life of a pipeline system is usually kept as 30 years and the life of the pipe should at least...
equal to the design life to avoid re-laying or rehabilitation. Moreover, the selected pipe must be commercially available in the recommended sizes in the local market.

4) Ease of transportation and handling: Since the pipeline also passes through remote areas and barren lands, it is important that transportation and handling of pipes are easy to minimise any negative impact on project time and cost.

5) Inertness and corrosion resistance: Since the water being carried by the pipeline is intended to be used for drinking and irrigation purposes, the material of the pipeline should be inert and thereby, suitable for transporting water. Inertness also prevents corrosion of the pipe.

6) Ease of laying and jointing: This would include the procedure that is used in the laying or installation of the pipeline and associated parts. Many pipelines have spigot-socket joints which are considered to be the easiest to install. Welding, on the other hand, is relatively difficult due to requirements for a licensed and trained personnel, high voltage electric supply, and ultrasonic and radiography testing.

7) Resistance to damage: The pipes must also be resistant to any damage which might occur due to various reasons such as improper handling, damage during transportation, tampering by external sources, and breakage due to falling down from a height.

8) Requirement of special equipment/skilled labour: Certain types of pipes, as discussed in section 1.1 and 1.2, may require specialised equipment and labour during the construction phase.

The above eight criteria were further used in the decision making process. These criteria broadly cover all the critical requirements associated with the pipe selection. Figure 1 demonstrates the hierarchy of AHP process wherein, we shall be evaluating five shortlisted pipe materials namely CI, DI, MS, BWSC and HDPE on the basis of these eight criteria to arrive at the decision of the most suitable pipe material for the proposed water supply project.

![Figure 1. Hierarchy showing final criteria and alternative pipe materials in selecting the best pipe material](image)

The important properties of the shortlisted materials are presented in Table 1. These have been sourced from market survey and information available in literature and relevant codes of practice.

In the next step, a decision-maker can express a preference between each pair as equal, moderate, strong, very strong, and extremely preferable (important). These judgments can be translated into numerical values on a scale of 1 to 9 (Table 2).
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CI</th>
<th>DI</th>
<th>MS</th>
<th>BWSC</th>
<th>HDPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure rating (Working pressure, variable)</td>
<td>2.1 MPa for K-9 class, DN 1.1-2 m</td>
<td>2.1 MPa for K-9 class, DN 1.1-2 m</td>
<td>2.5 MPa Working Pressure</td>
<td>Up to 2MPa for PE100 grade</td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>20-30 years</td>
<td>30 years</td>
<td>30 years</td>
<td>30 years</td>
<td>30 years</td>
</tr>
<tr>
<td>Commercially available sizes</td>
<td>100-600mm, higher on special</td>
<td>100-1600mm</td>
<td>300mm and above</td>
<td>250mm and above</td>
<td>Up to 2500 mm</td>
</tr>
<tr>
<td>Hydraulics</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Ease of tampering</td>
<td>Difficult</td>
<td>Difficult</td>
<td>Difficult</td>
<td>Difficult</td>
<td>Easy</td>
</tr>
<tr>
<td>Jointing method</td>
<td>Fabricated joints/ S&amp;S</td>
<td>Socket-Spigot with EPDM ring</td>
<td>Welding</td>
<td>Welding, Fillet</td>
<td>Fusion</td>
</tr>
<tr>
<td>Testing</td>
<td>Hydro-Test</td>
<td>Hydro-Test</td>
<td>Hydro+ radiography test (RT) + ultrasonic test (UT)</td>
<td>Hydro+RT+UT</td>
<td>Hydro-Test</td>
</tr>
<tr>
<td>Transportation and handling</td>
<td>Difficult</td>
<td>Difficult</td>
<td>Very Difficult</td>
<td>Very Difficult</td>
<td>Easy</td>
</tr>
<tr>
<td>Curve negotiation</td>
<td>Poor</td>
<td>Bad</td>
<td>Bends can be fabricated on site</td>
<td>Bad, pipe cannot be cut and welded</td>
<td>Excellent</td>
</tr>
<tr>
<td>Typical length of pipe</td>
<td>6 m</td>
<td>5.5m</td>
<td>12 m</td>
<td>5.5m</td>
<td>6m or Coil</td>
</tr>
<tr>
<td>Strength</td>
<td>Good, lower due to casting defects etc.</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Corrosion resistance</td>
<td>Low</td>
<td>High</td>
<td>High when lined</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Requirement of specialised equipment</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 2. Scale of relative importance for pairwise comparison

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the object</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance</td>
<td>Slightly favours one over another</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
<td>Strongly favours one over another</td>
</tr>
<tr>
<td>7</td>
<td>Demonstrated importance</td>
<td>Dominance of the demonstrated in practice</td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td>Evidence favouring one over another of highest possible order of affirmation</td>
</tr>
<tr>
<td>2, 4, 6, and 8</td>
<td>Intermediate values</td>
<td>When compromise is needed</td>
</tr>
</tbody>
</table>
The questionnaire was divided into two parts: Part-A dealt with the relative importance of criteria and Part-B focused on the relative comparison of the pipe material. For example, a question from Part-A was: While the selection of pipe material, what is of more importance- durability or hydraulics and to what extent? Whereas, a sample question from Part B was: As far as structural strength is concerned, between DI and HDPE, which is better and to what extent? Interviews were conducted with seven experts who had more than 20 years of experience in water supply projects. Their views in form of responses were recorded in the AHP response sheet. Due to space limitation, the procedure of AHP has not been discussed in detail here. The readers are encouraged to refer to available literature for a detailed step by step procedure for using AHP.

3 Results and Discussions

The responses from Part-A of the questionnaire were entered into the criteria decision matrix and weights of different criteria were obtained as shown in Table 3.

Table 3. Ranking on the basis of weights derived from the set criteria

<table>
<thead>
<tr>
<th>Rank</th>
<th>Attributes used for evaluation of pipe material</th>
<th>Weight derived (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Hydraulics</td>
<td>35.5</td>
</tr>
<tr>
<td>02</td>
<td>Economy</td>
<td>16.1</td>
</tr>
<tr>
<td>03</td>
<td>Durability</td>
<td>14.7</td>
</tr>
<tr>
<td>04</td>
<td>Structural strength</td>
<td>13.3</td>
</tr>
<tr>
<td>05</td>
<td>Resistance to corrosion</td>
<td>6.3</td>
</tr>
<tr>
<td>06</td>
<td>Ease in transportation and handling</td>
<td>5.7</td>
</tr>
<tr>
<td>07</td>
<td>Resistance to tampering</td>
<td>4.7</td>
</tr>
<tr>
<td>08</td>
<td>Requirement of special equipment</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Table 3 shows that for the given case study, ‘hydraulics’ received the maximum weight followed by ‘economy’ and ‘durability’. In the next step, we compared the five shortlisted pipe materials based on each of the eight attributes individually. The input matrix corresponding to each of the attributes was formed based on experts’ responses recorded in Part-B of the AHP response sheet. After the relative importance of predefined criteria was derived, different pipe materials were evaluated based on scores calculated by their performance against the given set of criteria.
Figure 2a shows that MS pipe received the maximum score for the current project, closely followed by HDPE. The result has been normalized and is shown in Figure 2b. It shows that if MS is assigned a score of 100, the relative score for HDPE, DI, BWSC and CI will be 94, 65, 61 and 32 respectively. Since the scores of both MS and HDPE are very close, both might be a suitable option for this case study project. However, during subsequent site visits, it was observed that some part of the pipeline stretch had weathered rock and hard rock strata. Consequently, this field condition limited the utility of HDPE pipes because they possess low structural strength and their use is not recommended in areas with rocky strata. Consequently, MS pipe was selected as the most suitable pipe material for the discussed project.

4 Conclusions

Using the AHP framework based on eight performance criteria, the present case study demonstrated that MS and HDPE emerged as the two best choices for pipeline material in the case study of a water supply project discussed in this paper. The outcome of the proposed methodology is likely to vary depending on the actual project conditions in respect to various criteria discussed here. However, the presented methodology would help construction practitioners in making an informed decision while choosing the most suitable pipeline material for a particular water supply project.

The future research should perform a detailed assessment based a more comprehensive list of criteria to enhance the applicability of the results in different conditions.

References

Construction risk tolerance: workers versus site-managers

Zou, Patrick X.W.¹*, Li, Penny P.P.², Wang, Jiayuan³ and
Ekambaram, Palaneeswaran⁴

Abstract: Risk tolerance has considerable importance in risk-decision making, and a comprehensive understanding of risk tolerance in construction industry is necessary in making safety related decisions. Construction worker and site managerial personal work closely on sites and often need to make judgement about the same safety risks. The aim of this research is to examine risk tolerance of both workers and site managerial personal under twelve different risk levels and scenarios which were designed based on construction statistics in Australia. Data were collected through questionnaire surveys and software BIM SPSS STATISTICS 23 was applied for statistics analysis with collected data. The results show that (1) both workers and managerial personals’ risk tolerance decrease as the risk level increase, and the change in managerial personal is more obvious; (2) workers’ risk tolerance is statistically higher than that of managerial personal; (3) compared with injury frequency, the severity shows stronger influence on risk tolerance judgement; (4) managerial personals care more about the scenarios with higher severity and higher frequency; whereas the workers take injuries with higher frequency but lower severity for granted. These results shows current areas where safety management improvement is needed for both workers and managerial personal.

Keywords: Risk tolerance; Construction workers; site managerial staff.

¹* Zou, Patrick X.W.
Corresponding author, Department of Civil and Construction Engineering and center for sustainable infrastructure, Swinburne University of Technology, Australia
E-mail: pwzou@swin.edu.au

² Li, Penny P.P.
Department of Civil and Construction Engineering, Swinburne University of Technology, Australia

³ Wang, Jiayuan
School of Civil engineering, Shenzhen University, China

⁴ Ekambaram, Palaneeswaran
Department of Civil and Construction Engineering and center for sustainable infrastructure, Swinburne University of Technology, Australia
1 Introduction

Safety evolution has significantly improved safety performance in the construction industry. However, in recent years, it appears that this improvement has plateaued and the industry is facing difficulties in achieving further improvements, while injuries and fatalities still occur on a regular basis\[^{1,2}\]. In Australia, there were 401 work-related fatalities in the construction industry over the 11-year period from 2003 to 2013 - an average of 36 deaths every year. As for injuries, 59,000 claimed injuries, which are equal to 156 injuries each day\[^{3}\]. In 2013 and 2014 the construction industry accounted for 9% of the workforce but accounted for 12% of work-related fatalities and 10% of workers’ compensation claims. These figures make construction industry one of the most dangerous ones in Australia.

In practice, site safety management commonly concentrate on physical conditions and work processes, whereas the ‘people’ element is often overlooked\[^{4}\]. However, violations of predefined safety rules is largely dependent on the practitioners’ judgement of confronting risks\[^{5,6}\]. Since these evaluations are usually carried out in a subjective manner\[^{7}\], relevant information that can increase the objectiveness of this process is of great importance.

Risk tolerance is an important aspect in risk-decision making\[^{8}\]. As indicated by Wilde\[^{9}\], improvement of safety cannot be fully achieved without considering the level of risk people are willing to tolerate. Risk tolerance is viewed as the amount of risks an individual is willing to accept in a given situation\[^{10,12}\], which plays an important role in individuals risk assessment. Slovic indicated that people accept and/or tolerate a certain level of risk in lives as necessary to achieve certain benefits\[^{13}\]. For construction workers, one reason why they continue painting on an unstable ladder may be because they are willing to tolerate the risks of falling down in pursuit of the goal of completing more paintings and/or finishing the tasks as soon as possible.

In the process of risk decision-making, risk tolerance determines the outcome of risk assessment as it can tell whether a risk is at an acceptable and/or tolerable level and then, relevant risk responses strategies are given\[^{12,14,15}\]. For construction workers, this judgment of own risk tolerance level is quite important. Unclear assessment of it would bring intentional error in performing construction tasks, as workers may believe they have the capability to tolerate potential losses, which brings underestimate of fronting risks\[^{12,16}\]. For managerial personal, they can benefit from taking further considerations of their risk tolerances in making informed and project-tailored strategies to deal with risks. Managing risk can be an expensive scheme, not only prioritizing identified risks and addressing the most crucial ones are of great importance, but also to know how much to reduce them so that the risks are acceptable is crux for improving decision-making\[^{17}\]. This will result in improved decision-making that leads to lower costs, better performance, and a shorter duration of the project\[^{17}\].

Accordingly, the present study aims to explore risk tolerance of workers and managerial personal in construction sector. Specifically, the two objectives are as follow: (1) assess and analyze current risk tolerance level of workers and managerial personal; and (2) compare risk tolerance differences between workers and managerial personal.

2 Methods
2.1 Samples

Data were collected from four on-going projects with similar types and scales with in Melbourne CBD. After half a year of strictly controlled surveys, 262 questionnaires for construction workers and 166 questionnaires for site managerial personal were received. After checking these questionnaires, 235 in workers responses and 150 in managerial personal responses are valid and can be used for further analysis.

2.2 Instrument

Based on the literature review, a self-reported assessment method was applied, which has been shown with good reliability in relation to risk tolerance measurements\cite{10, 11, 18, 19}. Scenarios-based survey is a common and appropriate way to measure practitioners’ willingness to tolerate risks in occupational health and safety\cite{20, 21}. In order to facilitate the respondents’ judgement, the scenario for each mode of injury was designed based on the most frequent safety risk identified in Australian construction sites. Accordingly, twelve construction safety risk scenarios were developed. A six-point Likert scales from 1= definitely intolerable, to 6=definitely tolerable was applied.

2.3 Data analysis

Risk tolerance levels were calculated by the average responses. The risk level (RL) represents the risk of the frequency of workers suffer an accident with a specific severity in one year. It was estimated for each risk scenario, which can be seen in Table 1, taking into account the accident number and its severity (number of lost work days) as follow: \(N*DL/100\), where \(N\) corresponds to the accident number and \(DL\) corresponds to the number of days lost. The accident number refers to accidents happened in one year.

<table>
<thead>
<tr>
<th>Items</th>
<th>Scenario descriptions</th>
<th>Risk level</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA1</td>
<td>In 100 workers, each year there are 7 worker suffering lower back injury due to fall from a 2-meter high ladder, which need 1 day time off.</td>
<td>0.07</td>
</tr>
<tr>
<td>RA2</td>
<td>In 100 workers, each year there are 8 workers suffering lower back injury due to fall from a 2-meter high ladder, which need 1 week time off.</td>
<td>0.56</td>
</tr>
<tr>
<td>RA3</td>
<td>In 100 workers, each year there are 2 workers suffering lower back injury due to fall from a 2-meter high ladder, which need 4 week time off.</td>
<td>0.56</td>
</tr>
<tr>
<td>RB1</td>
<td>In 100 workers, each year there are 7 worker suffering wrist injury due to disconnect power tools when the tool is not in use, which need 1 day time off.</td>
<td>0.07</td>
</tr>
<tr>
<td>RB2</td>
<td>In 100 workers, each year there are 8 workers suffering wrist injury due to disconnect power tools when the tool is not in use, which need 1 week time off.</td>
<td>0.56</td>
</tr>
<tr>
<td>RB3</td>
<td>In 100 workers, each year there are 2 workers suffering wrist injury due to disconnect power tools when the tool is not in use, which need 4 week time off.</td>
<td>0.56</td>
</tr>
<tr>
<td>RC1</td>
<td>In 100 workers, each year there are 8 worker suffering a leg injury due to slip on sites, which need 1 day time off.</td>
<td>0.08</td>
</tr>
<tr>
<td>RC2</td>
<td>In 100 workers, each year there are 30 worker suffering a leg injury due to slip on sites, which need 1 day time off.</td>
<td>0.30</td>
</tr>
<tr>
<td>RC3</td>
<td>In 100 workers, each year there are 10 worker suffering a leg injury due to slip on sites, which need 1 week time off.</td>
<td>0.70</td>
</tr>
</tbody>
</table>
3 Results and Discussion

3.1 Construction workers’ risk tolerance

Presented in Figure 1 is the analysis of workers risk tolerance level for each of the scenario. The risk level was computed while accounting for the number of accident occurrence and the number of days lost, as presented in Table 1. In accordance with Rodrigues and Arezes [23], for the scenarios of fatality was considered a loss of 7,500 workdays.

In general, the results show that the level of risk tolerance decreased slightly as the risk level of the scenario increased. However, there are some exceptions were observed. RD1 represents low frequent death scenario, though its computed risk level is replicative low (RL=0.08), workers show lowers tolerance of it. Another exception comes in RM (mental stress scenario), although the computed risk level of mental stress is high (RL=0.63), workers shows higher tolerance about it.

It is interesting to see that, there is no scenarios been viewed as unacceptable or slightly unacceptable. As the direct victims on site, workers regarded all mentioned risk scenarios as acceptable to some extent.

Regarding the four scenarios with the same risk level (i.e., risk level = 0.56), in which differ in severity and frequency for both modes of injury (RA3 and RB3 have higher severity). Result indicates that when the severity was higher, the level of tolerance tended to be lower (RA2-RA3, t=5.557, p<0.001; RB2-RB3, t=6.808, p<0.00).

![Workers' Risk Tolerance](image)

**Figure 1.** Workers’ risk tolerance level by risk level computed for each scenario

3.2 Site managerial personals’ risk tolerance

Figure 2 indicates the risk tolerance of managerial personals. Similar with workers, managerial personals’ risk tolerance also decreased as the risk level of the scenario increased; however, this
trend is much more obvious. In the overall trend, some exceptions can be observed from death scenarios. Compared with all evaluated scenarios, the lowest tolerance level appeared on two death scenarios.

From the perspective of different tolerance level, it is noticed that managerial personal assess scenarios with high frequency and very low severity (such as RA1, RB1 and RC1) as tolerable; whereas assess the scenarios with very high severity as slightly intolerable, no matter whether or not their frequency is.

Rundmo argued that the severity of the consequences has influence on the level of risk tolerance; however, if the severity is moderated or small, the importance is lower\textsuperscript{24}. This study showed that for both workers and managerial personal, severity of consequence is an important influencing factor for evaluating risk tolerance.

![Managerial personal's risk tolerance level by risk level computed for each scenario](image)

**Figure 2.** Managerial personal's risk tolerance level by risk level computed for each scenario

### 3.3 Comparison of risk tolerance between construction worker and managerial personal

Based on risk tolerance level shown in Figure 1 and 2, managerial personal evaluates the scenarios as more intolerable. For specific comparison, the difference value of risk tolerance level in each risk scenario between workers and managerial personal are calculated, which can be seen in Figure 3. It is noticeable that the big differences exist in mental stress, death scenarios and slip scenario; by applying independent T-test, these differences were proved with statistics evidence, which can be seen in Table 2.

In mental stress scenario, workers and managerial personal show the biggest different risk tolerance; on average, workers’ tolerance is 3.00, which regarded as tolerable level; whereas the figure in managerial personal is 1.65, which can be seen as intolerable. Based on Safe Work Australia, a construction employee who sustained an injury as a result of mental stress typically had 17.2 weeks off work, which was the highest time off compared to other injuries. Though its computed risk level is high, workers still evaluate it as more tolerable. In two death scenarios, differences between workers and managerial personal are also significant. Specifically, the latter
evaluates death risk as intolerable at around 1.30, while the former evaluates it at above 2.30. The comparison indicates that workers are less sensitive with the incidents that even with serious consequences but cannot be witnessed and/or heard frequently. Though mental and death scenarios showed higher severity, workers may believe they may not suffer due to lower possibilities. For managerial personal, prevention accident happen is one of their important responsibilities; as the accumulative of small injuries would be a recipe for a disaster, injuries with higher loss for project and company are also given higher attention.

Another big difference appears in high frequent slip incident, which shows lower severity but very higher frequency. Workers risk tolerance is 1.18 higher than that figure for managerial personal. This result is unexpected as it was thought that if workers come across these scenarios very often, they would show lower risk tolerance since they do not want to suffer similar injuries themselves. However, statistics indicate that though RC2 has very high frequency, its potential injury is slight, in which injured workers only need one day off. So, for workers, the lower severity may not be able to arouse considerate safety awareness, they may take it for granted. On the contrary, managerial personals show lower risk tolerance with these high frequency and low severity scenarios.

![Figure 3 Difference value of risk tolerance in construction workers and managerial personal](image)

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Statistical test</th>
<th>Statistical strength</th>
<th>Conclusion</th>
<th>Difference in sample means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Tolerance: workers vs management</td>
<td>Independent Sample T-Test</td>
<td>t=3.396 P=0.003</td>
<td>Strong statistical evidence</td>
<td>0.84</td>
</tr>
<tr>
<td>Mental disorder Tolerance: workers vs management</td>
<td>Independent Sample T-Test</td>
<td>t=5.517 P&lt;0.001</td>
<td>Strong statistical evidence</td>
<td>1.35</td>
</tr>
<tr>
<td>Death1 Tolerance: workers vs management</td>
<td>Independent Sample T-Test</td>
<td>t=4.694 P&lt;0.001</td>
<td>Strong statistical evidence</td>
<td>1.25</td>
</tr>
<tr>
<td>Death2 Tolerance: workers vs management</td>
<td>Independent Sample T-Test</td>
<td>t=4.645 P&lt;0.001</td>
<td>Strong statistical evidence</td>
<td>1.12</td>
</tr>
<tr>
<td>RC2 Tolerance: workers vs management</td>
<td>Independent Sample T-Test</td>
<td>t=5.616 P&lt;0.001</td>
<td>Strong statistical evidence</td>
<td>1.18</td>
</tr>
</tbody>
</table>

**4 Conclusions**
In the construction industry, risk management plays a critical role. If workers and managerial personal cannot understand each other’s risk tolerance level, management play is hard to be implemented in an appropriate way.

The results indicate that there are several safety issues that should be recognized and addressed. The first issue is that for both workers and managerial personal, their risk tolerance decreases with the increase of risk level and the decreasing change is more obvious in managerial personal. For moderate risk level scenarios, severity of the consequences has more important influence on assessment of risk tolerance. These findings provide references for further understanding the change of risk tolerance for both workers and managerial personnel.

The second issue is that the statistically significant difference of risk tolerance between workers and managerial. Current results not only support the findings of previous research that managerial personal and workers do not tend to share the same safety tolerance [6], but also indicated that even workers are regarded as the direct victims on sites, they possess high level of risk tolerance as compared with managerial personal. Especially in scenarios with high frequency-low severity and low frequency-high severity, in which managerial personal show pretty low risk tolerance. As a result, it is believed that workers having some ‘negative attitude’ towards safety issues on sites. They regard little minor injury and death for granted. For the minor injury, even they may happen frequently onsite, the severity is pretty low, which is usually only need one-day off. In addition, for the death scenarios, though its consequence is intolerable, its lower frequency may make workers believe they would never come cross with it. As a result, high risk tolerance happens. These results provide strong evidence that workers do not share the same safety and health vision which is set by managerial personal. This fact can be seen as the reason for routine violations of safety rules by worker; furthermore, it demonstrates that a weak safety climate was existed in the sample sites.

Areas of future studies may focus on why workers have such high risk tolerance, and include comparison with risk perception as well. As risk tolerance and perception are key processes in risk assessment, how do they change in different level of safety climate is important in safety management.

References


Physical and Mechanical Properties of High-Performance Lightweight Concrete

Evangelista, A.C.J.\(^1\), Tam, V. W. Y.\(^2\*) and Da Silva, L.C.F\(^3\)

Abstract: Due to the increasing demand of high-performance lightweight concrete (HPLWC) around the world, this paper aims to investigate its physical and mechanical properties and the possibility for its improvement. This paper varies parameters including mixture design proportion, dosages and types of superplasticizer and silica fume and cement content with the design strength for HPLWC of 45 MPa. Experimental results of density, compressive strength, and efficiency factor (ratio of the compressive strength and density) were presented and analysed. In the first studies, using an expanded clay coarse aggregate (D\(_{\text{max}}\)=25 mm) was obtained a maximum compressive strength of 30 MPa and an efficiency factor of 18.9 MPa dm\(^3\)/kg. However, reducing the maximum size of expanded clay coarse aggregate to a D\(_{\text{max}}\)=9.5mm were obtained a higher compressive strength of 46.9 MPa and an efficiency factor of 28.3 MPa dm\(^3\)/kg. Additionally, using an expanded shale coarse aggregate (D\(_{\text{max}}\)=9.5mm) it was reached the higher values of compressive strength and efficiency factor, 64.3 MPa and 36.3 MPa dm\(^3\)/kg, respectively. This paper provides an insight of possible HPLWC applications in the construction industry.

Keywords: high-performance lightweight concrete, lightweight aggregate; concrete; high performance.

\(^1\) Evangelista, A.C.J.
Federal University of Rio de Janeiro, Civil Engineering Department, Brazil and Western Sydney University, School of Computing, Engineering and Mathematics, Australia

\(^2\*)\ Tam, V. W. Y.
Corresponding author, Western Sydney University, School of Computing, Engineering and Mathematics, Locked Bag 1797, Penrith, NSW 2751, Australia and College of Civil Engineering, Shenzhen University, China.
E-mail: vivianwytam@gmail.com

\(^3\) Da Silva, L.C.F
Western Sydney University, School of Computing, Engineering and Mathematics, Australia
1 Introduction

Researches around the world have been showing high-performance lightweight concrete (HPLWC) as an interesting alternative construction material for the employment in various structures, including offshore platforms, bridges built by the cantilever method, floating bridges and high-rise buildings, whilst weight is an important variable for the project consideration [1]. For structural applications, compressive strength generally ranges from 40 to 60 MPa. Recently, [2] cited that the floating offshore plant has been emerging as a promising business for the next generation in Korea. These authors highlighted that many Korean ship buildings and construction companies have drawn additional attention to the feasibility of lightweight aggregate concrete (LWAC) as an offshore structural material. [3] reported that increasing the compressive strength of lightweight concrete above 55 MPa to develop a high-strength lightweight concrete (HSLWC) is challenging because the lightweight and porous aggregate tends to limit the concrete mechanical performance.

Lightweight aggregate density varies with its particle sizes. It is generally higher density for fine particle and smaller particle than the coarse particle. Magnitude of this difference also depends on the aggregate production methods [4]. Therefore, variations in the aggregate grain size can also result in the change density values. Table 1 shows some lightweight aggregate types and results published regarding high compressive strengths results. The water absorption rate of lightweight aggregate depends on the characteristics of its pores such as size, interconnection, distribution, and particularly its proximity to the grain surface. The fracture energy of LWC was lower than that of normal-weight concrete, indicating that the size-dependence of the fracture energy increases with decreasing concrete unit weight.

In the last few years, it is appeared a worldwide tendency to use high-performance compressive strength concrete aiming wide spans and durable structures. High-performance lightweight concrete (HPLWC) mixtures include mineral additives (silica fume) and chemical admixtures (superplasticizer). According to the experimental testing of physical and mechanical properties, production of HPLWC is a technically feasible alternative for use in structures where the concrete specific weight is a significant variable for the structural design. This research presents a practical nature base. Therefore, this paper aims to investigate its physical and mechanical properties and the possibility for its improvement.

2 Research methodologies

2.1 Material

Material used in this research includes cement, natural sand, lightweight coarse aggregate (expanded clay and expanded shale), silica fume, superplasticizer and water.

Cement

The binder used in the study is Portland Cement CPV ARI Portland cement (similar to ASTM Type III - high early strength).

Lightweight aggregate

Lightweight aggregate characteristics were performed according to [5]. Expanded clay presented maximum dimension of 9.5mm 12.5mm, 19mm and 25mm and fineness modules of 4.7, 6.17, 7.0
and 7.18 respectively. The expanded shale (Solite) aggregate presented Dmax = 9.5mm and 5.76 fineness modulus. The natural sand presented finesse modulus equal to 2.50. Expanded clay specific gravity and absorption were measured in accordance with the [6] whereas the aggregate was immersed in water for 24 hours to obtain the density of the grains in the saturated and surface-dried condition, as well as its absorption. In addition to the specific-density condition, it was also determined the density of grains in dry condition (in an oven at 120 °C), and the density of the impermeable material of the grains. The expanded shale lightweight aggregate (Dmax = 9.5mm) presented the specific gravity on saturated and surface-dried condition equal to 1.62 kg / dm3 and absorption of 11.3%. Table 1 presents the characteristics of expanded clay aggregate in accordance to the [3].

Mineral and chemical additives
This paper used silica fume as an aqueous suspension with solids content of 50% by weight and specific gravity of 2.2 kg/dm3. The chemical additives used was the superplasticizer (Sulfonated melamine formaldehyde), specific density of 1.2 kg/dm3 – 1.21 kg/dm3.

Water
The pH measured from five water samples during the experimental period showed consistent values between 6.5 and 6.7.

Table 1. Properties of natural sand and expanded clay aggregate

<table>
<thead>
<tr>
<th>Properties</th>
<th>Sand (Dmax=2.4mm)</th>
<th>Expanded clay (Dmax=9.5mm)</th>
<th>Expanded clay (Dmax=12.5mm)</th>
<th>Expanded clay (Dmax=19mm)</th>
<th>Expanded clay (Dmax=25mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk specific gravity S.S.D.*</td>
<td></td>
<td>1.19</td>
<td>1.25</td>
<td>1.28</td>
<td>1.17</td>
</tr>
<tr>
<td>(kg/dm³)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk specific gravity dry(kg/dm³)</td>
<td>2.67</td>
<td>1.09</td>
<td>1.15</td>
<td>1.6</td>
<td>1.01</td>
</tr>
<tr>
<td>Apparent specific gravity (kg/dm³)</td>
<td></td>
<td>0.62</td>
<td>0.60</td>
<td></td>
<td>0.62</td>
</tr>
<tr>
<td>Absorption 24 h(%)</td>
<td></td>
<td>9.3</td>
<td>9.4</td>
<td>19.7</td>
<td>14.9</td>
</tr>
</tbody>
</table>

* S.S.D - Saturate Surface Dry

2.2 Lightweight concrete mix proportions

The concrete mixture design was conducted considering that the size distribution of the fine aggregate remained constant, but the coarse aggregate was varied Dmax: 25mm, 19mm, 12.5mm and 9.5mm. Table 3 presents concrete mixes designed to evaluate the influence of silica fume and superplasticizer at the mechanical properties of high-performance lightweight concrete: A-reference (Dmax=25mm) , B – reference + SP (1% of the binder content weight) , C1 to C6 (Dmax=25mm; cement - 90% in mass and silica fume -10% in mass; SP-1% of the binder content weight), D (Dmax=19mm; cement - 90% in mass and silica fume -10% in mass; SP-1% of the binder content weight), E (Dmax=12.5mm; cement - 90% in mass and silica fume -10% in mass;
SP-1% of the binder content weight), F (Dmax=9.5mm; cement - 90% in mass and silica fume -10% in mass; SP-1% of the binder content weight) e G (Expanded shale aggregate, Dmax=9.5mm; cement - 90% in mass and silica fume -10% in mass; SP-1% of the binder content weight).

2.3 Properties testing

The average slump was in the range of 85–120mm. The physical properties were measured according to [7]. The compressive strength, the splitting tensile strength and the modulus of elasticity were performed according to [8, 9, 10] respectively.

Influence of chemical and minerals admixtures

Reference concrete (mixture A) shows a strength gain of 23% between the ages of 7 days and 28 days compared to the strength evolution of the mixtures B and C. The effect of water reducing by the use of superplasticizer (3% by cement mass) resulted in a reduction of water / cement + silica fume equal to 24%, leading to an increasing of 11% of the compressive strength.

Effect of cement content

Mixture C2 (450kg cement) with silica fume used in the cement replacement, resulted in a compressive strength (28 days) of 27.7 MPa. Mixture C1 (500kg cement), 10% silica fume added by cement weight, presented the compressive strength a higher (8%) than C2 with 29.9 MPa. It is important to notice that the mixture C3, although with a higher consumption of cement and minor relation of water / cement with silica fume, did not correspond to the higher result of fc. At this case, the lightweight aggregate is the weakest part of the concrete composition; and increasing the cement content did not lead to the increase of the LWAC mechanical properties.

Influence of the lightweight aggregate maximum size (Dmax)

Table 3 presents the results of mixtures C1, D, E, F and G performed using 100mm x 200mm and 150mm x 300mm to evaluate the influence of the Dmax reduction on the compressive strength. Regarding both specimens size, cylinders 100mm x 200mm and 150mm x 300mm, it was obtained that the mixture D (Dmax=19mm) reached an increase of 31% and 20%, 39.3 MPa and 38.3 MPa, respectively, compared to mixture C1 (Dmax=25mm). Mixture E (Dmax=12.5 mm) achieved an increase of 10% and 15% compared to mixture D, 43.3 MPa and 44.3 MPa respectively. Mixture F (Dmax=9.5mm) reached an increase of 10% and of 15% compared to the mixture E. Mixture G using the expanded shale aggregate (Dmax = 9.5mm) presented a compressive strength equal to 64.3MPa (specimens of 100mmx200mm), 37% higher than that achieved using the expanded clay aggregate (Dmax=9.5mm).
Table 3. Mixture proportions for lightweight concrete

<table>
<thead>
<tr>
<th>Materials</th>
<th>Mixtures [unit: kg/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Weight Aggregate(kg)</td>
<td>505 523 502 512</td>
</tr>
<tr>
<td>Sand (kg)</td>
<td>522 571 530 553</td>
</tr>
<tr>
<td>Cement(kg)</td>
<td>500 500 500 450</td>
</tr>
<tr>
<td>Water(L)</td>
<td>196 159 159 168</td>
</tr>
<tr>
<td>Silica fume(sf) (kg)</td>
<td>50 50 55 49</td>
</tr>
<tr>
<td>Superplasticizer (L)</td>
<td>4.2 4.6 4.2 4.2</td>
</tr>
<tr>
<td>Water/Cement+sf</td>
<td>0.39 0.32 0.31 0.34</td>
</tr>
<tr>
<td>Slump(mm)</td>
<td>85 115 90 90</td>
</tr>
</tbody>
</table>

Mechanical Properties

| fc7 (MPa) | 20.9 24.7 27.3 26.2 |
| cy. 100x200 mm | - - - - - |
| fc28 (MPa) | 24.8 25.8 29.9 27.7 |
| cy. 100x200 mm | - - - 27.9 23.7 30.4 31.5 36.5 |
| ft28 (MPa) | - - - 30.3 38.2 28.8 38.3 44.3 44.5 |
| cy. 150x300 mm | 3.73 4.38 5.55 |
| ft28 (MPa) | 3.8 4.57 - |
| cy. 150x300 mm | 20.8 21.4 25.0 |

3.3. Results and discussions

Structural Efficiency factor

Considering the lightweight concrete performance, it is important to reveal that the density is a significant material property. The structural efficiency is a ratio of the Compressive strength and density of the concrete [13]. The 28-day efficiency factor is a parameter to the lightweight
Concrete characterization. Figure 1 presents the efficiency factor of LWAC.

![Figure 1. Structural efficiency factor of LWAC](image)

Structural efficiency factor ranged from 16.5 to 36.3 MPa dm$^3$/kg, with the highest value corresponding to the concrete G with expanded shale aggregate. Table 10 shows that expanded clay Dmax=25mm mixtures results were lower than expected for high-strength concrete, about 25 MPa dm$^3$/kg. Regarding the expanded clay presenting Dmax = 25mm, the mixture C6 showed the highest efficiency factor, 20.2 MPa dm$^3$/kg, whereas the superplasticizer content was of 3% by weight of the cementitious material. Considering the mixtures with the expanded clay aggregate, the one with the highest efficiency factor was the mixture F (Dmax = 9.5mm). Both E (Dmax = 12.5mm) and F mixture showed results exceeding 25 MPa dm$^3$/kg which is consistent with the definition of high-strength lightweight aggregate concrete cited by several authors [3,11,12,13,14]. The results obtained in mixtures E and F were similar to those obtained by other authors [15] which used lightweight aggregate available in other countries. Mixture G, with expanded shale presented structural efficiency equal to 36.3 MPa dm$^3$/kg, 28% higher than that obtained with the expanded clay aggregate and according to the results presented in the accessed technical literature, except that achieved 49 MPa dm$^3$/kg.

4 Conclusion

This paper investigated the physical and mechanical properties of high-performance lightweight aggregate concrete. Using the lightweight coarse aggregate after 24 hours of water immersion, removed the workability loss problem at the time of mixing the materials, yielding the expected subsidence of 100 ± 20 mm, without the need for corrections in the mixture. The decrease of Dmax lightweight coarse aggregate, the addition of silica fume and superplasticizer, and increased percentage of mortar were the factors that contributed to the increased compressive strength. It has been proven that the compressive strength is directly proportional to its density, and inversely
proportional to absorption and concrete voids. Also it was found that the density of the fresh concrete was about 13% higher than the specific mass of the dry concrete. Concrete with lightweight coarse aggregate Dmax = 25mm, adding silica fume and superplasticizer, achieved an increase of 27% in compressive strength, reaching the value of 31.5 MPa. Employing coarse aggregate with Dmax = 9.5mm leads to the maximum compressive strength value measured in this study with expanded clay: 46.9 MPa (in 100 x 200 mm specimens). Also, the density of this concrete was 1.66 kg / dm³, resulting at the highest efficiency factor of 28.3 MPa dm³ / kg. It is important to notice that the highest efficiency factors were obtained for concrete of lower Dmax. Although the decrease in Dmax led to an increase in the concrete density, increasing the compressive strength was significant that lead to an increase of efficiency factor, which could justify the use of smaller maximum diameter. The efficiency factor can be improved because the density could be reached up to 2.0 kg/dm³, and a simple variation of the coarse lightweight aggregate can lead to a higher compressive strength of 50 MPa. The replacement of coarse expanded clay aggregate to the expanded shale, resulted in a high-performance lightweight aggregate concrete presenting the highest result of this study, fc28= 64.3 MPa. Also, had the highest density of 1.77 kg / dm³, and the highest efficiency factor of 36.6 MPa dm³/kg.

References


made with scoria aggregate containing mineral admixtures". Cement and Concrete Research, 33(10), 1595–1599.


Abstract: The construction sector plays a key role in the economy through its multiplier effect on many industries. Low productivity is perceived as one of the biggest challenges faced by the Malaysian construction sector. This paper analyse the productivity of construction sector and its four key subsectors. The data are extracted from the published reports of census and survey of construction industries conducted by the Department of Statistics, Malaysia between years 1996 and 2015. The analysis shows that productivity performance of the construction sector and its key subsectors are improved in recent years. Added value per employee recorded with higher amount despite decrease in both capital and labour inputs. The earnings of construction employees increased despite with decrease in unit labour cost. The improvement is attributed to the demand intensity and usage of more advanced building practices and systems such as the Green Building Index (GBI) and Building Information Modelling (BIM) resulting from several mega construction projects in the oil and gas as well as transportation industries nationwide. Similar improvement is also detected in the residential and non-residential subsectors.

Keywords: Productivity; Construction sector; Malaysia.
1 Introduction

The construction sector plays a key role in the economy because of its multiplier effects on many industries. The sector accelerates economic activities and provides infrastructure needed for further development [1]. In 2016, the GDP of construction sector is RM50.1 which contributed 4.5% of the national GDP. This represent 7.4% annual output growth of the construction sector. In addition, the sector hired 1.25 million employees, which provide 9% of total employment in the country. However, the construction sector recorded with the lowest productivity level among the different economic sectors [2].

This study analyse the performance of Malaysian construction labour productivity at the sectoral and its four key sub-sectoral levels, namely, residential, non-residential, civil engineering and specialised activities. The paper is divided into five sections. The first section provides a backdrop of the study. The second section examines the issue of productivity measurement. The third section provides a brief account of sources of data and the definition of productivity indicators. The fourth section analyses and interprets the productivity indicators. The final section concludes the main findings and their implications to the construction sector.

2 Construction Labour Productivity

The term productivity may seem rather easy to understand, however, there are several implications which have caused much confusion. A common mistake is to use productivity synonymous to measures of production, but, productivity is a relative concept, which needs to make comparisons either of variations from competitors or other standards at a certain point in time, or of changes over time [3]. Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use [4]. There are many different productivity measures. Broadly, productivity measures can be classified as single factor productivity measures (relating a measure of output to a single measure of input) or multifactor productivity measures (relating a measure of output to a bundle of inputs) [4]. Single factor productivity measures is also known as partial productivity measures. Examples of partial productivity measures are labour productivity (the ratio of output to labour input) and capital productivity (the ratio of output to capital input) [1]. Because construction is a labor-intensive industry and primarily dependent on human effort and performance, thus labor productivity is a crucial productivity index [5]. Measures of output include gross domestic product (GDP), added value and monetary value of production, while measures of inputs include total employed persons, total man-hours worked, capital or fixed assets, labour cost, energy and bought-in materials and services.

There are different hierarchical levels within productivity can be discussed. Construction labour productivity can be analysed at industry, project, and activity level [5]. This paper analyse productivity at industry level.

3 Research Methods

Department of Statistics Malaysia (DOSM) conducts a biennial Construction Industry Survey and
quinquennial Census of Construction Industry. The following productivity indicators are computed from the published data of five industry censuses (i.e. years 1997, 2001, 2007, 2011 and 2016) and six industry surveys (i.e. years 1999, 2003, 2005, 2008, 2012 and 2014). All values from the surveys/censuses are deflated to year 2010 prices using the Implicit Price Deflators for construction obtained from the National Accounts. Implicit price deflator is an economic metric that accounts for inflation by converting output measured at current prices into constant-dollar GDP. This specific deflator shows how much a change in the base year’s GDP relies upon changes in the price level.

Table 1 listed the types and indicators of productivity included in this analysis.

<table>
<thead>
<tr>
<th>Types</th>
<th>Indicators and measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour competitiveness</td>
<td>Added value per labour cost = Added value/Labour cost</td>
</tr>
<tr>
<td></td>
<td>Labour cost per employee = labour cost/ number of employee</td>
</tr>
<tr>
<td></td>
<td>Unit labour cost = Labour cost/Total output</td>
</tr>
<tr>
<td>Labour productivity</td>
<td>Added value per employee = Added value /Number of employees</td>
</tr>
<tr>
<td></td>
<td>Total output per employee = Total outputs/ Number of employees</td>
</tr>
<tr>
<td></td>
<td>Added value per hour work = Added Value/Total hours worked</td>
</tr>
<tr>
<td>Capital productivity</td>
<td>Added value per fixed asset = Added value/Fixed assets</td>
</tr>
<tr>
<td></td>
<td>Capital turnover = Total output/Fixed assets</td>
</tr>
<tr>
<td>Capital intensity</td>
<td>Fixed assets per employee = Fixed assets/Number of employees</td>
</tr>
<tr>
<td>Process efficiency</td>
<td>Added value/[(Total input) – (Bought-in materials and service)]</td>
</tr>
</tbody>
</table>

4 Results and analysis

The construction labour productivity, measured as added value per employee, of the construction sector recorded RM41,033 in 2015 (Table 2). The best perform subsector is civil engineering in year 2015, followed by special activities, non-residential and residential sectors.

Table 2. Labour productivity of Malaysian construction sector and sub-sectors (1996-2015)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil engineering</td>
<td>45.685</td>
<td>44.219</td>
<td>52.505</td>
<td>51.601</td>
<td>50.066</td>
<td>44.532</td>
<td>37.643</td>
<td>39.761</td>
<td>33.782</td>
<td>34.898</td>
<td>37.481</td>
<td>44.439</td>
</tr>
<tr>
<td>Non-residential</td>
<td>35.277</td>
<td>34.989</td>
<td>37.795</td>
<td>37.115</td>
<td>39.798</td>
<td>41.142</td>
<td>32.579</td>
<td>34.725</td>
<td>33.027</td>
<td>33.242</td>
<td>34.099</td>
<td>41.548</td>
</tr>
<tr>
<td>Residential</td>
<td>31.452</td>
<td>32.560</td>
<td>36.427</td>
<td>40.073</td>
<td>43.679</td>
<td>41.888</td>
<td>34.228</td>
<td>36.137</td>
<td>32.035</td>
<td>32.873</td>
<td>35.173</td>
<td>40.877</td>
</tr>
<tr>
<td>Special activities</td>
<td>35.206</td>
<td>37.362</td>
<td>43.778</td>
<td>48.328</td>
<td>47.026</td>
<td>46.322</td>
<td>37.045</td>
<td>37.516</td>
<td>32.036</td>
<td>32.202</td>
<td>35.798</td>
<td>37.081</td>
</tr>
<tr>
<td>Construction sector</td>
<td>38.063</td>
<td>37.797</td>
<td>42.900</td>
<td>44.141</td>
<td>45.337</td>
<td>43.382</td>
<td>35.479</td>
<td>36.995</td>
<td>32.778</td>
<td>33.342</td>
<td>35.621</td>
<td>41.033</td>
</tr>
</tbody>
</table>

The civil engineering subsector is the best performers for all the years under reviewed, with exception in year 2005. On the other hand, the residential sector emerges as the fastest growth subsector with productivity index recorded as 130 in 2015 (1998 =100), while civil engineering subsector is marginally declined to 97 in 2015 (1998=100) as shown in Fig. 1.
Figure 1. Value added, unit capital cost and unit labour cost of construction sector 1996-2013

Table 3 exhibits the labour cost competitiveness of construction sector and its subsectors. Civil engineering subsector appears to be the most competitive subsector with exceptions in years 2005, 2010 and 2013.

Table 3. Added value per labour cost of Malaysian construction sector and sub-sectors, RM at year 2010 constant price (1996-2015)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil engineering</td>
<td>1.86</td>
<td>1.75</td>
<td>1.90</td>
<td>1.74</td>
<td>1.81</td>
<td>1.81</td>
<td>1.45</td>
<td>1.65</td>
<td>1.63</td>
<td>1.71</td>
<td>1.66</td>
<td>2.02</td>
</tr>
<tr>
<td>Non-residential</td>
<td>1.62</td>
<td>1.56</td>
<td>1.63</td>
<td>1.55</td>
<td>1.59</td>
<td>1.66</td>
<td>1.35</td>
<td>1.43</td>
<td>1.60</td>
<td>1.63</td>
<td>1.63</td>
<td>1.95</td>
</tr>
<tr>
<td>Residential</td>
<td>1.51</td>
<td>1.46</td>
<td>1.46</td>
<td>1.52</td>
<td>1.66</td>
<td>1.69</td>
<td>1.34</td>
<td>1.52</td>
<td>1.57</td>
<td>1.61</td>
<td>1.62</td>
<td>1.88</td>
</tr>
<tr>
<td>Special activities</td>
<td>1.66</td>
<td>1.58</td>
<td>1.61</td>
<td>1.62</td>
<td>1.66</td>
<td>1.83</td>
<td>1.41</td>
<td>1.47</td>
<td>1.65</td>
<td>1.65</td>
<td>1.69</td>
<td>1.82</td>
</tr>
<tr>
<td>Construction sector</td>
<td>1.70</td>
<td>1.61</td>
<td>1.67</td>
<td>1.62</td>
<td>1.69</td>
<td>1.75</td>
<td>1.40</td>
<td>1.52</td>
<td>1.61</td>
<td>1.65</td>
<td>1.65</td>
<td>1.92</td>
</tr>
</tbody>
</table>

The returns to the individual employees were rising in the period of 1996 to 2002. But it shrunk since 2004 with a brief recovery in years 2007 and 2013 (Table 4). The employees of civil engineering subsector received the highest returns among the four subsectors for the period 1996-2015 with exception 2002-2009. The employees of special activities subsector received higher returns than employees in other subsector during the period 2002-2009.

Table 4. Labour cost per employee of Malaysian construction sector and sub-sectors, RM at year 2010 constant price (1996-2015)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil engineering</td>
<td>24,564</td>
<td>25,317</td>
<td>27,609</td>
<td>29,611</td>
<td>27,619</td>
<td>24,648</td>
<td>24,876</td>
<td>24,101</td>
<td>20,767</td>
<td>20,422</td>
<td>22,595</td>
<td>21,951</td>
</tr>
<tr>
<td>Non-residential</td>
<td>21,727</td>
<td>22,417</td>
<td>23,211</td>
<td>23,938</td>
<td>25,100</td>
<td>24,789</td>
<td>24,062</td>
<td>24,203</td>
<td>20,618</td>
<td>20,334</td>
<td>20,858</td>
<td>21,321</td>
</tr>
</tbody>
</table>
The overall capital productivity trend does not show any indicative pattern. It declines in six instances out of the twelve cases under study (Table 5). Residential sub-sector displayed a better performance than other subsectors except in year 2002 and 2005 which non-residential subsector outperformed the residential subsector. It implies a more efficient utilisation of fixed assets in residential and non-residential subsectors because of low capital intensive and higher labour intensive of the two sub-sectors. Contrarily, civil engineering and special activities subsectors are proven as more capital intensive subsectors as indicated in Table 6.

Table 5. Capital productivity of Malaysian construction sector and sub-sectors, RM at year 2010 constant price (1996-2015)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil engineering</td>
<td>3.13</td>
<td>2.65</td>
<td>2.69</td>
<td>2.01</td>
<td>2.31</td>
<td>2.20</td>
<td>2.32</td>
<td>2.17</td>
<td>1.68</td>
<td>3.13</td>
<td>2.65</td>
<td>2.69</td>
</tr>
<tr>
<td>Non-residential</td>
<td>3.27</td>
<td>3.25</td>
<td>4.04</td>
<td>3.93</td>
<td>2.69</td>
<td>2.52</td>
<td>2.33</td>
<td>2.48</td>
<td>2.32</td>
<td>3.27</td>
<td>3.25</td>
<td>4.04</td>
</tr>
<tr>
<td>Residential</td>
<td>4.13</td>
<td>4.19</td>
<td>4.06</td>
<td>3.13</td>
<td>2.87</td>
<td>2.50</td>
<td>3.01</td>
<td>3.79</td>
<td>2.82</td>
<td>4.13</td>
<td>4.19</td>
<td>4.06</td>
</tr>
<tr>
<td>Special activities</td>
<td>2.69</td>
<td>2.73</td>
<td>2.69</td>
<td>2.09</td>
<td>1.82</td>
<td>1.71</td>
<td>2.21</td>
<td>1.99</td>
<td>1.95</td>
<td>2.69</td>
<td>2.73</td>
<td>2.69</td>
</tr>
<tr>
<td>Construction sector</td>
<td>3.27</td>
<td>3.08</td>
<td>3.20</td>
<td>2.52</td>
<td>2.38</td>
<td>2.21</td>
<td>2.44</td>
<td>2.46</td>
<td>2.11</td>
<td>3.27</td>
<td>3.08</td>
<td>3.20</td>
</tr>
</tbody>
</table>

The overall capital intensity of the construction sectors fluctuates over the period under study with no obvious trend to be concluded. There are six instances of decline in capital intensity of the construction sector between years 1996 and 2015 detected (Table 6). The higher values recorded in civil engineering and special activities subsectors indicates that these two sub-sectors adopt high capital intensity policy than the other. There is noticeable rising trends of capital intensity in both residential and non-residential sub-sectors despite some disruptions in years 2005, 2007, 2010 and 2013. It indicates the two sectors are starting to adopt more capital intensity approach.


<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil engineering</td>
<td>19,854</td>
<td>24,622</td>
<td>29,580</td>
<td>22,470</td>
<td>24,514</td>
<td>20,848</td>
<td>21,805</td>
<td>18,075</td>
<td>15,335</td>
<td>13,904</td>
<td>15,849</td>
<td>22,182</td>
</tr>
<tr>
<td>Non-residential</td>
<td>11,939</td>
<td>12,511</td>
<td>12,782</td>
<td>15,475</td>
<td>15,855</td>
<td>12,837</td>
<td>9,678</td>
<td>13,559</td>
<td>13,118</td>
<td>13,202</td>
<td>12,621</td>
<td>15,015</td>
</tr>
<tr>
<td>Residential</td>
<td>9,570</td>
<td>12,499</td>
<td>13,453</td>
<td>13,217</td>
<td>13,502</td>
<td>13,000</td>
<td>12,774</td>
<td>13,235</td>
<td>12,797</td>
<td>10,103</td>
<td>8,520</td>
<td>12,136</td>
</tr>
<tr>
<td>Special activities</td>
<td>13,181</td>
<td>17,828</td>
<td>22,662</td>
<td>24,453</td>
<td>22,334</td>
<td>21,662</td>
<td>20,638</td>
<td>21,599</td>
<td>18,759</td>
<td>13,465</td>
<td>16,526</td>
<td>15,906</td>
</tr>
<tr>
<td>Construction sector</td>
<td>14,403</td>
<td>17,328</td>
<td>19,663</td>
<td>18,387</td>
<td>19,083</td>
<td>17,096</td>
<td>16,457</td>
<td>16,306</td>
<td>14,855</td>
<td>12,675</td>
<td>13,300</td>
<td>16,304</td>
</tr>
</tbody>
</table>

Figure 2 depicts relationship of labour productivity and capital and labour inputs of construction sectors between years 1996 and 2015. Figure 3 to figure 6 show the similar relationships of the four key subsectors during the same period. The vertical axis shows the unit capital cost whereas the horizontal axis shows unit labour cost. The bubbles represent value added per employee (labour productivity), their size proportionate to size of value added per employee. The larger size of the bubble symbolizes better performance of construction labour productivity and vice-versa. The left-
bottom quadrant is a quadrant with low unit labour and low capital cost.

The recent year bubbles gather at the left-bottom quadrant in Figure 2. It indicates that the construction labour productivity are improving with reduction inputs in both labour and capital for the period under study. In general, both unit labour and capital costs dwindled in recent years while the unit capital cost increased in year 2015.

The above observations are consistent with the sub-sectorial performances of civil engineering, residential and non-residential sub-sectors as shown in Figure 3, 4 and 5 respectively. However, both the unit capital cost of special activities subsector increased in year 2013 and 2015. The smaller bubble size after mid 2000s indicated that the value added per employee were in the falling trend.

![Figure 2. Value added, unit capital cost and unit labour cost of construction sector 1996-2015](image-url)
Figure 3. Value added, unit capital cost and unit labour cost of civil engineering subsector 1996-2015

Figure 4. Value added, unit capital cost and unit labour cost of non-residential subsector 1996-2015
Table 7 summarized the changes of productivity indicators between Construction Census in 1996 and 2016. The added value per employee of the overall construction sector are merely increased by 7.8%, the residential sub-sector registered the highest productivity growth of 30.0% followed by non-residential construction (17.8%) and special activities (5.3%). However the civil engineering subsector declined by 2.7%.
The outperformance of residential subsector is reaffirmed by the increase in total output per employee (50%). This is attributed to the capital deepening in the subsector which is shown by the capital intensity of 26.8%, as result of this, the unit capital cost and the unit labour cost are decreased by -49.8% and -30.2% respectively. Despite the decrease in the unit labour cost, the return to individual employee of the residential subsector is continue to rise by 4.8%. Indeed, this is the only subsector with increase in return to individual employee. Nevertheless, the increased in capital investment in the residential subsector resulted with the highest decline in the capital productivity of -38.2%. This is inevitable as capital investment will need a longer period to recover its investment. The added value content of residential subsector shows a greater decline of 13.4% reflected there is a high cost of bought-in materials and services. It is partially driven by the more off-site construction happened in the Malaysian construction industry because of the improving effort of Industrial Building System (IBS) adoption.

Table 7. Percentage change in productivity indicators between Construction Census 1997 and 2016 at year 2010 constant price

<table>
<thead>
<tr>
<th>Construction sub-sector</th>
<th>Civil Engineering</th>
<th>Non-Residential</th>
<th>Residential</th>
<th>Special Activities</th>
<th>Construction Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added value per employee</td>
<td>-2.7%</td>
<td>17.8%</td>
<td>30.0%</td>
<td>5.3%</td>
<td>7.8%</td>
</tr>
<tr>
<td>Total output per employee</td>
<td>5.2%</td>
<td>29.3%</td>
<td>50.0%</td>
<td>4.9%</td>
<td>16.8%</td>
</tr>
<tr>
<td>Added value per labour cost</td>
<td>8.8%</td>
<td>20.0%</td>
<td>24.0%</td>
<td>9.8%</td>
<td>13.1%</td>
</tr>
<tr>
<td>Labour cost per employee</td>
<td>-10.6%</td>
<td>-1.9%</td>
<td>4.8%</td>
<td>-4.1%</td>
<td>-4.7%</td>
</tr>
<tr>
<td>Unit labour cost</td>
<td>-15.0%</td>
<td>-24.1%</td>
<td>-30.2%</td>
<td>-8.6%</td>
<td>-18.4%</td>
</tr>
<tr>
<td>Unit capital cost</td>
<td>-35.0%</td>
<td>-40.1%</td>
<td>-49.8%</td>
<td>-26.2%</td>
<td>-40.4%</td>
</tr>
<tr>
<td>Capital productivity</td>
<td>-47.5%</td>
<td>-43.5%</td>
<td>-38.2%</td>
<td>-47.4%</td>
<td>-42.6%</td>
</tr>
<tr>
<td>Capital intensity</td>
<td>11.7%</td>
<td>25.8%</td>
<td>26.8%</td>
<td>20.7%</td>
<td>13.2%</td>
</tr>
<tr>
<td>Added value content</td>
<td>-7.5%</td>
<td>-8.9%</td>
<td>-13.4%</td>
<td>0.4%</td>
<td>-7.7%</td>
</tr>
</tbody>
</table>

Table 8 compares the changes of productivity indicators between the two most recent Construction Census in 2011 and 2016. The added value per employee of the overall construction sector is increased by 25.2%, the civil engineering sub-sector registered the highest productivity growth of 31.5% followed by residential sub-sector (27.6%), non-residential subsector (15.8%) and special activities (15.7%).

The residential sector registered a higher changes of output per employee (27.4%) than the civil engineering subsector (25.3%). However, the change of added value per labour cost unit of residential subsector (20.0%) is lower than the civil engineering subsector (24.4%). Notwithstanding there is a reduction in the unit labour cost of residential subsector (-16.5%), the return to the individual employee is continue to rise (6.4%). Despite the capital investment of the civil engineering subsector (44.6%) is deepened than the residential subsector (-5.2%), the capital productivity of residential subsector shows a positive growth (12.8%) while the civil engineering subsector shows a decline of 23.8%. As a result the unit capital cost of residential subsector is decreased by 25.6%, whereas the civil engineering subsector is increased by 15.4%. The added value content of residential subsector of 0.1% shows there is either no change in the cost of bought in materials or services or there is no increase in the usage of offsite construction components between the two census periods.
Table 8. Percentage change in productivity indicators between Construction Census 2011 and 2016 at year 2010 constant price

<table>
<thead>
<tr>
<th>Construction sub-sector</th>
<th>Civil Engineering</th>
<th>Non-Residential</th>
<th>Residential</th>
<th>Special Activities</th>
<th>Construction Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added value per employee</td>
<td>31.5%</td>
<td>25.8%</td>
<td>27.6%</td>
<td>15.7%</td>
<td>25.2%</td>
</tr>
<tr>
<td>Total output per employee</td>
<td>25.3%</td>
<td>25.4%</td>
<td>27.4%</td>
<td>15.4%</td>
<td>23.3%</td>
</tr>
<tr>
<td>Added value per labour cost</td>
<td>24.4%</td>
<td>21.7%</td>
<td>20.0%</td>
<td>10.4%</td>
<td>19.3%</td>
</tr>
<tr>
<td>Labour cost per employee</td>
<td>5.7%</td>
<td>3.4%</td>
<td>6.4%</td>
<td>4.8%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Unit labour cost</td>
<td>-15.7%</td>
<td>-17.5%</td>
<td>-16.5%</td>
<td>-9.1%</td>
<td>-14.9%</td>
</tr>
<tr>
<td>Unit capital cost</td>
<td>15.4%</td>
<td>-8.7%</td>
<td>-25.6%</td>
<td>-26.5%</td>
<td>-11.0%</td>
</tr>
<tr>
<td>Capital productivity</td>
<td>-23.8%</td>
<td>-7.9%</td>
<td>12.8%</td>
<td>14.4%</td>
<td>-4.4%</td>
</tr>
<tr>
<td>Capital intensity</td>
<td>44.6%</td>
<td>14.5%</td>
<td>-5.2%</td>
<td>-15.2%</td>
<td>9.8%</td>
</tr>
<tr>
<td>Added value content</td>
<td>4.9%</td>
<td>0.3%</td>
<td>0.1%</td>
<td>0.3%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

5 Conclusion

Low productivity is one of the biggest challenges faced by the local construction sector. But, there is an impressive productivity growth in recent years. The residential subsector shows the most impressive improvement with the fastest growth in labour productivity. Notwithstanding the subsector confronts with the fastest growth in labour cost, the unit labour cost is continuing decline. This reflects the subsector is transforming from labour-intensive to capital-intensive construction.

In addition, the non-residential subsector shows more intensify of capital. This is because of the public sector plays an important role in the non-residential subsectors. Considerable efforts are being made to increase the application of Industrialised Building System (IBS) to enhance construction productivity and reduce over-dependency on unskilled foreign labor as well as to promote quality and safety. The government has made it compulsory to utilize a minimum of 70% IBS components in the public sector and 50% in the private sector by 2015 as stated in the IBS Roadmap 2011-2015 [6]. Other measures that have been introduced include the adoption of more advanced building practices and systems such as the Green Building Index (GBI) and Building Information Modelling (BIM) [7].

The higher productivity growth is also attributed to the demand intensity and use of modern technology resulting from several mega construction projects in the oil and gas as well as transportation industries nationwide. They included the Petronas LNG Complex in Bintulu, Pengerang Deepwater Petroleum terminal with marine facilities and jetty, construction of the Pan-Borneo Highway, road upgrading works, including the Pulau Indah Highway and Bintulu–Samalaju Road, the ongoing Mass Rapid Transit (MRT) project as well as residential and commercial buildings [2].

References


A statistical yearbook data-based calculation method for building floor space in China and analysis on energy intensity

Ren Hong¹, Huo Tengfei,² Cai Weiguang³*

Abstract: Accurately assessing the building floor space is difficult owing to deficiencies in China’s statistical collection system and a lack of national surveys. This study proposes a set of calculation method for China building floor space by sectors (i.e., commercial floor space, urban residential floor space and rural residential floor space) during 2001 to 2014, and then the energy intensity trends are analyzed. Results indicate that the rural residential floor space increased from 20.4 billion m² to 24.5 billion m² during 2001-2014. The urban residential floor space saw a significant increase, increasing more than four times from 6.652 billion m² to 25.969 billion m², which indicated the rapid urbanization in China recent years. During 2001 to 2014, the commercial floor space increased more twice from 4.659 billion m² to 10.081 billion m² during the research period. And finally, energy intensity in building sectors are analyzed.

Keywords: Building stock, Building Floor space, Building energy consumption, Energy intensity, China

1. Introduction

The building sector is one of the three energy-consuming areas in addition to industry and transportation, and is also an important source of greenhouse gas emissions. The building sector accounts for about 30–40% of final energy use in most developed countries [1,2]. During 2000 to 2014, China building energy consumption increased 1.70 times, rising from around 301 to 814 million tons standard coal consumed [3], and is expected to increase further to 35% by 2020 [4].

The main driving force for the building energy demand growth is the rapid process of urbanization in China and the concomitant increase of the floor space [5]. As we all know, China urbanization rate has increased from 20% to 53.7% from 1980 and 2013 and it will continue grow rapidly in the next decades [6]. With the growth of the urbanization, more migrant workers flood into the urban areas. In order to accommodate new migrants in urban areas, China is now carrying out the construction activity at the largest scale. Nearly half of the world’s new building construction now is in China, which is about two billion square meters of new building floor area per year. These new buildings consumed 30–40% of the world's annual cement and steel production [7]. With the urbanization in China, the trend shows that more commercial energy will be used in buildings and the carbon emissions from fossil fuels will probably increase in the future at the same time. The
shorter lifespan of the Chinese existing building also led to the rapid growth of the construction activity, and this will further result in the material and energy demand. The direct consequence of the rapid turnover of building construction is the production of massive building wastes, approximately accounting for 30–40% of total waste production. Therefore, accurately measuring the magnitude of floor space has significant implications on the future building materials and energy demand, and it’s the key to carry out the building energy saving and it can enable the policy makers shoot the arrow at the target. It’s also the prerequisite to know whether China can achieve its carbon emission peaking goal in 2030.

Recent years, some scholars conducted some researches on projecting the building energy and material demand using floor space as one of the driving forces\[^4\,^8\,^9\], the result they obtained were highly problematic, because they directly obtained the commercial floor space by subtracting residential floor space from the total building floor space given in the statistic yearbook. This processing method is wrong, because the industry sector floor space is included when subtracting residential floor space from the total building floor space. Actually the basic time series data on present floor space in China are not available, especially the commercial floor space which cannot be obtained from China Statistical Yearbook. The root cause is that there exist many problems in China’s statistical system, such as the change of the statistical range, the change of the statistical caliber and the incomplete of time series data and so on. As a result, it’s hard to accurately measure the China’s building stock and floor space. Overall, there isn’t a general and authoritative time-series data on China floor space (i.e., commercial floor space, rural residential floor space and urban residential floor space). For this purpose, this study attempts to propose a set of China residential floor space calculation method based on Statistical Yearbook data.

This study first analyzes the existing problems of various types of floor space in China Statistical Yearbook by systematically combing the statistical reporting system related to the building area in China over the years, and then puts forward a set of floor space calculation method based on China Statistical Yearbook data using multiple regression model. And then China's floor space by types (i.e., commercial floor space, urban residential floor space and rural residential floor space) during 2001 to 2014 are measured using this new proposed method. Finally, the building energy intensity based on our original research on calculation of China building energy consumption data\[^2\] is analyzed. The proposed method not only eliminates the problem of inconsistent statistical caliber in the statistical yearbook, but also obtains the authoritative building area data, and this can provide accurate data support for the government and the policy making part to promote the building energy saving.

2 Existing problems for the floor space in China Statistical Yearbook

(1) Substantial changes occurred in the statistical caliber for the total floor space of urban buildings (year-end)

The urban floor space data is mainly from two statistical indicators (i.e., the total floor space of buildings (year-end) and the total floor space of residential buildings (year-end)) in “China Statistical Yearbook”. The time series data of these two indicators are valid during the time period 1995-2006. After 2006, these two indicators were deleted in the statistical yearbook. The total floor space of buildings (year-end) and the total floor space of residential buildings (year-end) changed suddenly from 2000-2001.

(2) Great discrepancies exist for the floor space of buildings completed from different data
sources

There are three statistical channels for the floor space of buildings completed in the statistical yearbook, which are derived from the "Statistical and reporting system for fixed assets investment", "the statistical and reporting system for the construction industry" and the "statistical and reporting system for the real estate". There are differences between these three channels and the caliber. In theory, the counting system based on the owner perspective is the most comprehensive statistical system, analysis and calculation of floor space should be based on the "floor space of buildings completed in the whole country". However, due to the statistical caliber have changed several times in the fixed asset investment statistical system during 2001-2014, the data in different time period is incomparable and not suitable for time series analysis. Therefore, this study uses the floor space of buildings completed in the "statistical and reporting system for construction industry" channel as the data source.

(3) The time series data on most of the statistical indicators are incomplete

In terms of the time series of this study (2001-2014), there existed data loss in varying degrees, except for the floor space of buildings completed by construction enterprises. The data on total floor space of buildings (year-end) in urban areas and total floor space of residential buildings (year-end) in urban areas after 2006 is missing. The data on total floor space of buildings (year-end) (including residential and commercial building) in urban areas after 2006 is missing. The data on per capita floor space of residential building in urban areas in 2001 and from 2013-2014 is missing. The data on per capita floor space of residential building in rural areas from 2013-2014 is missing. So, how to extend the relevant data to the entire time series requires a certain mathematical method for data processing.

(4) The data on the urban commercial floor space is unavailable in the statistical yearbook

Currently, the data about the commercial floor space in the statistical yearbook includes: total floor space of commercial buildings (year-end) in rural areas (from the year 2006), commercial floor space completed by construction enterprises (from the year 2006, quarterly data). There is no direct statistical data for the urban commercial floor space (including city and county). In fact, the difference between total floor space of buildings (year-end) in urban areas and total floor space of residential buildings (year-end) in urban areas includes two categories: commercial floor space and industrial floor space (also called productive buildings floor space). So, how to divide the urban commercial floor space and industrial floor space is the key issue we will address in this study.

(5) Large differences exist between two statistical calibers for urban residential floor space

In theory, these two statistical indicators should meet the following quantitative relationship: total floor space of residential buildings (year-end) in urban areas = urban population * per capita floor space of residential building in urban areas. However, there is a large difference between the total floor space of residential buildings (year-end) and the residential floor space derived according to the per capita floor space of residential building. The latter is 4 billion square meters higher than the former, 40% -50% higher than the former.

2. Methodology

2.1 Calculation method for rural residential floor space

As discussed in above section, the rural households survey is not related to the collective households and rental households and the per capita floor space of residential building in rural areas derived through this survey can objectively reflect the situation of the total building in rural areas.
Therefore, the rural residential floor space can be calculated according to the rural population and per capita floor space of residential building. The calculation formula is shown as follows:

$$S_{RUR}^{RB} = P_{RUR} \times A_{RUR} $$  \hspace{1cm} (1)

Where, $S_{RUR}^{RB}$ represents rural residential floor space, $P_{RUR}$ denotes the rural population and $A_{RUR}$ represents the per capita floor space of residential building in rural areas.

2.2 Calculation method for urban residential floor space

The data on the urban residential floor space from 2001-2006 will directly take the total floor space of residential buildings (year-end) in urban areas in the statistical yearbook, and the data for 2007-2014 will be fitted using multiple regression model. The procedure is as follows:

The floor space balance formula

$$S_t^B = S_{t-1}^B + C_t^B - D_t^B + \varepsilon $$  \hspace{1cm} (2)

Where $S_t^B$ represents total floor space of buildings (year-end) in $t$ year, $S_{t-1}^B$ represents total floor space of buildings (year-end) in $t-1$ year, $C_t^B$ denotes the floor space of buildings completed in $t$ year, $D_t^B$ represents the floor space of buildings demolished, $\varepsilon$ represents the adjustment change amount of the administrative division.

The data of the floor space of buildings completed in formula (2) can be obtained from the quarterly data on the statistical and reporting system of the construction industry, whereas the amount of the demolished buildings and the adjustment change amount of the administrative division cannot be derived. Considering the data availability, the floor space of buildings completed is taken as the main driving variable. We define the total floor space of residential buildings (year-end) $y$ is the function of the cumulated floor space of residential buildings completed $x$:

$$y = f(x) $$  \hspace{1cm} (3)

The total floor space of residential buildings (year-end) in urban area from 2007-2014 can be simulated with multiple regression model based on the data from 2001-2006.

2.1 Calculation method for commercial floor space

In view of China’s energy statistical system counted by sector, the tertiary industry energy consumption constitutes the major component of the commercial building energy consumption, not distinguishing urban and rural areas. Therefore, commercial buildings should also be calculated according to full caliber, including urban commercial buildings and rural commercial buildings, namely:

$$S_{CB} = S_{CB}^{URB} + S_{CB}^{RUR} $$  \hspace{1cm} (4)

$S_{CB}$ represents commercial floor space. $S_{CB}^{URB}$ denotes the urban commercial floor space. $S_{CB}^{RUR}$ denotes the rural commercial floor space. In line with the statistical caliber for the urban and rural construction, the urban areas contain cities and counties and the rural areas contains township completed area and villages.

(1) Rural commercial floor space

In the statistical yearbook, the time series of urban commercial floor space data is from 2006 to 2015. The changes of the rural commercial floor space is very small, basically within the 22-25 million square meters and showing a slow growth trend. The processing method for the data during 2001 to 2005 is to eliminate the outliers in 2008 and to linearly fit the time series data from 2006 to 2015, and then to extrapolate the data from 2001-2005.

(2) Urban commercial floor space

The procedure for simulating the urban commercial floor space can be divided into two steps:

Step 1: Identify the commercial floor space data from 2001-2006. The sum of the
industrial floor space and the commercial floor space can be obtained directly from the statistical yearbook, and the calculation formula is as follows:

$$S^{CB}_{URB} + S^{IB}_{URB} = S^B - S^{RB}$$  \hspace{1cm} (5)

Where $S^{CB}_{URB}$ represents the urban commercial floor space, $S^{IB}_{URB}$ represents the industrial floor space, $S^B$ denotes the total floor space of buildings (year-end) and $S^{RB}$ represents the total floor space of residential buildings (year-end). Therefore, we just need to identify the ratio of urban commercial floor space and the industrial floor space and the commercial floor space from 2001-2006 can be derived. Actually, there exists a relationship between this ratio and the proportion of area of land used for urban commercial construction and area of land used for industrial construction:

$$\frac{S^{CB}_{URB}}{S^{IB}_{URB}} = \frac{K^{CB}_{URB} L^{CB}_{URB}}{K^{IB}_{URB} L^{IB}_{URB}} = \frac{K^{CB}_{URB}}{K^{IB}_{URB}} \times \frac{L^{CB}_{URB}}{L^{IB}_{URB}}$$  \hspace{1cm} (6)

Where $S^{CB}_{URB}$ represents the urban commercial floor space, $S^{IB}_{URB}$ represents the industrial floor space. $L^{CB}_{URB}$ represents area of land used for urban commercial construction. $L^{IB}_{URB}$ represents area of land used for urban industrial construction. $K^{CB}_{URB}$ represents the average floor-area ratio of the urban commercial building. $K^{IB}_{URB}$ represents the average floor-area ratio of the urban industrial building. we conduct simulation on $S^{CB}_{URB}/S^{IB}_{URB}$ to make $K^{CB}_{URB}/K^{IB}_{URB}$ change the smallest during 2001-2006. And then the commercial floor space from 2001-2006 can be derived.

**Step 2: Calculate the commercial floor space data from 2007-2014.** To obtain the commercial floor space data from 2007-2014, the same method to calculate the urban residential floor space—multiple regression model—can also be adopted in this step. The accumulated value of urban commercial floor space completed can be taken as the driving variable and the multiple regression model can be used to obtain the total floor space of urban commercial buildings (year-end)

### 3. Measurement of the floor space in China based on CFSCM

According to the formula (1)~(6), the commercial floor space, urban residential floor space and rural residential floor space can be derived, which are shown in Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Total floor space</th>
<th>Commercial floor space</th>
<th>Urban residential floor space</th>
<th>Rural residential floor space</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>317.11</td>
<td>46.59</td>
<td>66.52</td>
<td>204.00</td>
</tr>
<tr>
<td>2002</td>
<td>339.33</td>
<td>50.48</td>
<td>81.85</td>
<td>207.00</td>
</tr>
<tr>
<td>2003</td>
<td>349.9</td>
<td>51.79</td>
<td>89.11</td>
<td>209.00</td>
</tr>
<tr>
<td>2004</td>
<td>359.81</td>
<td>52.65</td>
<td>96.16</td>
<td>211.00</td>
</tr>
<tr>
<td>2005</td>
<td>383.84</td>
<td>55.15</td>
<td>107.69</td>
<td>221.00</td>
</tr>
<tr>
<td>2006</td>
<td>395.35</td>
<td>58.46</td>
<td>112.89</td>
<td>224.00</td>
</tr>
<tr>
<td>2007</td>
<td>411.86</td>
<td>60.92</td>
<td>124.94</td>
<td>226.00</td>
</tr>
<tr>
<td>2008</td>
<td>434.81</td>
<td>69.74</td>
<td>137.07</td>
<td>228.00</td>
</tr>
<tr>
<td>2009</td>
<td>452.78</td>
<td>70.8</td>
<td>150.98</td>
<td>231.00</td>
</tr>
<tr>
<td>2010</td>
<td>471.08</td>
<td>75.1</td>
<td>166.98</td>
<td>229.00</td>
</tr>
<tr>
<td>2011</td>
<td>504.22</td>
<td>80.45</td>
<td>185.77</td>
<td>238.00</td>
</tr>
<tr>
<td>2012</td>
<td>532.54</td>
<td>86.79</td>
<td>207.75</td>
<td>238.00</td>
</tr>
<tr>
<td>2013</td>
<td>568.35</td>
<td>94.31</td>
<td>233.04</td>
<td>241.00</td>
</tr>
<tr>
<td>2014</td>
<td>605.5</td>
<td>100.81</td>
<td>259.69</td>
<td>245.00</td>
</tr>
</tbody>
</table>
From the Table 1 we can see, the total floor space in China saw an upward trend from 31.711 billion m² to 60.55 billion m², increasing about two times from 2001 to 2014. The rural residential floor space didn’t experience a dramatic increase, and it just increased from 20.4 billion m² to 24.5 billion m² throughout the whole period. The urban residential floor space saw a significant increase, increasing more than four times from 6.652 billion m² to 25.969 billion m², which indicated the rapid urbanization in China recent years. During 2001 to 2014, the commercial floor space increased more twice from 4.659 billion m² to 10.081 billion m² during the research period.

4. Analysis on the building energy intensity

(1) Analysis on the energy consumption per unit commercial floor space

In line with Table 1, the characteristic for energy intensity of the commercial building can be shown in Fig 1.

![Fig 1. The characteristic for energy intensity of the commercial buildings](image)

From Fig.1 we can see, the energy consumption per unit area of commercial buildings can be divided into three distinct stages. During the “10th Five-Year Plan” period (2001-2005), the energy consumption per unit area of commercial buildings increased year by year, from 17.93 kgce/m² to 23.32 kgce/m², an average annual growth of 6.8%. During "11th Five-Year plan" period (2006-2010), the total energy consumption per unit of commercial buildings remained relatively stable and saw some small fluctuations with fluctuations in economic growth, and fell into the trough in 2008. Since "12th Five-Year plan" period (2011-2015), the energy consumption per unit area of commercial buildings has been declining year by year, from 23.18 kgce/m² in 2011 to 20.18 kgce/m² in 2014, and the energy consumption per square meter has decreased by 2.35 kgce.

(2) Analysis on the energy intensity of the urban residential building

According to Table 1 and the building energy consumption data in Huo et al., (2017)[2], the energy intensity of the urban residential building consumption can be shown in Fig 2.
Fig. 2 The energy intensity of the urban residential building consumption

As shown in Fig. 2, energy consumption per unit area of urban residential buildings shows a decreasing trend in general, and the downward trend is more obvious after 2007. In 2014, the energy consumption per unit area of urban residential buildings was 8.62kgce / m², decreasing by 3.862kgce / m² compared with that in 2007, and the average annual decline rate was 5.2%. From 2002 to 2007, the electric power consumption per unit area of urban residential buildings increased annually. This trend changed in 2007, and the electricity consumption per unit area of urban residential buildings decreased obviously after 2007. It decreased by 20% from 2007 to 2014, with an annual decline rate 3.2%.

(3) Analysis on the energy intensity of the rural residential buildings

According to Table 1 and the building energy consumption data in Huo et al., (2017), the energy intensity of the urban residential building consumption can be shown in Fig 3.

Fig 3. The energy intensity of the urban residential building consumption

As shown in Fig 3, the energy consumption of rural residential buildings increased annually
from 2001 to 2014. Energy consumption per unit area increased from 2.82kgce / m2 in 2001 to 5.17kgce / m2 in 2014, an increase of 1.8 times and an average annual growth of 4.8%. The unit area electricity consumption grew faster from 3kWh / m2 in 2001 to 13.23kgce / m2 in 2014, an increasing 4.4 times and the average annual growth of 12%.

5. Conclusion

This study proposed a set of calculation method for China floor space by sectors (i.e., commercial floor space, urban residential floor space and rural residential floor space etc.) during 2001 to 2014, and then the energy intensity trends are analyzed. The results indicate that the rural residential floor space increased from 20.4 billion m2 to 24.5 billion m2 during 2001-2014. The urban residential floor space saw a significant increase, increasing more than four times from 6.652 billion m2 to 25.969 billion m2, and the commercial floor space increased more twice from 4.659 billion m2 to 10.081 billion m2. During the “10th FYP” period, the energy consumption per unit area of commercial buildings increased from 17.93 kgce / m2 to 23.32kgce / m2, and the figure remained relatively stable and saw some small fluctuations during “11th FYP”, and declined from 23.18kgce / m2 to 20.18kgce / m2 during “12th FYP”. The energy consumption per unit area of urban residential buildings decreased to 8.62kgce / m2, in 2007, while the energy consumption per unit area increased from 2.82kgce / m2 in 2001 to 5.17kgce / m2 in 2014.

This is one of our series of studies following up the measurement of the energy consumption in the building sector [3]. And our next study is to measure China’s building stocks, demolished buildings and newly-built buildings by type and vintage (construction periods).

Reference

Life-cycle costing as a tool for selecting optimum solutions for insulated floors in Australia

Illankoon, I.M.Chethana S.1, Tam, Vivian W.Y.2* and Le, Khoa N.3

Abstract: Material selection is one of the significant tasks in building construction. In this process cost is one of the vital components considered. However, apart from the initial cost, many other costs occur within the life-cycle of the building that is ignored in the initial decision making stage. Therefore, the life-cycle costing approach must be considered to make informed decisions from the beginning. This research focused on using life cycle costing as a technique to identify optimum solutions for insulated floors commonly used in six central business districts (CBD) in Australia. Various insulation material was considered to arrive at the required R-values measured in m²K/W. Net present value technique (NPV) was used to arrive at the life-cycle cost of floor solutions. Suspended slab with vapour permeable membrane floor solution has the lowest life-cycle solution, and it also satisfied the required R-Value. Costs other than the initial cost vary from 35% to 59% of the life-cycle cost in floor structures. This significant percentage illustrates the importance of using life-cycle cost for evaluating various options focusing on all the associated costs.

Key words: Floors, insulation, life-cycle cost, R-value

1 Illankoon, I.M.Chethana S.
School of Computing Engineering and Mathematics, Western Sydney University, Australia

2 *Tam, Vivian W.Y.
Corresponding author, School of Computing Engineering and Mathematics, Western Sydney University, Australia and College of Civil Engineering, Shenzhen University, China.
E-mail: vivianwytam@gmail.com

3 Le, Khoa L
School of Computing Engineering and Mathematics, Western Sydney University, Australia
1.0 Introduction

Cost is one of the significant factors considered for the selecting materials in building construction. According to Flanagan [1], life-cycle costing technique can assist in the selection of the best or the most economical solution from a range of options available in the construction industry. However, despite its importance, life-cycle costing is rarely used in the construction industry in material selection. The unavailability of reliable cost and time-related data and inconsistency in the underlying methodologies for life-cycle cost analysis have become major constraints on the implementation of life-cycle cost in the construction industry [2].

There are many definitions put forward by many researchers on life-cycle costing. It is a tool for assessing the total cost performance of an asset over time, including the acquisition, operating, maintenance, and disposal costs [3]. Similarly, Australian National Audit Office [4] identified that the process of life-cycle costing involves assessing costs arising from an asset over its life-cycle and evaluating alternatives that have an impact on this cost of ownership. According to Australian National Audit Office [4], there are five main phases triggering different types of costs that are design, purchase and construction, operation costs, maintenance costs, development costs and disposal costs. Therefore, it is necessary to consider all the costs arising from the different phases of the life-cycle when calculating the life-cycle costing.

Green buildings have become one of the main concerns of the construction industry due to pressing environmental issues and climate change. There are various criteria undertaken to improve the environmental performance of green buildings. A sound thermal insulation is a crucial step to reduce energy use of buildings [5]. The insulation of the building has a vital influence on the heating system [6]. Further, the external skin of the building such as walls, floors and roofs play a major role in the overall heat losses in the winter and heat gains in the summertime. According to Boafo, et al. [7], the performance of building envelope determines the ultimate energy efficiency throughout the life-cycle of a building; it is, therefore, necessary to use insulation for these building components. Therefore there are many research studies carried out focusing on building insulation focusing many aspects.

In the literature, there are various studies carried out focusing on selecting the optimum insulation material considering the thickness and material properties [6, 8-13]. However, in any of these research studies, the life-cycle cost of the insulation material was not considered. Unfortunately, there is a clear lack of studies on life-cycle cost analysis focusing on the insulation material used to obtain the necessary thermal resistance for buildings. Therefore this research intends to develop optimum solutions for floor structures in Australia using life-cycle cost analysis.

1.1 Types of floors commonly used in Australia

Green Building Council Australia (2015), identified the significance of the thermal insulation in energy efficiency and allocated up to five credits out of 20 for thermal insulation for energy efficiency in green buildings (Green Building Council Australia, 2015). Further, in green buildings, it is required to increase the minimum required R-value by 15% for floor insulation compared to the national standards in Australia. According to the building code of Australia, it is necessary for the buildings to achieve the minimum R-value for floors for each climate zone [14].

There is a wide variety of insulation material to obtain the required R-value for floor structures. Considering these requirements for insulation, Insulation Council of Australia and New Zealand [15] recognised three types of floor structures. Table 1 reports the types of floor structures commonly used in Australia and used in this research. According to Table 1, floor insulation used various materials such as taut vapour permeable sarking, single sided foil, double sided anti-glare foil, double sided bubble/foam and double sided antiglare expanded polystyrene (EPS) board. All these insulation material are aligned according to the standards given by the Insulation Council of Australia and New Zealand [15] to obtain the required R-values.
The total R-value of the floor is the summation of all the R-values of materials forming the floor. As an example, considering suspended timber floor (type F0100), the total R-value measured in $m^2K/W$, would be the summation of R-Values of the interior air film, timber floorboards, bulk insulation, sarking material, subfloor air film and ground thermal resistance. There are many insulation materials available to use which giving various flooring solutions with required R-values. Further, the R-Value of these insulation materials depends on the thickness of the material layer [16, 17]. This research considered all these various options in thickness of different material and calculated the life-cycle cost separately for each variant of floor structures.

2.0 Research methodologies

This research focuses on the calculation of life-cycle cost for different types floor structures with required insulation to identify the optimum solutions. Therefore, initially, life-cycle cost is calculated. All the costs incurred within the life-cycle must be captured and discounted into present day values to calculate the life-cycle cost. Therefore, this research used net present value (NPV) technique to calculate the life-cycle cost. The formula for NPV calculation is given in equation 1.

$$NPV(i,N) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$  \hspace{1cm} \text{Equation 1: NPV calculation}

Adapted from Dell'Isola and Kirk [9]

In Equation 1, $i$ denotes the discount rate; $t$ denotes the time of cash flow; $R_t$ denotes the net cash flow, and $N$ is the total number of periods. The discount rate is established considering the time value of money and the associated risk. The minimum attractive rate of return is commonly used as the discounting rate [9]. The rate of interest on a 25-year Treasury bond in Australia is 3.25% per annum [18]. Further, the return of assets for a non-residential construction firm is around 3.30% in Australia [19]. Therefore, considering these rates, the discounting rate is taken as 3.25% for this calculation. The period for the calculation is 60 years.

The life-cycle cost of floors includes the initial cost of construction, maintenance cost, demolition cost of the structure and reuse of material if applicable. Therefore, life-cycle cost calculation considered all these types of cost components. The material costs are collected from the main six central business districts of Australia, namely: Adelaide, Brisbane, Hobart, Melbourne, Perth and Sydney. All the prices are excluding Goods and Services Tax (GST) and profit. Further, Rawlinson cost database is used for initial cost calculations [20]. Current market prices are used for the costs developed based on the first principles. The initial cost included floor frame including timber frame or the concrete slab and insulation material.

Each of the floor structures has different maintenance requirements depending on the material used. Floor structures required general inspection and minor repairs. Usually, these different floor options require proactive maintenance to prevent costly repairs and full replacement. Further, the NPV calculation considered the replacement of material as well. The maintenance schedule is developed based on the detailed analysis provided by Dell’Isola and Kirk [9] and Stanford [21]. Table 2 illustrates the details of the required maintenance.

---

**Table 1: Types of external wall and floor structures**

Adapted from Insulation Council of Australia and New Zealand [15]

<table>
<thead>
<tr>
<th>Code</th>
<th>Type of external wall</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0100</td>
<td>Suspended timber floor</td>
<td>Timber floor consisting of standard 19 mm tongue and groove hardwood flooring fixed directly over 90mm floor joist. With no membrane in the flooring system, there is no air gap formed.</td>
</tr>
<tr>
<td>F0200</td>
<td>Suspended concrete slab</td>
<td>Concrete suspended floor, 150mm thick with no covering and a subfloor of 0.5m in depth.</td>
</tr>
<tr>
<td>F0300</td>
<td>Suspended autoclaved aerated concrete floor panels</td>
<td>Aerated Autoclaved Concrete floor consisting of 75mm re-in forced panel flooring fixed directly over 90mm floor joist with no floor covering</td>
</tr>
</tbody>
</table>
Table 2: Maintenance schedule for external walls and floor
Developed from Dell’Isola and Kirk [9] and Stanford [21]

<table>
<thead>
<tr>
<th>Type of external wall and floor</th>
<th>Type of maintenance</th>
<th>Maintenance interval</th>
<th>Time for maintenance (hr/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0100</td>
<td>General inspection and minor repair</td>
<td>every 5 years</td>
<td>0.18</td>
</tr>
<tr>
<td>F0200</td>
<td>General inspection and minor repair</td>
<td>every 10 years</td>
<td>0.36</td>
</tr>
<tr>
<td>F0300</td>
<td>For frame - General inspection and minor repair</td>
<td>every 10 years</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>For panels - General inspection and minor repair</td>
<td>every 5 years</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Maintenance and general inspections are labour intensive. Therefore, this research adopted a productivity-adjusted nominal growth of labour rate of 2.4% for all the CBDs and 2.5% for Adelaide [22].

This research considered disposing floor structures at the end of the life-cycle. The re-usable material included an additional cost for the extra care required for demolition. Further, the life-cycle cost calculation included the cost of preparing timber framing for reuse. The debris is assumed to be transported 15 km away from the site. Disposal of these items incurs at the end of the life-cycle. The life-cycle cost calculations included all these related costs which are the sum of all the categories of cost in present value.

The NPV calculation includes certain parameters such as discounting rates. Further, the life-cycle cost calculation significantly depends on the discounting rate considered. Therefore, this research conducted a sensitivity analysis to calculate the impact of these parameters towards the final life-cycle cost calculation.

3.0 Analysis on life-cycle cost for insulated wall and floor structures

Life-cycle cost is calculated for each of the floor structures in the main six CBDs in Australia. However, there are different lowest life-cycle options for different main CBDs due to the price changes. Therefore, Table 3 reports the lowest life-cycle options with required R-values for each floor type in the main six CBDs.

According to Table 3, all the floor types have similar life-cycle cost amount except suspended concrete slabs (type F0200), which has slightly lower life-cycle cost compared to other floor structures (refer Table 3). For suspended timber floors (type F0200), R1.5 EPS boards (60 mm) has the lowest life-cycle cost in many CBDs except in Hobart and Sydney. In Hobart and Sydney, floor boards R2.0 (90mm) has the lowest life cycle cost. Therefore, for suspended timber floors (type F0200), R1.5 EPS boards (60 mm) and floor boards R2.0 (90mm) is an economical solution for board insulation considering the life-cycle cost. Similarly, taut vapour permeable membrane and the double sided anti-glare foil is suitable as sarking material.

In Suspended concrete slabs (type F0200), R1.4 boards are commonly used for board insulation in the lowest life-cycle solution. Floor batts R2.0 (90 mm) is the life-cycle cost effective solution for autoclaved aerated concrete floors (type F0300). Different floor structures require different board or blanket insulation to arrive at the required R-values. However, for the optimum solutions with required R-values, and the lowest life cycle cost has various solutions for board insulation and sarking. Based on the calculations (refer Table 3), suspended concrete slab floor (type F0200) with R1.4boards and vapour permeable membrane is the lowest life-cycle option with a life-cycle cost of AUD 344.05 per square metre in Sydney.
Table 3: Life-cycle cost for various floor structures in six main CBDs in Australia

<table>
<thead>
<tr>
<th>Floor type</th>
<th>Adelaide Description</th>
<th>Life-cycle cost (AUD/m²)</th>
<th>Brisbane Description</th>
<th>Life-cycle cost (AUD/m²)</th>
<th>Hobart Description</th>
<th>Life-cycle cost (AUD/m²)</th>
<th>Melbourne Description</th>
<th>Life-cycle cost (AUD/m²)</th>
<th>Perth Description</th>
<th>Life-cycle cost (AUD/m²)</th>
<th>Sydney Description</th>
<th>Life-cycle cost (AUD/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0100</td>
<td>Suspended timber floor with R1.5 EPS board and double sided anti-glare EPS board</td>
<td>419.61</td>
<td>Suspended timber floor with R1.5 EPS board and double sided anti-glare EPS board</td>
<td>361.23</td>
<td>Suspended timber floor with floor batts R2.0 and taut vapour permeable sarking</td>
<td>335.22</td>
<td>Suspended timber floor with R1.5 EPS board and double sided anti-glare EPS board</td>
<td>329.91</td>
<td>Suspended timber floor with floor batts R2.0 and taut vapour permeable sarking</td>
<td>378.47</td>
<td>Suspended timber floor with floor batts R2.0 and taut vapour permeable sarking</td>
<td>450.89</td>
</tr>
<tr>
<td>F0300</td>
<td>Autoclaved aerated concrete floor panel with floor batts R2.0</td>
<td>445.35</td>
<td>Autoclaved aerated concrete floor panel with floor batts R2.0</td>
<td>455.73</td>
<td>Autoclaved aerated concrete floor panel with floor batts R2.0</td>
<td>450.35</td>
<td>Autoclaved aerated concrete floor panel with floor batts R2.0</td>
<td>433.98</td>
<td>Autoclaved aerated concrete floor panel with floor batts R2.0</td>
<td>478.13</td>
<td>Autoclaved aerated concrete floor panel with floor batts R2.0</td>
<td>413.10</td>
</tr>
</tbody>
</table>
In green building insulation, the floor insulation should be higher than the required minimum standards in each of the climate zone. Each main state of Australia has different climatic zones. Therefore, to obtain Green Star points, floor structures should have an R-value of 1.2 in climate zone 1, 2, 5 and 6, R-value 1.7 in climate zone 7 and R-value 2.9 in climate zone 8 [15]. The lowest life-cycle options in Table 3 only comply with the climatic zone in the CBD. Therefore, it is essential to identify the optimum solutions for floor structures for each climate zone. Table 4 illustrates the optimum solutions for floor structures for each climate zone.

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>Required R-value for Green Star (m²K/W)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0100</td>
<td>Suspended timber floor with floor batts R2.0 and taut vapour permeable sarking R-value – 3.1 Life-cycle cost (AUD/m²) - 450.89</td>
<td>Nil</td>
<td>1.2</td>
<td>1.7</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F0200</td>
<td>Suspended concrete slab with R1.4 board and vapour permeable membrane R-value – 2.5 Life-cycle (AUD/m²) -344.05</td>
<td>Nil</td>
<td>1.2</td>
<td>1.7</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F0300</td>
<td>Autoclaved aerated concrete floor panel with floor batts R2.0 R-value – 3.5 Life-cycle (AUD/m²) -413.10</td>
<td>Nil</td>
<td>1.2</td>
<td>1.7</td>
<td>2.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The majority of the floor structures could satisfy the Green Star requirements of minimum R-values. In floor structures such as suspended timber floor (type F0100) and autoclaved aerated concrete (type F0300), the lowest life-cycle cost option itself fulfils the required minimum R-Value for Green Star. Therefore, the optimum solution for suspended timber floors (type F0100) and autoclaved aerated concrete floors (type F0300) is the lowest life-cycle cost options available.

Life-cycle cost included different components of costs such as initial cost, maintenance cost, replacement cost and demolition cost. Certain external wall and floor solutions have a lower initial cost with higher maintenance costs, which can only be captured through a life-cycle cost analysis. Therefore, this research calculated the contribution of each of these types of cost to the life-cycle cost. Table 5 illustrates the different proportions of costs in floor structures.

<table>
<thead>
<tr>
<th>Floor type</th>
<th>Initial cost as a % of life-cycle cost</th>
<th>Maintenance cost as a % of life-cycle cost</th>
<th>Demolition cost as a % of life-cycle cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0100</td>
<td>41%</td>
<td>54%</td>
<td>5%</td>
</tr>
<tr>
<td>F0200</td>
<td>65%</td>
<td>22%</td>
<td>13%</td>
</tr>
<tr>
<td>F0300</td>
<td>51%</td>
<td>44%</td>
<td>5%</td>
</tr>
</tbody>
</table>
Table 5 included the replacement cost (if any available), in the maintenance cost when calculating the percentage of contribution to the life-cycle cost. The life-cycle costs other than initial cost vary from 35% to 59% of the life-cycle cost in floors. Suspended concrete floors (type 0200) have the highest initial cost proportion and the lowest maintenance and demolition cost. Timber floor (type F0100) has the highest maintenance cost proportion compared with other two floor types.

According to Table 5, suspended timber floor (type F0100), required 54% of the life-cycle cost for maintenance which is higher than the initial cost proportion. The main reason for this is the higher replacements costs needed for the timber flooring. The demolition cost for the suspended concrete slab (type F0200), is comparatively higher than other floor types. The reason is the difficulty in the demolition of concrete slab compared to stripping off timber flooring or floor panels. Costs incurred throughout the life-cycle will not be considered if the initial cost is considered for selecting the optimum solutions.

3.1 Sensitivity analysis to the changes in discounting rate

Discounting rate is one of the vital parameters in this research. The life-cycle cost significantly depends on these parameters. Therefore, it is necessary to identify to the extent of the changes in discount rate affect the final life-cycle cost of this research. As a result, a sensitivity analysis is conducted changing the discount rate. Figure 1 illustrates the results.

![Figure 1: Changes to the life-cycle cost to the changes in discounting rate](image)

According to Figure 1, the discounting rate is initially reduced up to 3%. Afterwards, the changes to the life-cycle cost are calculated by increasing the discount rate by 1%. The curve representing the sensitivity of life-cycle cost to the changes in discounting rate is concave to the origin (refer Figure 1). However, it represents that higher reduction in discounting rate has a significant increment in the life-cycle cost. Further, changes in discounting rate have a major impact on the life-cycle cost and floors. The life-cycle cost of external walls increases up to AUD/m² 404.27 from AUD/m² 344.05 when the discounting rate reduced by 1%.

4.0 Conclusions

This paper used life-cycle cost as a technique to identify optimum solutions for insulated floor structures in Australia. However, in construction, most of the selections are made based on the initial cost. Therefore, this research identified the optimum solutions for floor structures in Australia considering the life-cycle costing approach.

Initially, this research identified three types of floor structures. For these different types floor structures, the various insulation materials are considered to obtain the required R-value. The life-cycle cost is calculated using the NPV techniques. Life-cycle cost calculation considered all the life-cycle cost
including initial cost, maintenance cost, replacement cost and disposal cost. Afterw:

days, this research presented the optimum solutions considering the required R-value and life-cycle costs for floor structures selected from a large number of solutions.

The majority of the floor structures could obtain the minimum R-values required. Further, suspended slab (type F0200) with vapour permeable membrane floor solution has the lowest life-cycle solution, and it also satisfies the required R-Value. Floor batts R2.5 (90 mm) and R1.5 EPS boards are selected as the optimum solutions for floor insulation providing required R-value and the lowest life cycle cost.

Costs other than the initial cost vary from 35% to 59% of the life-cycle cost in floors. It is necessary to note that these costs are considered only in life-cycle cost calculations. This signifies the importance of using life-cycle cost for evaluating various options focusing on all the associated costs. According to the analysis, around half of the life-cycle cost is due to maintenance, replacement and disposal cost. Maintenance cost is vital in the life-cycle cost calculation.

Discounting rates have a significant impact towards the life-cycle cost of floor structures. The sensitivity analysis illustrates that the life-cycle cost significantly increases to a decrease in discounting rate. However, the changes in discounting rate have a significant impact on the life-cycle cost. This research provides valuable information on the life-cycle costs for each climatic zone in Australia, which can be used in initial decision making process of green buildings.

The major significance of this research is that it focuses on the commonly used floor structures and identifies optimum life-cycle cost solution with required R-values across the six main CBDs in Australia to obtain Green Star credit points. Further, this research signifies the importance of using life-cycle cost analysis for selecting optimum solutions in construction.

5.0 Acknowledgements

The authors wish to acknowledge the financial support from the Australian Research Council (ARC), Australian Government (No: DP150101015).

6.0 References


Understanding Behavioral Diversity of Onsite Employees in International Projects, Integrated Simulation Approach

Wu, C.K. ¹*, Xu, B. ² Shou, W.C. ³ and Wang, X.Y. ⁴

Abstract: It is common to recruit multinational and multicultural labors in international projects. Diversity of labors not only exert influences on their behaviors but also on project performances, which however is hard to monitor and control given the dynamic and complex nature of onsite production. This paper combines System Dynamics and Agent Based Model to propose a hybrid simulation approach to gain better understanding of behavior diversity, reveals its associated impacts and finally improves project management level. The paper first establishes the framework of the approach based on solid background knowledge review. Then, methods to quantify the framework is introduced. Finally, the proposed framework is applied in a real case study, aiming to explain the existing deviations and test its validity. It turns out that inadequate consideration of labor diversity will result in overestimation of labor production, which in turn leads to severe schedule overrun. Therefore management teams of international projects should bring labor diversity issue to the forefront and incorporate it into the development of construction plans.

Keywords: Labor Management, Behavior Diversity, International Project, Computer Simulation.

¹* Wu, C.K.
Corresponding author, Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: 404835780@qq.com

² Xu, B.
Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: xubo@cqu.edu.cn

³ Shou, W.C.
School of Built Environment, Department of Humanity, Curtin University, Australia
E-mail: Wenchi.shou@postgrad.curtin.edu.au

⁴ Wang, X.Y.
School of Built Environment, Department of Humanity, Curtin University, Australia
E-mail: Xiangyu.Wang@curtin.edu.au
1 Introduction

International construction projects usually involve multinational and multicultural practitioners thus are abbreviated as MPPs below. Project management teams (PMTs) of MPPs must adequately consider multinational co-ordination, foreign labor management, policy compliances and cultural issues. Among the concerns, labor is one of the top concerns[1]. Labor management in MPPs are more complex because usually multinational labors (MLs) from various cultural backgrounds are employed. Diversities such as motivation, working habits and skill level commonly exist. Such differences are likely result in large discrepancies of attitudes and behaviors which can negatively influence a project[2]. Besides, labor diversities may be magnified by external factors like weather and holiday. However, the fast development of information technologies (ITs) in construction sector provides new opportunities to improve labor and onsite management[3-5]. Thus, this paper proposes an integrated simulation approach to address the current challenges.

2 Background Knowledge

Recognizing the importance of human issues, many studies are conducted to discover factors that affect attitudes and behaviors of MLs. However, most previous researches focus on statistical analysis, which lack comprehensive consideration of individual properties hence is difficult to handle onsite labor behaviors. Consequently, only theoretical suggestions are provided and PMTs still do not have a practical tool to manage MLs. Besides, project management largely depends on the interactions between onsite employees (OEs) (i.e. labor and engineers)[6]. Such interactions are also inadequately addressed. Hence, there is an emergent need of a novel method to cope with the dynamic and complex nature of OEs. Fortunately, simulation techniques could address the problems, which are useful when the objects under study: 1) are highly dynamic; 2) contain large uncertainty; and 3) heavily depend on interactions of system components to generate outcomes. By now, system Dynamics (SD) and Agent Based Modelling (ABM) have been extensively adopted[7]. SD provides a rigorous way for description of complex systems at macro level, considering all influencing factors. In construction sector, SD is used to form feedback loops among project metrics such as quantity, duration and costs[8]. In contrast, ABM is built by intelligent agents that can sense the environment, dynamically interact and autonomously make decisions. Microscopic agent interactions determine macroscopic system behaviors. Applications of ABM include supply chain management and emergency planning[9].

Nevertheless, few study applies simulation approaches in MPPs, let alone MLs management. The paper thus develops an integrated approach, taking strengths of SD and ABM. The approach can improve onsite management by better understanding the behavior diversity of MLs. Four research steps are involved: 1) literatures review; 2) observe OEs and summarize distinct behaviors and interactions; and 3) develop the simulation model; and 4) apply the model in an ongoing MPP.

3 Methodology

In this section, the simulation framework is built and quantified. Fig. 1 demonstrates relationship and essential components of SD and ABM.
Provided the strengths of ABM and SD, ABM is applied at individual level to accommodate labor attributes and behaviors while SD is used at project level to forecast holistic project outcomes.

![Figure 1. Conceptual Framework of the Proposed Simulation Model](image)

For ABM, the core is the state-chart, including: 1) status of agent; 2) transitions between states, along with triggering conditions; and 3) behaviors agents take when they are in, entry and leave a state. MLs are categorized by nationality. In each category, a unique state-chart is created based on personal and cultural properties. Fig. 2 shows conceptual state-charts for local and overseas labors and engineers respectively. It can be observed that the basic structures are similar while detailed states designs and interactions differentiate. For instances, states injury and suspended are only applicable for MLs while “learning period” is additionally required for less skilled labors. There are four interaction types: 1) interactions within construction tasks, such as local labors are guided by skilled ones performing the same task; 2) interactions between tasks, such as interruption; 3) interactions between MLs and engineers, such as the responses to supervision; and 4) interactions with external environment, including management policies, economy conditions and weather. It is in these dynamic mechanisms that MLs behavior diversity is revealed. Detailed introduction of ABM modelling components is beyond the scope of this paper.

![Figure 2. Agent Based Model for local labor (a), overseas labor (b) and engineers (c)](image)

As shown in Fig. 3, SD consists of three modules: production progress (PP), labor productivity (LP) and external factor impacts (EFI). PP module contains three stocks as cumulative indicators of the project: work in progress (WIP), work checked and accepted (WCA), and rework (RW)\(^7\).
The arrows in and out of stocks indicate increase and decrease of the stock value where the change rate is determined by a set of dynamic variables, parameters and the stocks themselves. These elements mutually affect and form feedback loops. “+” or “−” at the end of arrows indicate the loop is reinforcing or balancing\(^{10}\). LP module simulates productivity of each labor category. EFI module evaluates the influences of external factors and determines system inefficiency (SI), which is transferred to LP. In LP, ABM passes productivity frontier (PF), number of labor (NOL) and operational inefficiency (OI). PF is static while NOL and OI are subject to labor behaviors.

![Figure 3. PP module, EFI module and TLP module in System Dynamics model](image)

### 3.2 Model Quantification

Quantification includes data collection, parameters determination and assignment and equation building. Data is collected through: 1) accessing public database and reports; 2) searching project database, looking up drawings and interviewing PMTs; and 3) observing and surveying OEs.

Quantifying SD requires to insert equations between parameters, dynamic variables and stocks. Some equations are easy to formulate. E.g. the relationship between WCA and remaining quantity. Other equations are built by extrapolation or taking use of existing formulas. E.g., schedule pressure is calculated using Eq. 3.1, developed in other well recognized studies\(^7\). The maximum schedule pressure is 2 while the least is 1. If the remaining time is greater than initial plan, the pressure is defined as the ration between the values of the two variables.

$$\text{MIN}(\text{Remaining Time} > \text{Planned Duration}) \? \left(\frac{\text{Remaining Time}}{\text{Planned Duration}}\right):1,2)$$  Eq. 3.1

As for ABM, the key is to create two types of functions: 1) allow labors to make decisions; 2) compute labor production status and communicate the results to SD. E.g., “WorkTime()” of CLs is formed by conditional expressions in Eq. 3.2 so that the labor could decide when go to the site. The equation means if today is the local holiday (the 13th day), the labor will not work until three
days later. If today is Thursday, the labor will come back after weekend (two days). Otherwise, the labor comes to the site at working time tomorrow (i.e. 7 am).

\[
\text{Date} = 13\? (7,0)+\text{DAY}, 3\? ; \text{Today} = \text{THU}\? (7,0)+\text{DAY}, 2\? ; (7,0)+\text{DAY}, 1 \quad \text{Eq. 3.2}
\]

The second type of function is illustrated in Eq. 3.3, which presents the process of computing OI:

\[
OI_i = NP \times EP \times OP \times LP \quad \text{Eq. 3.3}
\]

NP, EP, OP, LP is productivity variation when labors conduct non-value adding activities, do extra work, work overtime and are being trained. OE and LE are evaluated by existing regression model[11]. NE and EE are state parameters. Nevertheless, despite the quantification process, the approach remains conceptual and should be applied in practice to match specific conditions.

4 Case Study

4.1 Project Brief and Model Materialization

The project was in Africa, managed by an overseas large contractor. Two tasks, rebar binding and scaffolding on the ground floor are simulated by Anylogic 7.3. There were three labor categories: AL, BL and CL. BLs are skilled overseas labors who are able to perform both tasks. ALs perform either of the two trades, who were less productive and feature leisure attitude. CLs had little skills or experiences, who can only undertake rebar binding task. Besides, BLs are assigned to CLs for guidance to guarantee minimum quality. Labor and engineer behaviors are shown in Fig. 4.

![Flowchart](image)

Figure 4. Behavior Patterns of Labors and Decision Making Process of Engineers

4.2 Analyze the Effects of Labor Behavior Diversity
Fig. 5 compares simulated and planned schedules. The model output is 30 days thus serious schedule deviations exist. The model is used to analyze the root causes of deviation in the project. Fig. 6 show the large fluctuation and uncertainty of actual productivity. For ALs, productivity is wasted by chatting and lingering if engineers are absent, causing periodical productivity dropping. For BLs, productivity reduction is mainly due to guiding CLs. For CLs, the productivity depends on the learning process, see Fig. 7. Fig. 6-7 also reflect the effects of raining.

As the project proceeds, more diversities appear. Interruption is reflected by the horizontal lines in Fig. 5. CLs and ALs could not be transferred to other tasks in case of interruption, which triggers labor wastes. In addition, some labors might not come back when the work is resumed, which extends the delay. Fig. 8 sheds lights on the effects of special dates where ALs refuse to work.

Rejected work or mobility are also associated with labor diversity. Fig. 9 distributes compares reject rate in normal and extra work hours. Meanwhile, the number of ALs and CLs who leave are dotted in Fig. 9. It is obvious that most labors choose to leave site during or after interruption.
There are three findings: 1) during extra working, the reject rate increases and largely offsets the additional production. 2) Contribution of CLs is overestimated because they are error prone and less productive, especially when they work along in extra working. 3) Overtime, extra working and interruption are the driving factors of mobility. Labors may leave if interruption and overtime working last too long or extra working is asked too many times. It can be concluded: 1) various diversities exist among MLs, which may lead to large behavior discrepancies; 2) poor consideration on MLs diversity could result in severe estimation errors; 3) labor behaviors are highly dynamic and project dependent; 4) Data platform, such as BIM could be incorporated as an information repository to facilitate model building and modification\cite{12,13}.

5 Conclusion
The paper proposes an integrated simulation approach to improve the understanding of labor behavior diversity in MMPs. Through the case study, the impacts of MLs diversity on labor behaviors and the project are revealed and the reasons of schedule overrun are analyzed. There are two contributions: 1) innovatively integrates simulation approaches into labor management of MMPs; 2) provides a flexible and practical tool for PMTs that could effectively monitor, control and forecast onsite production taking labor diversity into account.

Acknowledgment

The authors wish to extend their gratitude to the KAEFER Integrated Services Pty Ltd for their financial support.

References

An analysis framework of risk interactions in international construction projects: A Bayesian network approach

Yan, P.¹, Liu, J.Y.²*

Abstract: International construction projects involve an increasing number of stakeholders, and these stakeholders tend to apply the partnering strategy for managing enormous risks effectively. However, on one hand, the close connection among stakeholders rise their capacities for risk management, but on the other hand, the close connection also makes risks more interdependent. The objective of this research are to (1) introduce a framework of risk interactions in international construction projects and (2) improve the cost overrun risk assessment with considering casualties among risks. To achieve this objective, a Bayesian network (BN) based method is developed. Moreover, an international building project is provided to demonstrate the performance of model. In addition, a sensitivity analysis is conducted to explore the impact of states of each risk on probabilities of project cost overrun, and some effective risk response strategies are identified based on the analysis results. This framework provides a visual tool for international project management teams to analyze risks’ casual interrelations, and it can help them to prioritize risks and support them to develop proper risk response schemes.

Keywords: International construction projects; Risk analysis; Risk interactions; Bayesian network.

¹ Yan, P.
Department of Construction Management, College of Management and Economics, Tianjin University, China

²* Liu, J.Y.
Department of Construction Management, College of Management and Economics, Tianjin University, China
E-mail: liujunying@tju.edu.cn
1 Introduction

The global construction market will provide contractors with huge opportunities to develop new and different future markets and increase their competitive advantages\textsuperscript{1, 2}. However, international construction projects will involve more uncertainties and risks which result in higher possibility of cost overrun compared with domestic ones\textsuperscript{3, 4}. Hence, an effective project risk management is necessary for contractors to survive and gain profits in overseas markets.

For successful risk management, participants tend to adopt the partnering strategy and cooperate closely with others in international construction projects\textsuperscript{5}. However, on one hand, the increasingly close connection among participants can promote the flow of information, and rise the individual stakeholder’s capacity for risk management, but on the other hand, it also could increase the probability of risk propagations\textsuperscript{6}. Hence, the risks should not be managed independently. The chain effects and interactions among risks need to be considered to better reflect the reality.

The objective of this research are to (1) develop a framework of risk interactions in international construction projects, and (2) improve the cost overrun risk assessment with considering risks’ casual influences in these projects. A Bayesian Network (BN) approach is employed to represent interdependences among various risks. The proposed method is applied using a case from an international building project implemented by a Chinese contractor.

2 Background

2.1 Managing risk in international construction projects

A considerable number of studies have focused on managing risks in international construction projects. Some of them developed a comprehensive risk list and assigned them into different categories. For example, Han and Diekmann\textsuperscript{1} identified 33 international project risks which belong to five categories of political, economic, cultural/legal, tech/construction and other. Wang, et al.\textsuperscript{7} built a key risk list in international construction projects especially those in developing countries and grouped these risks into three levels of country, market and project. Furthermore, some studies payed attention to specific category of risks in international projects. For example, Deng and Low\textsuperscript{8} identified 85 variables that affect political risk levels in international construction projects and provided alternative strategies to response those risks. Han, et al.\textsuperscript{9} investigated on the risk factors that impact the cash flow in overseas projects and classified them into two categories of financial risks and project-specific risks. Ling and Hoang\textsuperscript{10} focused on political, economic, and legal risks encountered by foreign firms when performing construction projects in Vietnam.

Except to the research focused on identifying diverse risk factors in international construction projects, there also have been diverse studies on developing techniques for assessing risks in these projects, and several techniques including influence diagramming\textsuperscript{11} and radial maps\textsuperscript{12} have been proposed.

However, most of existing studies about managing risks in international projects assumed risks are mutually independent and overlooked interactions among them. Recently, some scholars have discussed the importance of analyzing risk interactions in international construction projects and demonstrated causal effects exist among risks\textsuperscript{3, 13}. However, these studies do not attempt to evaluate the risks that in the end of risk interrelation chains, such as the cost overrun. Further research should develop the proper method to model risk interactions and evaluate the likelihood of
cost overrun in international projects.

2.2 Project Risk interactions

Risk interactions have received increasing attention in the domain of project management (PM) research and a variety of methodologies have been proposed to model project risk interactions. Ackermann, et al.\cite{6} applied the causal mapping to develop a modelling process which intends to help managers to understanding of the influence of project risk interactions through explicitly engaging an extensive stakeholder base. Yang and Zou\cite{14} explored relations among risks and built a stakeholder-associated risk network in complex green building projects using the social network analysis (SNA) approach. Nguyen, et al.\cite{15} introduced a Bayesian network (BN) based method to evaluate causal factors leading to the risk of falling from heights in construction projects. Ellinas, et al.\cite{16} built a model to analyze the cascade process of project systemic risk by employing the complex network approach. Using the similar approach, Hwang, et al.\cite{17} proposed a method to assess risk interactions with considering changes in relationships among risks across different project stages.

In addition, there are also some studies concentrating on assessing and measuring the interactions among risks. Fang and Marle\cite{18}, Fang, et al.\cite{19} and Fang, et al.\cite{20} applied the Design Structure Matrix (DSM) approach to measure interrelations among project risks. To simply the analysis process of DSM, the binary interaction strength was used. Zhang\cite{21} proposed an advanced approach to measuring project risk interactions, and the author used a linguistic seven-term scale to represent differences in strengths of risk interactions. Furthermore, Aloini, et al.\cite{22} employed a Delphi approach to assess the strength of interconnections among risks.

The above studies have made important contributions to project risk interactions analysis, but they also have some shortcomings: existing studies mostly overlook to prioritize risks that in the project risk paths network and then choose strategies to response these risks. This research will fill the gap and build a BN-based method to model risk interactions and propose an integrated process to manage risks in international projects.

3 Bayesian Networks

The Bayesian network is based on the conditional probability theory. The network is represented as a graph, which consist of a set of nodes and arcs. The nodes represent random variables and arcs represent probabilistic dependencies or casual relations between nodes. Mathematically, the Bayesian network represents the joint probability distribution of all variables $X = (X_1, X_2 ..., X_n)$ in the network as expressed below:

$$P_{\text{BN}}(X) = \prod_{i=1}^{n} P_{\text{BN}}(X_i | \prod X_i)$$ (1)

Where $\prod X_i$ represents the set of parent nodes of variable $X_i$. $P_{\text{BN}}(X_i | \prod X_i)$ represents the conditional probability distribution of $X_i$ when its parent nodes are given. If $X_i$ is root node that have no parent nodes, then $P_{\text{BN}}(X_i | \prod X_i)$ represents the marginal probability distribution of $X_i$. 

4 A model for risk interactions in international construction projects

This research introduces a BN-based method to capture interrelations among risks factors and determine the risk of cost overrun in international construction projects. The development process of this method will be discussed as follows:

4.1 Input

The BN-based method has two main kinds of inputs: the general international project risks \( C_i \) \((i = 1, 2, ..., n)\) and risk sources \( CR_j \) \((j = 1, 2, ..., m)\) which will trigger other risks in the risk paths network. The two kinds of risks will be identified by the project management team according to previous experiences and current project characteristics.

4.2 BN

The network will be developed as indicated in Figure 1. There are three kinds of nodes in a BN: (1) a root node—a node that have no parents; (2) a leaf node—a node that have no children; (3) an intermediate node—a node which belong neither to root node nor leaf node. In this proposed BN, the root node corresponds to the risk source \( CR_j \), the intermediate node corresponds to the general risk \( C_i \) and the leaf node corresponds to the risk of cost overrun.

During this stage, marginal probability distributions of root nodes and conditional probability distributions of intermediate nodes must be evaluated, and the conditional probability table will be built to represent the distributions of these nodes. For facilitating analysis, each variable in the BN is assigned two opposite states. The states of root node risk of cost overrun include yes and no, and the two states of other variables include of high and low. The value of state of each variable will be determined by the project management team.

In this stage, a computational BN module will also be proposed. This module will be programmed in the MATLAB environment, and the Bayes net toolbox (BNT) will be applied. The module includes four submodules: (1) creating variables and defining their states and interrelations among them; (2) importing the conditional probability table; (3) assigning the conditional probability distribution for each variable from the conditional probability table; and (4) creating an inference engine, running simulation and conducting a sensitivity analysis.

![Figure 1. A generic BN model for analyzing risk interactions in international projects](image-url)
4.3 Output

Having finished above steps, a series of analysis can be conducted. The powerful analyses yield by the BN-based method include predicting probability distributions for the risk of cost overrun under different scenarios, analyzing the effect of each variable’s state on the cost overrun and prioritizing risks that in the project risk paths network. These analyses will provide insightful information for project managers to manage international project risks.

5 Case study implementation

In this section, a building project, which was implemented by a Chinese international contractor, is applied to illustrate the use of the proposed method. Risk sources and general risks were identified by the project management team which includes of a project manager, and three experts experienced in international project risk management. The project management team also determined the casual relations among these risk factors. A customized BN is constructed as indicated in Figure 2.

![Customized BN model for analyzing risk interactions in the case project](image)

After development of customized BN, the marginal probability of risk sources nodes and the conditional probability of general risks were determined by the project management team, and the conditional probability table for each variable was built. The size of a conditional probability table for a specific variable depends on (1) the number of variables that influence this variable (i.e., its parents); (2) the number of states of this variable and its parents. The representative conditional probability table (for the risk of unavailability of resources) is indicated in Table 1. As shown in Table 1, given that (1) the macroeconomic risk was high, and (2) the legal risk was low, then the value of high and low state of unavailability of resources were judged as 0.6 and 0.4.
Table 1 The conditional probability table for variable “unavailability of resources”

<table>
<thead>
<tr>
<th>Parent nodes</th>
<th>Unavailability of resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Macroeconomic risk</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>0.75</td>
</tr>
<tr>
<td>Low</td>
<td>0.2</td>
</tr>
</tbody>
</table>

After completion of the structure of BN and determination of probabilities, a MATLAB program with the support of BNT was developed. This program can be applied to assess possibilities of different states of the risk of cost overrun and other variables. The probabilities of the cost overrun risk under different scenarios in this case project are indicated in Table 2. In the base run and states of all risks impacting the project cost are not knew, the likelihood of project total cost overrun is 24.54% (Table 2). This assessment result indicates that some effective risk response strategies must be implemented to prevent cost overrun in this case project.

Table 2 Predicting probability distributions for the risk of cost overrun under different scenarios

<table>
<thead>
<tr>
<th>Risk</th>
<th>State</th>
<th>Probability distributions of cost overrun (%)</th>
<th>Sensitivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base run</td>
<td>N/A</td>
<td>24.54</td>
<td>75.46</td>
</tr>
<tr>
<td>Resource price fluctuation</td>
<td>High</td>
<td>33.96</td>
<td>66.04</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>20.14</td>
<td>79.86</td>
</tr>
<tr>
<td>Client's incompetency</td>
<td>High</td>
<td>25.31</td>
<td>74.69</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>24.18</td>
<td>75.82</td>
</tr>
<tr>
<td>Design changes</td>
<td>High</td>
<td>36.22</td>
<td>63.78</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>19.50</td>
<td>80.50</td>
</tr>
<tr>
<td>Unavailability of resources</td>
<td>High</td>
<td>31.41</td>
<td>68.59</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>22.51</td>
<td>77.49</td>
</tr>
<tr>
<td>Design problems</td>
<td>High</td>
<td>28.70</td>
<td>71.3</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>21.17</td>
<td>78.83</td>
</tr>
<tr>
<td>Host government-related risk</td>
<td>High</td>
<td>25.48</td>
<td>74.52</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>24.44</td>
<td>75.56</td>
</tr>
<tr>
<td>Project complexity</td>
<td>High</td>
<td>24.69</td>
<td>75.31</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>24.52</td>
<td>75.48</td>
</tr>
<tr>
<td>Macroeconomic risk</td>
<td>High</td>
<td>25.12</td>
<td>74.88</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>24.29</td>
<td>75.71</td>
</tr>
<tr>
<td>Legal risk</td>
<td>High</td>
<td>27.55</td>
<td>72.45</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>23.67</td>
<td>76.33</td>
</tr>
<tr>
<td>Contractor's lack of managerial skills</td>
<td>High</td>
<td>25.87</td>
<td>74.13</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>24.21</td>
<td>75.79</td>
</tr>
<tr>
<td>Decrease in productivity</td>
<td>High</td>
<td>37.11</td>
<td>62.89</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>19.45</td>
<td>80.55</td>
</tr>
</tbody>
</table>

This program can be applied to conduct the sensitivity analysis to explore the impact of states of each variable on the probability of other variable. This analysis also can help the project
management team to prioritize risks and support them to select proper risk response strategies. For example, the probability of cost overrun is 36.22% when the state of design changes is high (Table 2). Conversely, the probability of project cost overrun is 19.50% if the state of design changes is low (Table 2). It can be referred as the project cost overrun risk is very sensitive to design changes. However, such risks as project complexity, client's incompetency and contractor's lack of managerial skills are not too sensitive in this case project.

According to table 2, decrease in productivity, design changes and resource price fluctuation can be regarded as critical risks that impact project total cost. Strategies such as including a proper risk allocation scheme in contract can significantly mitigate the impact of resource price fluctuation, and such strategies as adding flexibility terms in the contract during negotiation can reduce the probability of design changes. Under satisfying the budget constraint of risk response, these strategies can be included in the optimal risk response strategies set to achieve a high effect of risk response.

6 Conclusion

This research seeks to introduce a framework to analyze risk interactions and assess the cost overrun risk with considering causal influences among risks in international construction projects. A BN-based method is proposed. An international building project is used to illustrate the applicability of the proposed method. The sensitivity analysis highlights the impact of states of each risk on probabilities of the cost overrun, and results indicate that effective risk response strategies set include strategies aiming to increase the productivity and those aiming to reduce changes of design and fluctuations of resource price.

This proposed method provides a deep understanding of risk interactions in international construction projects. In addition, it can be applied by the international project management team to prioritize risks and develop a proper risk response scheme.

In the further, this research can be extended to perform more validations to test and confirm the proposed method. In addition, further research also could to explore the influence to project characteristics on risk propagations and diffusions in international construction projects.

References


Research on the Risk Factors of BIM Application in Construction Enterprises

Hu, S.J.1*, Wang, J.P.2*, Xu, B3*

Abstract: In recent years, building information modelling (BIM) has been widely acknowledged and applied into businesses, especially for mega-projects, within construction industry. However, applying BIM into uses may cause losses for companies in that BIM increased the risks due to the development of BIM technology, industry environment, structures of companies and human resources, which make companies cannot reach their goals and even perform worse. Based on risk theory, risk factors are identified, revised and theoretical structural equation model (SEM) are given on applying BIM into uses for construction companies, as well as hypotheses of the model. Then empirical analysis about the risk factors is conducted in accordance with the model and hypotheses through the data collected by questionnaires. And five first-class risk factors are put forward according to SEM output, respectively, responsibility distribution, related policy and supporting, BIM related standard, model management, to help practitioners lower the risks and improve performances existing in BIM using.

Key words: Construction companies, BIM, Risk factors, Structural equation model (SEM)
1 Introduction

Developing rapidly in China in recent years, construction industry has already become a pillar industry. However, according to a comparison of manufacturing which is intensive and efficient, the weaknesses like low efficiency, high energy-cost and unstable quality of products, are exposed universally. Therefore, construction industry is considered as an extensive industry in China.

Meanwhile, Building Information Modeling (BIM) is gradually used by people who realize the mentioned problems in Chinese construction industry. BIM not only innovates the model of traditional construction, but also transforms the way of traditional thinking. However, BIM has not been totally applied by all companies for the potential risks of technology development, industry environment, enterprise organization and human resource level or some losses caused by applying BIM in some circumstance. To decrease the risk of BIM and ensure the efficiency of BIM application, it is critical to explore and analyze the risk factors in the early BIM application in enterprises, then drawing the conclusion of how the risks will affect the result of BIM, for the impact of a greater degree of risk factors, recommendations would be proposed to minimize the negative impact to promote BIM application.

This paper focus on the risk factors during BIM application from the perspective of construction enterprises, aiming to provide reference and reasonable measures of risk control for construction companies, in which way to ensure the positive result of BIM application thereby achieving the widely use of BIM, which will promote industrial upgrading and sustainable development.

2 Literature Review

According to Eastman, risks and challenges come with new technology, BIM is no exception. It is reported that the application of BIM leads to the adjustment of cooperation and grouping, legal changes on document ownership and document production, modification of program process and challenges of practice. Eastman also pointed out that the most critical approach to boost BIM application is to identify the risks then take solutions [1][1]. Ashcraft analyzed the differences between BIM and traditional working process and contract model, stated that companies need to adjust their organization structure base on BIM characters, and apply new contract model to decrease potential risks although BIM could benefit the users from work efficiency and production quality [2]. And after analyzing the advantages, disadvantages, risks and challenges, Azhar stated the main risks of BIM remaining in legal and technological aspects. For the legal side, the lack of BIM-related standards or rules and the ambiguousness of responsible subject are the main problems. As for the technological side, the main problems are poor data interaction, faulty data security and inefficient cooperation between workers [3]. Eadie emphasized the risks of BIM are high investment, hardship of operation, obstruction of information sharing, ambiguousness of ownership or intellectual property right and long payback period[4].

Apart from the related research, the solutions of risks of BIM has been introduced in worldwide authorize BIM publications. Advice on duty allocation and intellectual property protection was given in Singapore BIM Guidebook [5]. America National BIM Application Guidebook stipulates structural data storage to guarantee BIM data reused efficiently, which
benefits the data security \[6\]. Meanwhile, AEC Industry BIM Agreement in the U.K. has passed a unified data standard as solution of BIM data interaction to decrease risks \[7\].

Jun Xu introduces the application of BIM in railway industry, and the risks from political, economic, technological and managerial aspects are analyzed then following the solutions \[8\]. Minglong Xu induces the risks of BIM in the progress of construction contracting, including legal risks, data interaction risks and model management risks, and he explores the solutions \[9\]. By using the Paradigm to analyze the whole progress of BIM application, Li Guo proposes the frame of risk solving towards BIM in construction projects base on study of the principles in every links \[10\]. Zhi Li introduces the trend of BIM application and general application points, emphasizes seven risks that are easy to be ignored during the BIM development and proposes the appropriate solutions which could be referenced to other construction projects \[11\]. According to the contents of BIM in construction project risk management, Fei Wang identifies the risks of BIM, including risks of application, risks of evaluation, risks of human resource loss and risk of modification on process mode and managerial mode, during construction stage\[12\].

3 Identification for the risk factors of applying BIM in construction companies

First, based on the outcomes of former researcher, risk factors of applying BIM within construction companies were constructed through literature research. Due to drawback existed in literature research and ascertain the completeness and timeliness, Delphi Method was implemented to modify those identified risk factors. Then, all 23 modified risk factors were categorized into five dimensions, namely, technology, economy, management, environment and human, showing in the Table 1.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Software maturity, Data interactivity, Technical applicability, Model accuracy, technical difficulty</td>
</tr>
<tr>
<td>Management</td>
<td>Model management, Changes in business management model, Business process reorganization, Management-level factors, Selection of BIM technology, Coordination and communication (C&amp;C) with participants</td>
</tr>
<tr>
<td>Economy</td>
<td>Short-term cost input, Additional cost, Payback period</td>
</tr>
<tr>
<td>Environment</td>
<td>BIM related standards, Contract issues, Intellectual property disputes, Successful experience in BIM application, Related policies and supporting, Allocation of responsibilities</td>
</tr>
<tr>
<td>Human</td>
<td>Qualities of BIM practitioners, Insufficiency of BIM practitioners, Operators’ initiative</td>
</tr>
</tbody>
</table>

4 Structural equation model and research hypothesis

4.1 The structural equation model

According to Risk Theory, risks of applying BIM can be defined as this: potential or possibility of loss to the companies, due to some existing factors, subjective or objective, caused by the poor performance of applying BIM which is far away from expected. So supported by definition,
whether a risk factor lead to risk occurrence can be validated by studying the casual relationship between risk factor and its effect in applying BIM.

The impact of information technology innovation is mainly manifested in three aspects of product organization and process based on the virtual design and construction (VDC) theory put forward by Stanford. Supported by the VDC theory [13], and taken into consideration that the performance of applying BIM into business can be evaluated from five aspects, respectively, product, finance, organization, process and strategy; and with the former analysis of implementing BIM into business in construction companies, an integral optimized structural equation model was formulated, shown in Figure 1.

![Figure 1. Integral optimized structural equation model](image)

### 4.2 Hypotheses

Following hypotheses about this research is proposed supported by the analysis of the concept of Risk Theory and the basis of literature, combined with SEM:

H1: The technical risk factors have a significant effect on applying BIM in construction companies.

H2: The management risk factors have a significant effect on applying BIM in construction companies.

H3: The economic risk factors have a significant effect on applying BIM in construction companies.

H4: The environment risk factors have a significant effect on applying BIM in construction companies.

H5: The personnel risk factors have a significant effect on applying BIM in construction companies.
After proposing those hypotheses above, empirical research will be conducted in next chapter.

5 Data description

5.1 Data collection

In order to acquire the data for all the observation variables, in this research, Likert scale method was implemented to design questionnaires to study the influence of the five external variables on the application of BIM in construction enterprises. Standardized questionnaires were designed based on the principles proposed by Salant in 1994. There are three part in the questionnaires. The first part contains the general information of the interviewees, aiming to guarantee effectiveness. And the second and third part were designed to get the evaluation about risk factors of BIM application and about the application effect of BIM in construction enterprises. Following Likert scale method, scores from 1 to 5 stand for strongly disagree, disagree, neither agree nor disagree, agree, strongly agree.

To maintain the reliability of the research, 800 questionnaires were distributed to enterprise managers, project managers and technicians working for BIM-applied construction corporations through multiple available methods and 244 were responded. After removing those Invalid questionnaires answered by those without BIM related experiences, 214 valid questionnaires were collected, which meet the data demand that the sample size must be large enough for applying SEM, and Tabachnick considers the number of valid samples shall be larger than 100 and over 200 is better. Table2 shows the distribution of the valid questionnaires collected.

5.2 Data inspection

To meet SEM requirements, kurtosis and skewness were tested to make sure that all observation variables are distributed normally or nearly normal. Checked by SPSS22.0, it is true that all observation variables satisfied the requirements as kurtosis and skewness of each variables are in ranges from -1.05 to 0.106 and from -0.647 to 1.245.

After checking the distribution of variables, reliability and validity test of observations were conducted to guarantee the consistency of results, accuracy of the model and the effectiveness of the questionnaire. The results of the calculation of Bartlett Sphere (BS) Test and Kaiser-Meyer-Olkin (KMO) test output by SPSS22.0 show that the overall KMO value is 0.884 under the significance level of 0.001 and the approximate chi-square value in BS test is 2649.734 under the significance level of 0.000, which all concluded that observation data satisfied the validity requirement for analysing. According to the output of Cronbach α coefficient, the overall value is 0.919 and for each of the variables, the value is between 0.7 and 0.9, indicating that observations has high reliability and internal consistency is credible.

6 Results

After data checking, in this part, the empirical research results calculated by AMOS24.0 are demonstrated as the reliability of the data and the optimization of the model are all fulfilled.
According to the results, showing in Table 2, all five dimension of risk factors may have effect on BIM applying in construction companies. And all the hypotheses set up above are verified as all coefficients is greater than 0.

In terms of the results of the influence from observations (risk factors) to latent variables (dimensions), it is showing Table 3.

### Table 2. Influence from external latent variables to internal latent variables

<table>
<thead>
<tr>
<th>External latent variables (dimension)</th>
<th>Relation</th>
<th>Internal latent variables</th>
<th>Coefficient</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>→</td>
<td>BIM application effect in construction enterprise</td>
<td>0.572</td>
<td>***</td>
</tr>
<tr>
<td>Management</td>
<td>→</td>
<td></td>
<td>0.691</td>
<td>***</td>
</tr>
<tr>
<td>Economy</td>
<td>→</td>
<td></td>
<td>0.642, 0.019</td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>→</td>
<td></td>
<td>0.756</td>
<td>***</td>
</tr>
<tr>
<td>Human</td>
<td>→</td>
<td></td>
<td>0.564</td>
<td>***</td>
</tr>
</tbody>
</table>

Note: *** stands for Probability <0.001. The same for below.

### Table 3. The influence of risk factors

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Relation</th>
<th>Dimension</th>
<th>Coefficient</th>
<th>P</th>
<th>CII</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software maturity</td>
<td>→</td>
<td>Technology</td>
<td>0.529</td>
<td>***</td>
<td>0.3026</td>
<td>17</td>
</tr>
<tr>
<td>Data interactivity</td>
<td>→</td>
<td>Technology</td>
<td>0.861</td>
<td>***</td>
<td>0.4925</td>
<td>6</td>
</tr>
<tr>
<td>Technical applicability</td>
<td>→</td>
<td>Technology</td>
<td>0.347</td>
<td>***</td>
<td>0.1985</td>
<td>21</td>
</tr>
<tr>
<td>Model accuracy</td>
<td>→</td>
<td>Technology</td>
<td>0.647</td>
<td>***</td>
<td>0.3701</td>
<td>15</td>
</tr>
<tr>
<td>Technical difficulty</td>
<td>→</td>
<td>Technology</td>
<td>0.294</td>
<td>***</td>
<td>0.1682</td>
<td>23</td>
</tr>
<tr>
<td>Model management</td>
<td>→</td>
<td>Management</td>
<td>0.816</td>
<td>***</td>
<td>0.5639</td>
<td>4</td>
</tr>
<tr>
<td>Changes in business management model</td>
<td>→</td>
<td>Management</td>
<td>0.310</td>
<td>***</td>
<td>0.2142</td>
<td>19</td>
</tr>
<tr>
<td>Business process reorganization</td>
<td>→</td>
<td>Management</td>
<td>0.678</td>
<td>***</td>
<td>0.4685</td>
<td>7</td>
</tr>
<tr>
<td>Management-level factors</td>
<td>→</td>
<td>Management</td>
<td>0.606</td>
<td>***</td>
<td>0.4187</td>
<td>11</td>
</tr>
<tr>
<td>Selection of BIM</td>
<td>→</td>
<td>Management</td>
<td>0.634</td>
<td>***</td>
<td>0.4381</td>
<td>9</td>
</tr>
<tr>
<td>C&amp;C with participants</td>
<td>→</td>
<td>Economy</td>
<td>0.644</td>
<td>***</td>
<td>0.4450</td>
<td>8</td>
</tr>
<tr>
<td>Short-term cost input</td>
<td>→</td>
<td>Economy</td>
<td>0.627</td>
<td>***</td>
<td>0.4025</td>
<td>13</td>
</tr>
<tr>
<td>Additional cost</td>
<td>→</td>
<td>Economy</td>
<td>0.645</td>
<td>***</td>
<td>0.4141</td>
<td>12</td>
</tr>
<tr>
<td>Payback period</td>
<td>→</td>
<td>Economy</td>
<td>0.556</td>
<td>***</td>
<td>0.3570</td>
<td>16</td>
</tr>
<tr>
<td>BIM related standards</td>
<td>→</td>
<td>Environment</td>
<td>0.803</td>
<td>***</td>
<td>0.6071</td>
<td>3</td>
</tr>
<tr>
<td>Contract issues</td>
<td>→</td>
<td>Environment</td>
<td>0.567</td>
<td>***</td>
<td>0.4287</td>
<td>10</td>
</tr>
<tr>
<td>Intellectual property disputes</td>
<td>→</td>
<td>Environment</td>
<td>0.507</td>
<td>***</td>
<td>0.3833</td>
<td>14</td>
</tr>
<tr>
<td>Successful experience in BIM application</td>
<td>→</td>
<td>Environment</td>
<td>0.379</td>
<td>***</td>
<td>0.2865</td>
<td>18</td>
</tr>
<tr>
<td>Related policies and supporting</td>
<td>→</td>
<td>Environment</td>
<td>0.879</td>
<td>***</td>
<td>0.6645</td>
<td>2</td>
</tr>
<tr>
<td>Allocation of responsibilities</td>
<td>→</td>
<td>Environment</td>
<td>0.917</td>
<td>***</td>
<td>0.6933</td>
<td>1</td>
</tr>
<tr>
<td>Qualities of BIM practitioners</td>
<td>→</td>
<td>Human</td>
<td>0.900</td>
<td>***</td>
<td>0.5076</td>
<td>5</td>
</tr>
<tr>
<td>Insufficiency of BIM practitioners</td>
<td>→</td>
<td>Human</td>
<td>0.368</td>
<td>***</td>
<td>0.2076</td>
<td>20</td>
</tr>
<tr>
<td>Operators’ initiative</td>
<td>→</td>
<td>Human</td>
<td>0.333</td>
<td>***</td>
<td>0.1878</td>
<td>22</td>
</tr>
</tbody>
</table>
Based on the coefficient in Table 2, five category of risk factors have a great impact on BIM application in construction companies due to all coefficients are greater than 0.5 and all coefficients are significant, at least, under the significance level of 0.019. And risk factors categorized into environmental dimension has the biggest influence on BIM application in construction companies followed by management, economy and technology. Risks from human ranks last among five dimensions.

Through combing Table 2 and the coefficients in Table 3, the comprehensive impact index (CII) of each risk factor is computed by simple weighted method. For instance, to compute the comprehensive impact of software maturity, 0.529 was multiplied by 0.572, and we got 0.3026 approximately and other factors’ impact can be calculated in the same way. Following the criteria proposed by Cohen\cite{16}, all risk factors are ranked in descending order according to its comprehensive impact index showing in the last column of Table 3, and are classified into three levels according to its comprehensive index. The factors whose comprehensive impact index ranging over 0.500 are categorized into the first level and those ranging from 0.2000 to 0.5000(include 0.5000) are sorted into second level, while those ranging below 0.2000 (include 0.2000) are in the third level.

7 Recommendations

By conducting empirical research, the influence of risk factors of applying BIM in construction companies were ranked and sorted. In this part, recommendations aiming to solve the first level risks are proposed as they are the most influential ones among all factors.

First, to solve the risks from allocation of responsibility, duties writing in the contract shall be specified and documented. And company managers shall pay close attention to BIM laws and regulations, and suggest to government to diminish the risk. For risks from BIM related policies and supporting, companies ought to exert their own initiatives actively, like combing their development goals with nation’s willingness to advance BIM application and finding supports from government proactively, even make suggestions to them. In terms of risks caused by BIM related standards, construction companies are suggested to get familiar with existing standard, both domestic and abroad, to frame their own customized standards, which shall be updated or revised promptly to guide their actions. In order to reduce risks from model management, BIM model management model system could be a better way as well as installing and implementing BIM model management platform like Project Wise platform designed by Bentely. Last, to enhance the quality or performance of BIM practitioners, more experienced BIM engineers shall be recruited and let them train the beginners. Moreover, tasks should be allocated perfectly, for example, experienced practitioners ought to take more responsibilities on pivotal or important tasks, like decision-making, and beginners are supposed to follow the guidance issued by manager and handle with some less important tasks, such as modelling and data processing.

8 Conclusion

Starting from the status quo of applying BIM in construction companies, this paper quantitatively analyses the risk factors influencing BIM application in construction enterprises through structural equation model based on the risk theory, and countermeasures for the first-level risk factors are
put forward as an reference to help reducing the risk while implementing BIM into business. However, there are still some limitations existing during this research, like incompleteness of identified risk factors, deviations comes from data collected and lack of further causal analysis for each factors and so on. Further research must pay more focus on identification of risk factors and optimize the questionnaire, such as enlarging the sample size, increasing the depth and studying intrinsic logics among factors.

References


Research on Policy Path of Culture-led regeneration: Based on government Roles analysis

Luo, D\(^1\)*, Li S.L.\(^2\)

Abstract: Commonly recognized as the soul of the city, culture can contribute significantly to the development of economy, society and some other aspects during the urban regeneration process. It is known that how to use culture into urban regeneration has increasingly become a key issue. This article aims to explore government roles in Culture-led regeneration in the process of cultural regeneration. By comparing the path of policy of five advanced countries and summarizing general characteristics of policies, a series of corresponding suggestions in regard of stages of policy and roles of government are provided.

Keywords: Urban regeneration; Culture; Government role; Suggestion

\(^1\)* Luo, D
Corresponding author, School of Construction Management and Real Estate. Chongqing University
E-mail: ldtracy214@163.com

\(^2\) Li, S. L
School of Construction Management and Real Estate. Chongqing University
1 Introduction

Contemporary cities have distinctive American styles [1], whether world-wide or in China. With recent years witnessing the advance of Chinese urbanization, majority of Chinese cities set their goals of city development as “Modernization, commercialization, internationalization”. Among 661 cities, 183 of which set forth the aims to become “Modern international metropolis”, 30 cities wish to establish Central Business District. These cities, however, are losing its vitality since they developed regardless of inheriting culture.

Lewis Mumford once described culture as the life of a city. Although we can’t claim culture as the panacea for many urban problems, it is sure that culture plays an essential role in improving city images, enhancing economic development, optimizing spatial reuse and gathering elite. Unique as every city culture is, using culture can achieve the differentiation of city brand marketing and avoid city homogenization. As one of the high value-added industries, cultural industry will contribute to attracting investment and increasing city economic development. The creative spaces of culture industries can be transformed from some abandoned urban sites such as former warehouses and factories; hence the spatial reuse is achieved in the process [2]. Furthermore, the improvement of city culture is conducive to gathering elite and forming a virtuous circle.

Government, entrepreneurs and citizens are the main stakeholders in the whole process. Entrepreneurs make the decision mainly contingent on commercial interest, which means they wouldn’t be motivated in producing and renewing city cultural product if they can’t see beneficial potency. As the receiver and participant of those product, citizens influence the whole process to some degree but the impact is limited. Government is the main provider of public and industry product, shouldering the mission of inheriting culture vestige and promoting city development. Not only can government make a plan from top to bottom, but also can assure culture’s prosperity in city via guiding industry, authorizing counterpart projects and guaranteeing policy. Hence, this article aims to summarize previous experience of developed cities, which can shed some light for finding a reasonable match between government action and culture-led urban regeneration in China.

2 Government role under process prospective

2.1 Concept definition of culture-led urban regeneration

During 1970s-1980s, the United States and some European cities regenerated their old city center when confronting city economic recession and inner city recession. Government began to combine culture and hardware of city as an effort to twist the old city economic downturn. A series of culture-led policy aimed at promoting city economic diversity, ameliorating cultural tourism and addressing local residents’ employment problem came into being in Western countries [3].

Culture-led regeneration, also known as Culture-policy-regeneration or Cultural regeneration, is an urban regeneration mechanism started from 1970s in the United States [4]. European cities such as Barcelona and Athletic Club Bilbao have also used it as a guideline to solve post-industrialization problem [5]. Culture-led urban regeneration is regarded as a creative mean to enhance economic development, which can also facilitates the realization of city brand differentiation, promotion of cultural tourism development, attraction of investment and agglomeration of creative industries.
However, in China, plenty of cities are confronting problems in the process of culture-led urban regeneration. For instance, Certain parts of government roles are absent, and the policy support is usually weak. Another problem lies in the lack of connection between cultural planning and city development. In other words, Cultural department and City plan department work respectively and collaboration of both departments is deficient \(^6\). Additionally, the concept of construction and process are policy-oriented, which may result in a general and obscure planning since most of the plans and construction implementations are from top to bottom \(^7\).

2.2 Government roles under culture-led urban regeneration process

Urban regeneration is a complicated system-engineering. Analysis under process perspective can contribute to cover government roles comprehensively. The process is shown in Figure 1.

![Figure 1. The process of Urban regeneration](image-url)

From the perspective of culture-led urban regeneration, government plays different roles in the strategic phase, planning phase, implementation phase and the operation phase. Compared to the normal urban regeneration, the process of culture-led urban generation starts from national level strategy and settles in the implementation of specific projects since it emphasizes the importance of culture during the process of city development: Firstly, a comprehensive blueprint is drafted by the government through analyzing indigenous market and learning from experience of advanced cities. Secondly, government releases several policies to guarantee the readiness of the whole environment and the availability of the talent and capital. Thirdly, Some creative projects can be carried out as a specific mean to improve culture-led urban regeneration. Many cities realize urban regeneration and the promotion of economic as well as industrial development through the implementation of some cultural projects. For instance, South of Houston in New York and 798 District of Beijing both provide inspirational ideas and serve as good examples to other cities. Lastly, not only can government push the planning forward, but also adjust the next stage of plan implementation by releasing incentive policies according to ongoing feedback in the process to ensure that the entire procedure work orderly.

From the process analysis, it is clearly that government roles in culture-led urban regeneration can be divided as planner, authorizer, guarantor and motivator. The role classification and function definition as shown in Figure 2.
Figure 2. The category and function of government roles

3 Policy path analysis based on government roles

Government roles vary with disparate phases in culture-led urban regeneration. This article chose London, New York, Singapore, Hong Kong and Beijing as typical examples to study and compare the similarity and difference of relevant policies, and therefore analyze the evolvement of government roles during the whole process.

A great amount of cities, especially capital cities, are likely to formulate customized local policies in respond to the ones at national level, which may lead to the situation that the policy will change alternatively between national and local policy framework. In addition, culture-led urban regeneration and cultural industry policy is highly correlated. Thus, some policies such as copyright law, talent incentives and etc. Though might appear irrelevant at first glance, can be significant and meaningful to promote urban regeneration process due to the underlying transmission mechanism. The United States and the United Kingdom are the early batch of cities which utilized cultural policies to regenerate cities and gained remarkable achievement. Singapore submitted “Creative Singapore Project” in the end of the 19th century, by which it realized a transformation from “Cultural desert” to “Cultural Capital”. Hong Kong and Beijing are two typical representatives of cultural urban regeneration cities in China, and their experience of cultural strategy development and cultural policy releasing is worth referring to. The policy path of studied cities is shown as Table1.

<table>
<thead>
<tr>
<th>Table 1. Policy path of advanced cities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phase</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>New York</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Singapore's Creative Economy Development

<table>
<thead>
<tr>
<th>Hong Kong</th>
<th>1. Hong Kong Infinite three-year plan 2001-2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Quality Migrant Admission Scheme</td>
</tr>
<tr>
<td></td>
<td>2. West Kowloon Cultural District Project</td>
</tr>
<tr>
<td>Beijing</td>
<td>1. Dashanzi Art District project</td>
</tr>
<tr>
<td></td>
<td>2. Roundness Art Community project</td>
</tr>
<tr>
<td></td>
<td>3. Special plan for talent introduction in Beijing</td>
</tr>
<tr>
<td></td>
<td>4. Fund for Venture capital guidance</td>
</tr>
</tbody>
</table>

By comparing the policy path of the five cities, we can summarize the disciplinarian as follows:

In the process of urban regeneration of those cities, government roles are dynamic and basically follow the rules of "planners - guarantor - authorizer - motivator". When function as a planner, the government is mainly responsible for the top-level planning and upper policy, deciding the main direction on the combined development route of cultural industry and city development at the same time. Shoudering the function of guarantor, the government provides necessary factors for culture-led urban regeneration and regulates market environment to attract and support the talented group while following the formulated policy path. Shoudering the function of indemnitor, government leads the development of cultural creative clan and market exploiting from top to bottom. It combines cultural development and urban regeneration together by endowing specific projects and taking the occupation of supervision and approval. Shoudering the function of motivator, the government attracts the creative class gathering by releasing relevant tax incentives and special funds, and therefore realizing the transition to mature phase of many cities. To sum up, the roles of government are adjusted along with the growth of culture-led urban regeneration.

Referring to the case study, it can be shown that cultural policy has a conductive effect on urban regeneration. According to the different contents, this article divided the cultural policy into three categories: industrial development policy, guarantee policy and incentive policy:(1) The releasement of industrial development policy has a direct impact on the development of culture in the city. One typical example is Singapore. In 1990s, the city development of Singapore encountered “ceilings” under the original economic development. In order to ameliorate this situation, the "Creative Singapore Plan" was born at that time. By analyzing the successful experience of countries such as British and the United States, Singapore government raised the goal that to catch up with Glasgow, Melbourne in 5-10 years and to catch up London and New York in the ensuing phase. Under the implementation of this plan, Singapore not only fully utilized the multiculturalism and vigorously developed its cultural infrastructure, but also paid much attention to the city cultural expression and cultural space improvement. It also chose three main realms to develop creative economy, which is arts and culture, design and media. By the end of 2015, Singapore was selected as "design creative capital" certificated by the United Nation and became one of the world's 18 design creative city, which contributed a lot to the enhancement of city image and development of city tourism. (2) Guarantee policy and incentive policy play supporting roles, which have indirect effect on the development of culture-led urban regeneration. Culture industry is a knowledge-intensive industry, in which intellectual property right is one of the distinguishing features from other industries. Hence, only under the perquisite that the
intellectual property and environment are guaranteed, can it be possible to attract the gathering of
talent, technique, capital and other factors. In addition, incentive policies mainly for cultural
enterprises and art groups also encourage the development of culture in city from top to the
bottom. To illustrate it more clearly, an appropriate example is Beijing, whose cultural industry
developed dramatically and attracting the majority of the creative class gathering in the past
decades, crediting its achievement to the various cultural policies, such as the introduction plan of
Beijing high-level talent, Special fund for the small and medium-sized enterprises development,
identification of Beijing strategic emerging industrial base and so on. All of which guaranteed the
environment of the cultural development in Beijing.

Figure 3. The transmission mechanism of Cultural policy

4 Policy suggestions under government roles

4.1 Early stage: Shouldering planning-oriented function, deciding strategy
direction

(1) Imply planning at the first place, take cultural development into city development
strategy

The primary task is to develop the culture from the strategic height of city's sustainable
development, combining culture with urban social and economic goals. In order to design an
effective cultural and urban development strategy, the government shall draw the personnel from
the cultural and the urban development departments to from specific organization to carry out the
basic research and strategic planning, analyze and integrate the urban cultural elements and
strengthen the basic research of culture. The advanced experience of developed cities could be
borrowed to imply upper design according to local conditions. Government should make the plan
by phases and set up short-term and long-term goals which are accessible.

Basic research could provide a complete information support for the government to formulate
policies and ensure the coherence, precision and effectiveness of the government's policy. First,
basic elements like local urban matrix, talents and technology as well as cultural atmosphere shall
be fully understood and dug; then, the focus shall be laid on developed cities' policy being prompt,
systematic and supportive, clarifying the organizational structure and staffing of the government
and tracking the development path and the policy mechanism. The development strategy shall be
designed in line with the industrial direction, covering outstanding talent cultivation, infrastructure
construction, cultural activities, cultural image marketing and other aspects, to fully use the cultural industries as a mean for motivating local economy and renewing of urban facilities.

(2) Determining focus area, designating urban regeneration unit
The determination of focus area is contingent on synthesis judgment of cities’ advantages, regional resources and local cultural factors. Government should combine culture and emerging industry together and utilize self-advantages to release relevant policies and support potential fields. Culture-led urban regeneration emphasizes the integration of culture in the early planning, it drives the economy through the construction of cultural consumption space. Therefore, three dimensions (commercial, cultural and public) shall be taken into consideration when dividing the urban regeneration unit. In the commercial dimension, the government shall allocate the unit to the area where the traffic is relatively convenient and the site is close to the central area. The scale of the land should match the function developed in the future to revitalize the land stock assets. The cultural dimension should consider the degree of cultural factors agglomeration to improve the convenience of elements' entry with a focus laid on the historical cultural regions to dynamically inherit the city context. In the public dimension, the urban cultural products can not deviate from the nature of public services. It is necessary to consider the residents' needs and a good communication with the public.

4.2 The middle stage: Shouldering authorize and guarantee-oriented function, ensuring supervision

(1) Determine the reasonable authorization method
Government should regenerate the city via implying projects, including Cultural infrastructure, cultural flagship project, cultural festivals, cultural industry cluster area and so on. Adopting the method of government-leading and civil participation to authorize projects and inviting the professional firms to plan together is conducive to enhance the operability and practicality of projects. In the aspects of supervision, government ought to optimize the process of cultural-led urban regeneration, take the degree of utilization of cultural elements into approval for the sake of the homogenization phenomenon of city cultural products.

(2) Establish a systematic guarantee system
Government is responsible to establish a systematic guarantee system which is available for the culture development in cities. This system is supposed to guarantee the policy completion, strengthen the protection of intellectual property, and regulate the market properly. On the one hand, government should establish a specialized organization, On the other hand, government can establish a public service platform, which is established by government or the collaboration of government and citizen, aiming to provide multifunction such as consulting, communicating, hatching, talent dispatching and so on. It can realize information match by big-data and therefore guarantee the flow of factors like capital, information and labor.

(3) Guarantee talent nurturing and storing
There are two main methods. One is to cultivate a batch of talent by education. Government ought to innovate education mechanism of cultural talent, emphasize the supporting of cultural education and imply cultural talent training measures, set up relevant curriculums in colleges and carry out city cultural activities to build up the cultural atmosphere. The other method is to make plans for talent introduction. It is independent to combine leadership and universal talent together and pay
much attention to the introduction and restoration of high-leveled talent.

4.3 The late stage: Shoulderng motivate-oriented function, establishing various bridge

(1) Establish capital bridge, apply various economic supporting
The government should emphasize the exclusiveness and encouragement of the funds to guide enterprises to choose a reasonable financing model. First, Exclusive funds are launched for different market players from a policy level. The second move is tax concession by combining the direct after-tax preferential policies like raising threshold and tax exemption with the before-tax preferential options like tax rebate, investment refund and cost reduction, so as to encourage the private capital investment through the regulation of macroeconomic policies.

(2) Establish experience bridge, realize sharing of advanced experience
It’s essential to advocate the combination of “bring in” and “go out”, reinforce the city collaboration and establish the experience bridge by means of product export, industry forums, project cooperation and so on. And therefore creating a cultural environment which is open, friendly, inclusive and innovative.

5.Conclusion

The process of urban regeneration in China should not only focus on the improvement of outdated facilities, but also pay close attention to the inherence of city culture, the establishment of city image, and the enhancement of city economic. This article divided the government roles under the process of culture-led urban regeneration into planners, guarantor, authorizer, and motivator, following which the policy path of government is suggested for different phases and distinctive functionalities. It made some reference to government decision-makers from the macro level and has good theoretical meaning and practical value.

References

Resilience for construction project-based organizations: definition, critical factors and improvement strategies

He, Q.H.¹, Zheng, M.² and Wang T.³*

Abstract: Organizational resilience has been a research hotspot recently. However, studies concentrated on construct project areas are rather limited. Therefore, this study aims to define and identify the critical factors affecting organizational resilience in construction projects. Firstly, comprehensive literature review was conducted to give a definition and to select potential factors in organizational resilience analysis. Secondly, prove the rationality behind the selected critical factors, based on which construct interview outline. Thirdly, the definition and critical factors were further corrected against the interviewing results and thereby propose management strategies on improving resilience for construction project-based organizations. As a result, there were 15 critical factors and 3 major improvement strategies were identified in total. This article enriches the organizational resilience theory and provides decision-makers with a better understanding to develop strategies to enhance resilience in construction projects.

Key words: organizational resilience; construction project; definition; critical factors; interview.

1 He, Q.H.
Professor, Research Institute of Complex Engineering and Management, School of Economy and Management, Tongji University, 1063 Siping Road, Shanghai 200092, China
E-mail: heqinghua@263.net

2 Zheng, M.
Research Institute of Complex Engineering and Management, School of Economy and Management, Tongji University, 1063 Siping Road, Shanghai 200092, China
E-mail: zhengmian94@hotmail.com

3* Wang T.
Corresponding author, Ph.D candidate. Research Institute of Complex Engineering and Management, School of Economy and Management, Tongji University, 1063 Siping Road, Shanghai 200092, China
E-mail: wangting2016@tongji.edu.cn
1 Introduction

Construction projects are characterized as long-periodic, large-scale, complicated from conceptual stage to final delivery. During the whole construction period, these projects do not only encompass plenty of workers, materials, machines are involved, but some disruptions and negative impacts including natural (earthquake, hurricane etc.) and manmade (political turmoil, terrorism etc.). Even more, the advanced technology increases the complexity of projects and poses threats to the realization of project goals, like quality decline, cost overruns, and even cease of the construction\[1\]. Therefore, increasing number of researchers begin to consider, in such a dynamic, turbulent and unpredictable environment, how can construction projects minimize the negative impacts?

Resilience originates from the Latin word Resiliere, it was first introduced into the realm of ecology by C.S Holling who also defined it as a measure of “the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables\[2\]". Resilience is indeed important to construction project itself. Faced with disruptions and discontinuities, some projects fail and never recover while others overcome quickly and even capitalize on disruptive events to accelerate the construction process. The fundamental reason lies in the difference in organizational resilience of construction projects: highly resilient projects are capable of coping with perturbations caused by uncertainty, but projects with low resilience usually lag in response, unable to adapt\[3\]. However, existing studies on organizational resilience in construction project realm are lagging far behind when compared with other’s such as enterprise resilience etc.\[4\], no matter in theory and in practice.

Therefore, this study aims to investigate organizational resilience in construction project area and present promising suggestions for further improvement. Admittedly, it is rather difficult to adequately summarize practices all around the world as the economic level and management regulations vary substantially across different countries. Thus, this paper determines to carry out a study in mainland China. And to be specific, the research objects include (1) to make a definition, identify critical factors for resilience in organizational-level in construction projects; (2) to examine and revise the definition and critical factors via in-depth interview; (3) to propose improvement strategies for a higher resilience in future practice. The research path is illustrated in Fig 1.

2 Research methodology

A combined research strategy is adopted to conduct this study, including reviews of related literature, brain storming and semi-structured interviews. Publications cited in authoritative academic databases, including Web of Science, Scopus and the most widespread Chinese academic database CNKI, which enables authors gain comprehensive understanding of studies on resilience, especially in organizational resilience. Based on the above understanding, brain storming was conducted on 25 May, 2017 and lasted around 30 minutes with the purpose of objectivity of all critical factors identified from existing papers. The five experts consist of two professors and three senior construction project managers who all have sufficient understanding and construction project experience. Afterwards, semi-structured interviews were performed from 27 May from 6 July, 2017 with 10 experts (including four project managers from consultant company, two from the owner, three site engineers from the contractor and one from supervisory company), who have fruitful experience of construction project management. In each interview, a series of questions in terms of
three main parts, namely basic understandings, critical factors, status-quo and improvement strategies of resilience for construction project-based organizations. Each interview lasts from 30 to 40 minutes, depending on the interviewee’s actual response.

3 Definition and critical factors

3.1 the definition and critical factors of organizational resilience

In 1973, the concept of resilience is first introduced, since then, two typical types of definitions of resilience in ecological areas have been distinguished. One of the definitions can be summarized as “ecological resilience”, which emphasizes on the capacity of one system to absorb changes and still persist after a shock. And the other one is called “engineering resilience”, which defined as resistance to disruption and quick return to the pre-existing equilibrium\(^5\).

Over past few years, the concept of resilience applied to organizations has taken on a wider meaning in management literature. Organizational resilience was firstly illustrated as the capacity to resist and recover from shocks and disasters that could affect an organization or a system either in internal or external\(^4\). Recently, increasing number of scholars have pointed out that organizational resilience is a cross-level concept, and should be viewed as a ‘whole-system’ response to change\(^3\), which means the directed actions of the organization as a whole as enacted by its members working in concert with each other. Representative definitions of organizational resilience can be divided into two parts. On one hand, some perspectives of organizational resilience focus on how organizations can absorb the impacts of external extreme events and quickly restore their performance to a more favorable or pre-impact state in case of any disruptions\(^6\). On the other hand, organizational resilience has been developed by borrowing form the concept of resilience in ecology, focusing on the persistence of organizations when encountering adverse impacts instead of
recovery [7]. The more detailed definitions in existing studies are shown in Table 1.

In addition, organizational resilience is a complicated and multi-dimensional concept. Therefore, how to establish a comprehensive framework of organizational resilience which covers as many dimensions as possible, to accurately describe the resilience of an organization, is one of the most important research topics. Mallak summarized seven characteristics of organizational resilience: perceive experiences constructively, perform positive adaptive behaviors, ensure adequate external resources, expand decision-making boundaries, practice bricolage, develop tolerance for uncertainty, and build virtual role system [8]. Vogus & Sutcliffe emphasized the importance of slack resources, learning and diverse perspectives to organizational resilience, the idea of redundancy is essential to resilience because maintaining adequate redundancies is necessary for responding to unexpected events and operating beyond a comfortable redundancies for too long invites disaster [9]. Lengnick-Hall pointed out three dimensions of organizational resilience: cognitive, behavioral and contextual, and described them from the perspective of human resource management [7]. Norris et al. identified economic development, social capital, community competence, and information & communication as four basic capacities contributing to community resilience [10]. Pal et al. set up a theoretical framework of organizational resilience consisting of four key factors: assets & resourcefulness, dynamic competitiveness, learning and culture [11].

Table 1. Representative definitions in existing papers

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sutcliffe &amp; Vogus</td>
<td>2003</td>
<td>A characteristic or capacity of individuals or organizations, or more specifically (1) the ability to absorb strain and preserve (or improve) functioning despite the presence of adversity (both internal adversity—such as rapid change, lousy leadership, performance and production pressure—and external adversity—such as increasing competition and demands from stakeholders), or (2) an ability to recover or bounce back from untoward events.</td>
</tr>
<tr>
<td>Starr</td>
<td>2003</td>
<td>The ability and capacity to withstand systemic discontinuities and adapt to new risk environments; the ability to effectively align its strategy, operations, management systems, governance structure, and decision-support capabilities so that it can uncover and adjust to continually changing risks, endure disruptions to its primary earnings drivers, and create advantages over less adaptive competitors.</td>
</tr>
<tr>
<td>McManus</td>
<td>2008</td>
<td>A function of an organization’s overall situation awareness, management of keystone vulnerabilities, and adaptive capacity in a complex, dynamic, and interconnected environment.</td>
</tr>
<tr>
<td>Lengnick-Hall</td>
<td>2011</td>
<td>The firm's ability to effectively absorb, develop situation-specific responses to, and ultimately engage in transformative activities to capitalize on disruptive surprises that potentially threaten organization survival.</td>
</tr>
<tr>
<td>Pal</td>
<td>2011</td>
<td>The system’s ability to maintain a growing or constant healthy state over time, despite being subjected to negative and/or destructive events, or to make a quick positive turnaround from one state to the other to finally enter the healthy state.</td>
</tr>
<tr>
<td>British Standard</td>
<td>2014</td>
<td>The ability of an organization to anticipate, prepare for, respond and adapt to incremental change and sudden disruptions in order to survive and prosper.</td>
</tr>
</tbody>
</table>

3.2 Critical factors of resilience for construction project-based organizations

Construction projects are typical project-based organizations, even though there are few studies of organizational resilience focusing on construction project areas. The general characteristics of organizational resilience, especially of those organizations that belong to complex systems, are usually applicable to organizational resilience of construction projects as well. Therefore, we propose the following definition: the capacity of an organization of construction project to absorb pressure, develop positive adaptive behaviors, and quickly recover from adverse impacts in order to preserve functions to achieve expected targets despite of being subjected to disruptive events in a complex and dynamic environment.
Although existing papers regarding resilience studies differ in research objects, research backgrounds, research methods or data quality etc. which could influence dimensions or factors identified. It is recognized by most scholars that resilience is a set of capacities consisting of critical factors. Eventually, the three-dimension framework made up of absorptive, adaptive and restorative capacity was developed in this study after the brainstorming to identify critical factors and experts were invited to attend the discussion on 25 May, 2017. Each factor is carefully analyzed under the background of construction projects and with consideration of characteristics of construction projects. A total of 15 critical factors of resilience for construction project-based organizations are identified, including four for absorptive capacity (slack resources, hazard awareness, planning strategies, organizational learning), six for adaptive capacity (organizing capacity, leadership, coordination, communication, information and knowledge, innovation), and five for restorative capacity (acceleration capacity, external resources, recovery priorities, loss assessment, insurance awareness).

4 Results and discussions

4.1 Interview results and discussions

Respondents basically agree with the definition which defined in Section 3.2 of this study, and the realization of project objectives is emphasized by most of respondents. Construction project-based organizations are typical types of temporary organizations, and the task is usually the reason why a temporary organization is set up. This characteristic determines that even if disturbed by adverse impacts, the target should not be changed easily. In addition, two respondents pointed out that recovery is possibly necessarily needed, while a certain amount of deformation should be acceptable as long as realization of project objectives. Also, critical factors have been adjusted into five factors in absorptive capacity, six in adaptive capacity and four in restorative capacity, (shown in Table 2 in details). And other major results are discussed as follow:

(1) “Redundancy” is most frequent factor mentioned in absorptive capacity

Eight of ten respondents mentioned “redundancy” in their interview. Unlike permanent organizations, a construction project organization consists of many stakeholders and a certain degree of redundancy in human resources is necessary. For example, if three staff in the same team are assigned similar tasks, when one of them is under pressure, the rest two can offer effective support. This is a type of redundancy in human resource allocation, which guarantees the project organization still be capable to achieve preset objectives despite disruptive events. In addition, financial redundancy is also essential and “insurance” is mostly mentioned during interview process. In mainland China, it is prevalent that stakeholders purchase some kinds of compulsory insurances.

(2) Good project planning is the basis of redundancy.

Project planning requires a comprehensive understandings of project requirements, difficult points, potential risks, etc. to achieve a clear and profound understanding of the project. Generally, organizations vary from characteristics of each project, thus the structure of organization can only be set up after in-depth analysis of the project characteristics in the prophase; meanwhile, redundancy mechanism should be carefully considered, which helps to make organization resilient.

(3) Risk analysis is more important than hazard awareness

There are six out of ten respondents mentioned “risk” in interviews. Of course, risk objectively exists and risk management is a core idea that throughout the whole process of construction projects.
As many risks in construction projects can be predicted to a certain extent, it is important to reasonably use of risk analysis to reach a clear understanding of potential risks and take preventive measures in advance, ensuring strong absorptive capacity against adverse risk events. In actual, hazard awareness is not likely to be very helpful for an organization to set up feasible solutions to practical problems; instead, risk analysis based on a large amount of detailed and reliable information is actually important.

(4) Centralized decision-making is important to adaptive capacity

Among the factors of adaptive capacity, organizing capacity is complicated. In construction projects, most interviewers pointed out that the horizontal structure of project organizations is not necessarily helpful to deal with crises; by contrast, decentralized decision-making mechanism is recognized to be more helpful in many cases. This is because that, in emergency, centralized decision-making model is generally more efficient to make decisions and deal with unexpected events.

(5) Loss assessment and re-planning are the two critical factors to recovery capacity

When crises occur, loss assessment should be carried out in no time to assess extent of actual losses, identifying which parts still function well, which parts need reinforcements, repair or complete reconstruction, etc. After loss assessment, re-planning is also critical. Disruptive events may lead to great adjustments for previous project plans, thus the organization needs to develop new or adjusted plans that fit new situations to help the project recover and still able to achieve targets. In re-planning, priorities of activities needed to be recovered should be consider carefully, in other words, reasonable orders of recovery activities should be done.

4.2 Management strategies of resilience for construction project-based organization

- Emphasis on preliminary planning and redundancy mechanism
  Planning in pre-stage should be emphasized, with in-depth analysis of the project to determine its characteristics and requirements. Besides, redundancy mechanism should be preset in the organization to ensure that the capacities of participants can meet the requirements and fully cover the risks. For example, for a project with high structural difficulty, apart from a design group skilled in structure, a consulting group and an auditing unit may also be embodied in the project organization, so that the capacities of multiple groups can be combined to ensure the structural safety.

- Making plans of emergencies in advance
  When risk management cannot fulfill the purpose of effective protection, or some unpredictable disastrous events occur, there should be plans in place to reduce the personal, financial and environmental losses. Emergency plans are based on safety evaluation and the conditions of specific facilities and environments, and they provide scientific and effective arrangements for agencies, personnel, equipment, facilities and conditions of emergency rescue, course and program of action, methods and procedures for controlling loss aggravation, and so on forth.

- Implement objective management and hierarchical control
  Construction projects are characterized with clear and definite objectives. In order to ensure the fulfillment of the objectives despite all kinds of uncertainties, objective management and hierarchical control are indispensable. During the formulation of the objective management system, low-level objectives should be strictly controlled, while high-level objectives should be moderately easy, leaving some room for management and making the project resilient. Taking Shanghai
Disneyland construction project for instance, if the objective of government level was set on June 1st, the objective of Walt Disney company level may be scheduled on May 1st. Similarly, the project levels may be scheduled on April 1st, and the general contractor level’s needs to be further controlled on March 1st. In this way, the objective system that is hierarchical controlled leaves room for adjustment in the condition that unexpected disruptive events have negative impacts on the construction schedule, so that the realization of overall objectives will not be affected.

Table 2. Critical factors adjusted based on interview results

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Factor</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorptive Capacity</td>
<td>Slack resources</td>
<td>Reserve adequate margin in resources and rationalize the distribution of them; make sure organizational capabilities meet the requirements of the project.</td>
</tr>
<tr>
<td></td>
<td>Risk analysis</td>
<td>Identify sources of risk, anticipate the probability and consequences of risk events.</td>
</tr>
<tr>
<td></td>
<td>Planning strategies</td>
<td>Make careful planning in the prophase, set flexible and adjustable plans, simulate emergent situations and practice how to act.</td>
</tr>
<tr>
<td></td>
<td>Insurance awareness</td>
<td>Arrange the necessary insurance cover, get the hang of the details of insurance policy including coverage, exclusions, liability identification mechanism, compensation procedures, etc.</td>
</tr>
<tr>
<td></td>
<td>Organizational learning</td>
<td>Create, share and apply knowledge; transmit and share information efficiently across the organization to reach consistent recognition.</td>
</tr>
<tr>
<td>Adaptive Capacity</td>
<td>Organizing capacity</td>
<td>Flexibly utilize a diversity of organizing methods and maximize the use of project resources, including setting up good authorization mechanism and emergency decision mechanism.</td>
</tr>
<tr>
<td></td>
<td>Leadership</td>
<td>Make continuous assessment on project objectives and work procedures, as well as provide reliable management and decisions in times of crises.</td>
</tr>
<tr>
<td></td>
<td>Coordination</td>
<td>Maintain good relationships among the parties inside and outside the project through communication, collaboration and cooperation, focusing on the common interest.</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>Wisely choose the content, object and timing to communicate, have good communication ways and channels.</td>
</tr>
<tr>
<td></td>
<td>Information and knowledge</td>
<td>Capture useful information in the environment, integrate project information, and improve the knowledge level of project personnel.</td>
</tr>
<tr>
<td></td>
<td>Innovation</td>
<td>Test, verify and apply new or improved products, services and processes, adopt new ideas and methods to solve existing or emerging problems.</td>
</tr>
<tr>
<td>Restorative Capacity</td>
<td>Loss assessment</td>
<td>Investigate, count and verify the range and extent of actual losses.</td>
</tr>
<tr>
<td></td>
<td>Re-planning</td>
<td>Make new or adjusted plans that fit new situations, understand the priorities of recovery issues and make arrangements accordingly.</td>
</tr>
<tr>
<td></td>
<td>External resources</td>
<td>Obtain resources and assistance from organizations outside the project, which help solve problems that are hard to solve on its own or cost too high to solve.</td>
</tr>
<tr>
<td></td>
<td>Acceleration Capacity</td>
<td>Be able to offset the effects of disturbance on project schedule by accelerate production.</td>
</tr>
</tbody>
</table>
5 Conclusions

In recent years, the concepts of resilience have become very topical and popular. However, studies concentrated on construct project areas are rather limited. Therefore, with the consideration of general characteristics of construction project, this study defined the concept of organizational resilience in construction project area; and identified 15 critical factors concerning organizational resilience based on a wide literature review and brainstorm. Afterwards, in-depth interviews conducted to help to revise the definition as well as critical factors. Finally, three major management strategies were put forward. As an exploratory research, this article enriches organizational resilience theory and provides decision-makers with a better understanding to develop strategies to improve resilience in construction project.

Acknowledgment

The authors wish to express our sincere gratitude to the National Natural Science Foundation of China (Grant No. 71571137, No. 71390523) for their financial support on this research.

References

A Framework of Enhanced Location Based Management System Using Simulation Models


Abstract: Critical Path Method is currently criticized for being unable to protect production efficiency. To address the deficiencies of CPM, Location Based Management System was developed. LBMS takes repetitive locations as the computing unit and containers of project elements, through which resources flow in sequences. By incorporating multiple theories and methods in lean construction, it is continuous production that is highlighted in LBMS. To achieve the goal, LBMS needs to collect detailed project data at specific location level, e.g. room and corridor to support related calculation. LBMS by now are mainly used for schedule and costs estimation. However, with the rich data, the potential of LBMS to better accommodate the attributes and interactions of dynamic project elements, e.g. labor, materials and drawings have not been adequately exploited. Fortunately, the current deficiencies can be addressed by applying computer simulations. This paper first introduces LBMS and mainstream simulation methods; then develops a framework that integrates Discrete Event Simulation, System Dynamics and Agent Based Model into LBMS. The framework is formed by a database, a simulation engine and a demonstration tool, which aims to improve decision making by taking individual attributes and interactions and risky processes into consideration. Finally, a case study is introduced to demonstrate how the proposed framework works.

Keywords: Location Based Management; Computer Simulation; Integrated Framework

1* Wu, C.K.
Corresponding author, Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: 404835780@qq.com

2 Wang, J.
School of Built Environment, Department of Humanity, Curtin University, Australia
E-mail: jun.wang15@postgrad.curtin.edu.au

3 Wang, P.
School of Built Environment, Department of Humanity, Curtin University, Australia
E-mail: peng.wang10@postgrad.curtin.edu.au

4 Wang, X.Y.
School of Built Environment, Department of Humanity, Curtin University, Australia
E-mail: Xiangyu.Wang@curtin.edu.au
1 Introduction

Critical Path Method (CPM) is the traditional algorithm for project scheduling. In CPM, activities are the basic units and the project duration is estimated by summing the durations of activities that take the longest time\[^{1}\]. However, studies point out CPM overemphasizes schedule compression while to some extent neglects the importance of continuous production. As a result, numerous suspensions appears due to task interruptions. In contrast, Location Based Management System (LBMS) takes repetitive and hierarchical locations, such as floor and room as the computing unit and containers of project elements, through which resources, such as labors and equipment flow. LBMS aims to protect continuous production. Consequently, the duration may be longer but the risk is lower\[^{2}\]. Besides, higher sustainability can be achieved\[^{3}\]. However, implementation of LBMS is still in infancy. Most projects adopt LBMS only for computation of schedule and costs. Given the development of information technologies, LBMS could be enhanced by incorporating various innovations in IT sector\[^{4,5}\], e.g., computer simulations. Discrete Event Simulation (DES), System Dynamics (SD) and Agent Based Model (ABM) are the most extensively used simulation techniques by now. Nevertheless, few study attempts to integrate them in LBMS. Thus, this paper builds an integrated framework combing DES, ABM and SD to improve LBMS functionality.

2 Background Knowledge

In this section, LBMS is introduced first, followed by the concepts, strengths and applications of the three simulation techniques.

![Figure. 1 Example of Flow Line Diagram in LBMS](image)

LBMS requires information in four aspects, namely location breakdown structure (LBS), layered logics (i.e. dependencies of tasks), task quantities in each location and labor productivity. The entire project is divided into smaller locations complying a well-organized hierarchy (e.g. building, floor, apartment and room). The principle is to ensure only one activity can proceed without interventions at the lowest location level. Next, activities are listed while quantities to complete the activities are computed. Then, activities are combined to form tasks flowing through locations. For instance, the task interior wall erection is conducted at all rooms and comprise three activities, i.e. installing the wall panel on one site, cabling and installing the panel on the other side. Each of these activities in turn involves certain amounts of quantities. Task dependencies are established...
based on five layer-logic. Layer 1 logic forces activities of different tasks to be completed in sequence within a location; layer 2 logic links activities with different LBS levels (e.g. to link tasks of exterior wall installation, which floor based task to ceiling, which is room based task); layer 3 logic is set between activities of the same task in different locations; layer 4 logic is applied in cyclic works (e.g. framework erection, rebar reinforcing and concreting); layer 5 logic is used to link activities when there are more than one LBS. Given productivity data, duration of each task is calculated and project progress is represented by flow lines. As shown in Fig. 1, the slope of lines exhibits productivity while gaps of tasks reflect interruptions. In order to minimize interruptions, available approaches include changing quantities, adjusting crew size, overtime working, manipulating task sequences and adding buffers[2].

Figure. 2 Example of Simulation Models (top left: ABM, top right SD, bottom DES)

Compared with traditional CPM method, LBMS comprises more complexity and unpredictability since: 1) the project management of LBMS are at specific location level, which requires more detailed and accurate data processing and utilization. 2) To keep continuity, which is the upmost goal of LBMS. Interactions among many elements, such as labor, task and material have to be considered. To address these challenges, simulations techniques are feasible alternatives because they are particularly useful if: 1) the objects of interest involve large uncertainties; 2) outcomes heavily depend on interactions among system entities; 3) the processes are dynamic[6].

Fig. 2 show the basic structures of the three simulation techniques. DES specializes in modelling discrete processes where entities consume resources to conduct activities. Resources availability, activities sequence and the time to complete an activity are the most common DES parameters. However, DES more or less ignores the diversities and interactions of individual elements[7]. In contrast, ABM is made up by intelligent agents which are assigned unique parameters and are able to make dynamic decisions by sensing the environment, constantly interacting with environment and other agents to achieve the pre-defined goals. The top-level system is determined by agents
behaviors at microscopic level\cite{8}. The modeler defines states to describe status that an agent may experience, rules that trigger transitions between states and actions that agents take when they are under certain states or conduct certain transitions. Last but not least, SD can be regarded as an experimental method which provides a rigorous way for description, exploration and analysis of complex systems considering all influencing factors. SD model consists of dynamic variables, flows and stocks. Stocks records system performances, which is computed based on the values of the other two. These elements are connected and form feedback loops according to causality\cite{9}. In practice, DES are more applied in estimating schedule and costs of sequential construction tasks\cite{7}. ABM is usually adopted to model human behaviors and interactions in various scenarios, such as emergencies\cite{10}. Finally, SD is used to compute macroscopic metrics, such as holistic project duration, costs and labor composition\cite{11}. It is clear that the three techniques have unique strengths and can complement each other. Hence, increasing studies begin to develop integrated simulation models, including but not limited to post-disaster restoration, workplace safety management and equipment layout optimization\cite{10}.

In a word, LBMS involves intensive information processing, numerous unpredictable activities and complex interactions, which match the strengths of simulation techniques, especially when they are applied in integrated manner.

3 Methodology

The framework consists of three modules: project database, simulation engine and demonstration tools. The entire structure of the framework and the information flows are shown in Figure 3.

3.1 LBMS Database

The LBMS database provides information required by the simulation. Current database techniques has already been able to collect, store and reuse various graphical and non-graphical information of construction tasks. Because a project database is frequently accessed by different disciplines, the framework suggests to develop an individual memory space that especially extracts and stores information for LBMS to avoid intervention. To make the database function effectively, the user should be aware that: 1) Apart from data collected in normal project management, e.g. quantities and costs, more information such as the possibility of issuing change orders and the timing of
material deliveries are also needed. 2) Information should reflect real-time and dynamic onsite conditions instead of using merely historical data. For instance, one should ask for commitments from the subcontractors to access accurate productivity data. 3) Information must be reorganized, stored and managed at location level. In addition, since only numeric data is used in simulations, XML and XLS are the formats to serve data exchange. Besides, an Application Program Interface (API) should be developed as the intermedium for automatically export and import.

3.2 Integrated Simulation Engine

DES, ABM an SD are used to address different problems. In ABM, there are two types of agents, namely, locations and labor crews. The model adequately accommodates unique attributes, actions and interactions of these agents and compute real-time productivity. Results of ABM are fed into SD model, which monitors the construction progress, controls commencement of succeeding tasks and evaluates project performances (e.g. costs, duration and labor utilization). DES focuses on independent external events that are to some degree out of control from project manager but still directly affect project outcomes, such as delivery of design drawings or materials.

For both crews and locations agents in ABM, a set of parameters are carefully selected to which values are assigned. For location agents, these parameters include tasks required to complete the location, along with the quantity, difficulty, drawing and materials for each task. Location agents should at least have four states: “No work”, “Construction”, “Inspection” and “Completed” (see Figure 2). On the other hand, parameters of crew agents reflect personal features like skill level, daily payments, error rates, learning speed and possibility of return if leave. States of crew agents can basically consists of “idle”, “normal working”, “overtime working” and “rest” depending on the timing and behavior agents. The design of states and transition rules in ABM are based on studies of LBMS and labor behaviors. With data generated from ABM, dynamic variables in SD model elements summarize productivity of crew agents to determine the holistic production rate. Provided the production rate, SD 1) calculates completion of planned schedule to control start of tasks in subsequent locations; 2) proceeds quality inspections for completed tasks, which may result in rework if related standards are not met; 3) produces metrics of project performances, such as total costs, schedule deviation, labor utilization and wastes due to task interruptions. The framework refers to existing SD models to establish links among SD elements and numerical equations in these links[7].

3.3 Results Demonstration Module

One drawback of simulation is the difficulty to graphically explain numeric results in a way well understood in AEC sector. Thus, to take fully use of the results and make it easy co-ordinate with other project team members, a demonstration tool is indispensable. LBMS software like Visco is implemented to represent the construction progress with flow-line diagram. Besides, other tools can be selected as well, depending on specific purposes. For instances, if project progress is the main concern, schedule software like Microsoft Project and 4D BIM software such as Naviswork is applicable; if the manager cares more about labor utilization and costs saving, 5D BIM like Golden could be the option[8]. In addition, for convenience, project information is all exported into XML format to be fed into the simulation engine and mapped to corresponding digital elements in the adopted demonstration software. Apart from demonstration tools, one should note that other components, such as information types stored in the database and the parameters embedded in simulation models are all adjustable according to specific conditions and standards. Thus the
framework is flexible and practical.

4 Case Study

The case project is a hotel in Orhan, Algeria. The project is managed by CSCEC which is a large Chinese contractor. The features of LBMS can be well illustrated since: 1) locations are classified into groups with distinct attributes; 2) material deliveries in such international projects are risky, where many cases must be shipped overseas; 3) given the limited availability of overseas labors and requirements of local laws, the general contractor usually has to employ local labors. As a result, the crew consists of multi-national labors who are quite different in many aspects, such as skill level, religion, culture and working habits.

In each floor, locations are classified into three groups: office, public area and ballroom, where differences exist in quantities, materials and required labor skills. Three tasks: wall plastering, ceiling and tiling are conducted in sequence where office rooms are completed first, followed by ballroom then public area. Both foreign and daily paid local labors are utilized to perform these tasks. In addition, material procurement is a critical external process due to the owner explicitly requires a Europe brand ceramic tile to be laid in the ballroom. Data is stored in Access database.

Anylogic 7.3 is adopted as the simulation engine. Figure 4 shows the relating data. Two issues, labor arrangement and material procurement are modelled to present how the framework controls production. Continuity, resultant costs and duration are the project performance metrics.

![Figure 4. Relating Data in the Case Study](image)

### 4.1 Issue 1: Labor Arrangement

Foreign labors are expensive but able to work with high productivity immediately after arriving at site. In contrast, local labors are cheap but less skillful and have to learn before reaching rational productivity. The number of local labors is twice or triple of foreign labors. There are three types of interaction: 1) if tasks are interrupted (i.e. the subsequent tasks proceed too fast while the precedent tasks have not completed), production will suspend based on the technical dependencies and all labors become idle; 2) if the crews that undertake tasks include both of the labor types, the productivity of local labors will increase and their rework rate will reduce; 3) the optimum crew size is four, either exceeded or inadequate Manning will affect the production negatively. Different policies of crew formation and recruitment are tested and Table 1 shows the results.

<table>
<thead>
<tr>
<th>Crew Parameter</th>
<th>Foreign</th>
<th>Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>daily cost</td>
<td>25 $</td>
<td>11.2 $</td>
</tr>
<tr>
<td>plastering productivity</td>
<td>3.5 m/ha * U</td>
<td>2 m/ha * U</td>
</tr>
<tr>
<td>ceiling productivity</td>
<td>2.5 m/ha * U</td>
<td>1 m/ha * U</td>
</tr>
<tr>
<td>tiling productivity</td>
<td>1.2 m/ha * U</td>
<td>0.5 m/ha * U</td>
</tr>
<tr>
<td>error rate</td>
<td>0.05 * U</td>
<td>0.15 * U</td>
</tr>
</tbody>
</table>

Table 1. Comparison between different labor arrangement options

<table>
<thead>
<tr>
<th></th>
<th>3 F&amp;6 L</th>
<th>3 F&amp;9 L</th>
<th>6 F&amp;6 L</th>
<th>6 F&amp;12 L</th>
<th>6 F&amp;15 L</th>
<th>6 F&amp;18 L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Costs</td>
<td>18918 $</td>
<td>20004 $</td>
<td>18776 $</td>
<td>20238 $</td>
<td>23970 $</td>
<td>27212 $</td>
</tr>
<tr>
<td>Duration</td>
<td>434 hours</td>
<td>398 hours</td>
<td>294 hours</td>
<td>262 hours</td>
<td>334 hours</td>
<td>373 hours</td>
</tr>
<tr>
<td>Interruption</td>
<td>122 hours</td>
<td>111 hours</td>
<td>87 hours</td>
<td>82 hours</td>
<td>99 hours</td>
<td>125 hours</td>
</tr>
</tbody>
</table>
PS: F refers to foreign labors and L refers to local labors

Six options are tested when materials are assumed to be delivered on time. Two facts are identified: 1) option 1–3 illustrate that foreign labors are significantly more effective on compressing schedule and controlling costs because learning process is saved and rework due to low quality are minimized. 2) option 3–6 show the effects of overmanning. Too many labors will result in over fast succeeding tasks and lead to suspension. Besides, within the tasks, productivity is reduced as well if the optimum crew size is exceeded. More importantly, labors should be properly allocated to align construction especially if material delivery is considered, which is discussed below.

4.1 Issue 2: Material Procurement

The special requirement of ceramic tile in the ballroom makes start of the tiling task unpredictable. To shed light on the uncertainty, three scenarios are modelled: 1) order materials at the beginning of project, 2) after plastering in the ballroom; 3) after ceiling in the ballroom and 4) after tiling in all office rooms. The material takes dozens of days to arrive and causes large interruptions even ordered once the project begins. To reduce interruption, material is ordered with a lead, which is assumed to be ten days. Also, labor policy is changed: 1) tiling labor will be called on site until the material arrives; 2) the number of crew of fast predecessors, namely plastering and ceiling is reduced to two and one respectively. Consequently, most interruptions are eliminated with an extension of only two days, see Figure 5.

![Figure 5. Effects of Management Methods](image)

5 Discussion and Conclusion

To this end, some suggestions can be provided: 1) As long as the local policies are not violated, companies should try to employ more foreign labors, because the extra costs will be outweighed by the low rework rates and high productivity. 2) Procurement is highly unpredictable. Project
managers should be aware of the time and risk of oversea material procurement to take proactive actions. Moreover, procurement could be a useful tool to avoid interruptions because some fast subsequent tasks can’t start without certain materials. Hence, procurement and labor policies can be combined to strengthen the control. 3) Information platform like BIM should be implemented to serve as in data repository\(^1\). There are three limitations: 1) Scenario is abstracted and more factors could have been included, such as weather and changes. 2) Other management methods such as changing task sequences can also be tested. 3) Some techniques, like data exchange API are in experimental stages. Despite all, basic functions of the framework have been demonstrated.

The paper builds an integrated simulation framework of LBMS. The framework follows the LBMS principles and takes uses of strengths of ABM, SD and DES to model productivity, track construction progress and evaluate risk of external events. Despite the limitations, the framework provides a novel way to implement LBMS thus contributes to existing study.

**Acknowledgment**

The authors wish to extend their gratitude to the KAEFER Integrated Services Pty Ltd for their financial support.

**References**


System reliability optimization research for the construction project quality-cost tradeoff via modified Genetic Algorithm

Xie, Z.J.¹, Gu, T.Y.²*, Xu, P.P.³, Wang, D.⁴

Abstract: Most comments on the quality of constructions in China are negative. There are two reasons accounting for this phenomenon. The first is that the quality problem has not got enough attention, and the second is that it’s not easy to control the quality under the constraint of cost and time. Authors analyze the question via system reliability optimization theory. Firstly, Authors quantify the quality by applying the reliability principle and find out physical arrangements among sub-projects which compose the whole construction project. Then we can get the system reliability structural function through the logical operation. According to the nonlinear cost-reliability function, it is easy to solve the problem by mathematical method. The Genetic Algorithm is used to optimize this question based on MATLAB. With the analysis of a case study, the model is proved to be feasible and accurate. Decision makers can easily and directly achieve the information about the quality and take measures to improve the reliability of the construction project.

Key words: Quality; System reliability theory; System reliability optimization; Genetic Algorithm

¹ Xie, Z.J.
Faculty of Construction Management and Real Estate, Chongqing University

² * Gu, T.Y.
Corresponding author, Faculty of Construction Management and Real Estate, Chongqing University
E-mail: gladys1111@163.com

³ Xu, P.P.
Faculty of Construction Management and Real Estate, Chongqing University

⁴ Wang, D
Faculty of Construction Management and Real Estate, Chongqing University
1 Introduction

As one of the four pillar industries of China, Construction industry has always been an important industry. In the next 50 years, the urbanization rate in China will reach 76%, Chinese construction market has a great potential for development.

A construction project can be seen as a large-scale complicated system which is consist of both sub-projects and risks. Some measures should be taken to reduce such kind of risks in order to improve the reliability. Reliability means the ability of a system or component to perform its required functions under stated conditions\textsuperscript{1}. System reliability optimization refers to producing better products at lower cost\textsuperscript{2}. In other words, we want to achieve the highest system reliability under the resource constraints.

This paper focuses on the relationship between cost and quality and wants to establish the model of the construction project quality-cost tradeoff. The authors quantify the quality and uncertainty of the construction with the system reliability optimization to improve the reliability.

2 Literature Review

Early studies on project management often focus on improving the relationship between time and cost. James E. and Kelly Jr.\textsuperscript{3} present the CPM(critical path method), aiming at analyzing the relationship between time and cost. Siemens\textsuperscript{4} and Goyal\textsuperscript{5} find the linear function about time and cost. Based on these researches, Khang and Myint\textsuperscript{6} use the linear programming theory to optimize the relationship among time, cost and quality, and apply the model into a concrete plant project. Patrick O’Connor and others\textsuperscript{7} define the reliability as the ability for a system to perform a given function within a specified time period under given constraints. E-Rayes and Kandil\textsuperscript{8} establish a multi-objective optimization model of time, cost and quality based on the genetic algorithm. In 2012, Ran Tao and Chi-Ming Tam\textsuperscript{9} from the City University of Hong Kong use system reliability optimization theory to quantify the quality of construction and build the model. They use LM+UG to find the optimal solution.

In previous researches, they seldom take the relationship between quality and cost into consideration from the perspective of the whole building. This paper uses system reliability optimization to quantify the construction and optimize the model with the modified genetic algorithm.

3 System Reliability Theory

System reliability refers to the probability that a sub-project of completing a defined function without breakdowns in a specified condition (time or environment). System reliability model refers to the conceptual model of the logical relationships between the elements and components of the system from the perspective of reliability. In order to establish the system reliability model, we need to convert the physical working relationships among sub-projects to logical relationships among elements. Rausand and Høyland\textsuperscript{10} use four methods to quantify the reliability: time to failure, reliability function, failure rate function and mean time to failure. In this paper, we use the reliability function to quantify the quality of sub-projects. Reliability function \(R(t)\) refers to the probability that sub-projects can operate without breakdown. So \(R(t)\) is defined as:
\[ R(t) = Pr(T > t) = 1 - F(t) = 1 - \int_0^t f(u) du = \int_t^\infty f(u) du \]

For the whole construction project, each project is composed of many sub-projects. The overall reliability of the project is determined by physical relationships among sub-projects and its own reliability level. According to Nachlas [11], there are four main types in system reliability model: series structure, parallel structure, voting redundant structure and complex structure. In the series structure, only if all sub-projects are effective, the entire system will be effective. The reliability model is shown in Fig 1. The structure function is defined as follows:

\[ R_s(t) = R_1(t) \cdot R_2(t) \cdot R_3(t) \cdots R_n(t) = \prod_{i=1}^n R_i(t) \]

The second is parallel structure. In the system, at least one sub-project is effective, and then the whole system can be effective. The reliability model is shown in Fig 2. The structure function is defined as follows:

\[ R_p(t) = 1 - F_s(t) = \prod_{i=1}^n [1 - R_i(t)] \]

The third is voting redundant structure. Redundancy refers to repeating some sub-projects. When a system does not work, the redundant sub-system intervenes and undertakes responsibility for the work from the defective sub-project in order to reduce the system downtime. For example, n out of k structure refers to that in the system, at least k subprojects are valid, then the system is effective. 2/3 structure is shown in Fig 3. The structure function is defined as follows:

\[ R_v(t) = 1 - [1 - R_1(t)] \cdot [1 - R_2(t)] \cdot [1 - R_3(t)] \]

The last is complex structure. In most realistic cases, most of the system structure is often a complex structure. The complex structure is composed of the series structure and the parallel structure.

### 4 System Reliability Optimization Model of the Construction Project

System reliability optimization is to find a best design under required resource constraints, so that the system can achieve the highest reliability. There are four main steps to build the system
reliability optimization model[9]:

Firstly, according to the characteristics of construction activities, we define the main construction activities and divide them into different sub-projects. The second step has two parallel parts. The main task of the first part is to use the reliability theory to quantify the quality of construction projects. This paper uses reliability function to quantify the quality. When \( t=0 \), it indicates the time when the sub-project is completed. Hence the corresponding reliability level \( R_i(0) \) represents the reliability level of the \( i \)th sub-project. Then we establish the relationship between the basic cost and the actual cost based on Fang’s research[11]:

\[
C(i) = T(i) \cdot \left\{ \tan \left[ \frac{\pi}{2} \cdot \frac{R_i(1)}{R_i(1)_{min}} \right] \right\}^{1-RIFI}
\]

\( i \) refers to the \( i \)th sub-project. \( C(i) \) refers to the actual cost of the \( i \)th sub-project. \( T(i) \) refers to the basic cost of the \( i \)th sub-project. The basic cost refers to the \( i \)th sub-project is finished with the lowest reliability. \( R_i(1)_{min} \) refers to the minimum reliability required for the \( i \)th sub-project. \( RIFI \) refers to the reliability improvement flexibility index of the project. The main task of the second part is to define and distinguish physical relationships among sub-projects, build the system reliability model and establish the system reliability function \( R_s(t) \). The third step is to build the objective function and constraint conditions. The final step is to use genetic algorithm to find the optimal solution based on the MATLAB.

5 Modified Genetic Algorithm

“Natural selection” is the core of the Darwinian evolution. All creatures in nature will experience the survival, reproduction, evolution or elimination, which reflects the natural adaptability. Those who have weak Adaptive ability will be eliminated and those who have strong adaptive ability will survive. As a result, their strong adaptive genes will be preserved by multiplying and become part of the racial gene. According to the natural behavior of these animals, people were inspired and created the genetic algorithm. The computer simulation is a kind of computer simulation algorithm based on biological behavior. The genetic algorithm works by simulating the process of gene knockout and inheritance.

The three most important operators in genetic algorithms are: selection, crossover and mutation. The main steps are: encoding and decoding, generation of initial population, calculation of fitness values, selection, crossover and mutation.

The first step is encoding and decoding. In general, decision variables of practical problems are made up of decimal numbers. Decision variables will be transformed to strings by coding. This means an individual is represented as a string which is composed of binary numbers. The second step is to generate the initial group. We randomly generate the initial population consisting of \( n \) groups, that is randomly generate \( n \) initial binary strings. Each binary string refers to an individual and each individual is an initial solution. The third step is to calculate the fitness value. The fitness value represents the individual’s adaptability to the environment. The degree of adaptation of the individual to the environment is represented by the magnitude of the fitness value. The magnitude of the fitness value indicates the probability that the individual will be selected. If the fitness is bigger, then the probability of the individual be selected and transmitted is higher. If the fitness is smaller, the probability of the individual be eliminated is higher.

The forth and the most important step in this paper is selection. The selection is to select the
best individual from the current generation according to certain methods so that they can be preserved and inherited to the next generation. If the fitness value of the solution is bigger, the solution will be more easily inherited to the next generation. This behavior is like the process of the survival of the fittest in nature, the fitness value is the reflection of the degree of adaptation to nature. In selection, this paper improves the traditional genetic algorithm and uses the optimal preservation strategy and betting round selection method. At the beginning, we will find two groups of solutions which have maximum and minimum fitness value in the current population. In order to ensure that the solution with the maximum fitness will not be destroyed by the crossover and mutation operation, we allow the group to not enter the crossover and mutation operations, but to directly go into the next generation population. Then we choose the remaining individuals by betting rounds. It is possible to ensure that the fitness value of each individual which has been screened out has always been increased. In this way, the result can be more accurate. If we do not take this method, maybe an optimal solution in previous round will not be selected into the next round by accident.

The fifth step is crossover. Crossover is the most significant step in genetic algorithms. For each solution, we cross it with a given probability. If we decide to cross a set of solutions, select the cross point randomly, exchange chromosomes and form new solutions. In this paper, we adopt the single point crossover, that is, only one position in the code string is selected as a cross point. The last step is mutation. The mutation refers to selecting one bit for each code string from the population to be mutated. Crossover is the main way to generate new individuals, and mutation is the auxiliary way to generate new individuals. The probability of mutation is low, about 0.001 to 0.1. The coding method adopted in this paper is binary coding, so we only need to randomly select the position of the mutation point with the mutation probability, and then reserve the value of the position, which means change 1 to 0, or 0 to 1.

6 Case Study and Discussion

We choose a high-rise residence in Xi’an as an example[12]. The project is huge and contains more than 30 subprojects. The data come from the standard floor. The simplified network diagram and basic cost of each subproject is shown in Fig 3. According to the requirement, the minimum system reliability is 0.5, and the total cost must be less than 600000 yuan.

![System reliability block diagram of the case study](image)

Firstly, we divide the main sub-projects into seven sub-projects. Secondly, according to the network diagram, we tease out the logical relationships among physical arrangements and get the system reliability structure function \( R(s) \). In this case, we want to maximize system reliability \( R(s) \). Then we need to take restrictions into consideration and the model is shown as follows:

\[
 f(s) = \text{Max } R(s) \quad \text{(objective function: maximize system reliability)}
\]
\[
\begin{align*}
&= \text{Max } R_1 \cdot (1 - R_2) \cdot (1 - R_3) \cdot R_4 \cdot (1 - R_5) \\
\text{s.t. } \sum_{i=1}^{7} T(i) \cdot \{\tan(\frac{R(i)}{2} - \frac{R(i)}{R(i)_{\text{min}}})\}^{(1 - RIFI)} \leq 600000 \quad \text{(cost restriction)} \\
&\quad 0.5 \leq R(i) \leq 1 \quad i=1,2,3...7
\end{align*}
\]

Then we use MATLAB and genetic algorithm to calculate the optimal system reliability and the reliability level of each sub-project. Then we will have a brief analysis on the code.

In the case, the population size is 200 (\text{popsize}=200), the probability of crossover is 0.9 (\text{pc}=0.9) and the probability of mutation is 0.01 (\text{pm}=0.01). The first step is to decode and encode. We need to convert binary code to decimal code. The second step is generating the original population. In this case, we randomly generate an initial matrix which size is \(200 \times 91\) and each unit is \{0,1\}. The third step is to calculate the fitness value. Because the total cost must smaller than 600000 yuan, we need to do punishment on the objective function whose value is bigger than 600000 yuan. In this paper, the punishment is to multiply the objective function value by 0.5 to decrease the probability of being selected.

The forth step is selection and it is also the innovation of this article. In this case, in order to ensure that the fitness value of the optimal solution in the new population after circulation has been improved continuously, we adopt the optimal preservation strategy. After calculating the fitness value, the solution which has the maximum value can be directly entered the next circulation without selection, mutation and crossover. In this way, we can improve the accuracy of the search. In this example, before entering the selection operation, we remove two solutions which have maximum and minimum fitness value. As the result, only 198 solutions enter the selection, crossover and mutation. After 198 solutions experiencing the selection, crossover and mutation, we re-add the solution which has the maximum fitness value into new population and repeat twice, replace the solution which has the minimum fitness value. The purpose is to keep the optimal individuals from the previous operation can go directly into the next operation. As a result, we can ensure that the number of optimal individual will not decrease. At the same time, the maximum fitness value is repeated twice in the new population to replace the minimum fitness value which has been abandoned directly. In this way, we can increase the probability that the solution which has the maximum fitness value can be inherited.

This is the optimal save strategy and the code is shown as follows:

```matlab
function [newpop]=selection(pop,fitvalue)
popsize=length(fitvalue);
ps=fitvalue/sum(fitvalue);
pscum=cumsum(ps);
r=rand(1,popsize);
selected=sum(pscum*ones(1,popsize)<ones(popsize,1)*r)+1; newpop=pop(selected,:);
newpop1=newpop;
```

The fifth step is crossover. In this case, we adopt single point crossover. To be specific, we randomly select an intersection point in the string by \text{pc}. Then two solutions exchange the remainder genes after the point to form two new individuals. Before crossing, re-disrupting the order of the fitness, so that the value will be more real and effective. The last step is mutation. Because we adopt binary coding in this paper, we only need to randomly select the mutation point by \text{pm}, and then reserve the value of the position.

After calculating, we know that when \text{RIFI}=0.8 and \text{cost}=600000, the optimal solution is:
$R_1=0.8699$, $R_2=0.5211$, $R_3=0.8257$, $R_4=0.9293$, $R_5=0.9297$, $R_6=0.5201$ and $R_7=0.971$, and the $R(s)_{\text{max}}=0.6961$. The optimal reliability level of the sub-project is shown in Fig 8. When values of RIFI and total cost are given, we need to pay more attention to $R_1$, $R_4$, $R_5$ and $R_7$, in order to achieve the highest overall reliability of the system. The optimal solution system reliability distribution is shown in Fig 4.

![Fig 4. Optimal solution system reliability distribution](image)

At the same time, the authors have changed the value of RIFI. When RIFI equals 0.8, 0.7, 0.6 and 0.5, what kind of operation results will be. RIFI refers to reliability flexibility index. The higher the RIFI, the reliability level of each sub-project and the system reliability will be higher. The result is shown in Fig 5.

![Fig 5. Optimal solution of system reliability under different RIFI values](image)

In this way, we can understand how to achieve maximum system reliability under different constraints, or how to achieve lowest cost in the premise of maximum system reliability. Through this method, we can adjust the relationship between cost and quality in the project management to achieve the maximal benefits as well as high quality.

7 Conclusion

Quality has always been the most important feature for building products. Companies have put more attention to the cost control in current construction market. Even if some companies want to pursue the high quality, it’s difficult for them to quantify and optimize the quality. Therefore, this paper establishes the quality-cost system reliability model of construction project and provides decision-makers with decision-making suggestions. The system reliability theory can be used to
quantify the quality of subprojects, establishes models through logical relationships among subprojects, and performs logical operations to quantify the whole system reliability. The optimal individual of each circulation is preserved and allowed to enter the next generation without participating in the crossover and mutation. It can ensure that the fitness value of best individual will not decrease and can help to ensure the authenticity of the optimal solution.

Looking forward to the future research, we can apply the system reliability optimization model based on the reliability theory to more research goals. We can extend the research to the multi-objective optimization model, such as time-cost-quality. We even can target at more comprehensive optimization including weather, policy and market.

References


Vertical Integration and Goodwill: The Case of Real Estate Companies

Gong, X.R.\textsuperscript{1*} and Chau, K.W.\textsuperscript{2}

Abstract: Vertical integration refers to hiring and organizing resources to produce output or intermediate outputs within a firm instead of directly purchasing them from the market. Examination of the annual reports of listed real estate companies in Hong Kong suggests that they have varying degree of involvements in various activities of producing real estate assets, ranging from planning and design, real estate development, investment, construction, building materials/components manufacturing, property maintenance and property management. This provides us a good opportunity to examine why companies integrate vertically. We propose that vertical integration is necessary for companies which have invested in “goodwill”. It is usually impossible for a real estate company to produce high quality buildings using the market, e.g. selecting an outside construction contractor using the tendering process. Since, the latent defects cannot be detected easily, the transaction cost of procuring such buildings or its components become prohibitively high. Careful direct supervision of workers and direct purchase of materials are essential to producing high quality buildings and hence vertical integration. Not all real estate companies have successfully created a good reputation of delivering high quality buildings. For those that are successful, the higher building qualities are reflected in higher transaction prices in second-hand market. For the empirical tests, this study will make use of second-hand housing transaction data in Hong Kong to estimate a Goodwill Index (which is the average difference in the second-hand transaction price of a standardized unit developed by different real estate companies). The estimated Goodwill Index should be positively correlated with the degree of vertical integration (measured by the number of building production actives involved), holding other factors constant.

Keywords: Vertical integration; Goodwill; transaction cost; real estate companies.

\textsuperscript{1*} GONG, X.R.
Corresponding author, Department of Real Estate and Construction, The University of Hong Kong, Hong Kong
E-mail: u3003746@connect.hku.hk

\textsuperscript{2} Chau, K.W.
Department of Real Estate and Construction, The University of Hong Kong, Hong Kong
1 Introduction

This research aims at first investigating factors leading to vertical integration in the context of real estate industry in order to further shed light on factors affecting vertical integration generally.

1.1 Vertical integration

A firm’s production line is where turning all kinds of factors for production into the firm’s final product for consumption. The factors needed during the producing process include capital, physical materials as well as human resources. The firm’s final product could be either corporeal commodities or incorporeal services, which will be sold in the market. In most industries, the production process usually involves a number of sequential production stages with intermediate inputs and outputs.

Usually there are mainly two ways for a firm to allocate those intermediate outputs: one is using the market by purchasing what needed in next production stage from another independent party; the other choice is using command within the firm, by making use of the firm’s internal resources, such as a related or supportive department or even a firm’s subsidiary to provide the intermediate outputs by itself. The latter strategy for a firm to allocate intermediate outputs needed in the production process is vertical integration. In spite of a large number of studies on it, the definition of vertical integration still remains vague. Frommueller and Reed (1996) considered the statement that “vertically integrated firms is a firm which owns as well as controls two or more adjacent economic stages, and outputs of earlier stages are used all, or in parts, as in puts for subsequent stages” to be the most generally accepted definition of vertical integration. More recently, Huang and Liu (2014) defined this pattern of firm strategy as “a combination of two or more production phases or allocation phases, which are normally separate”. Such combination can be either the demand-supply relationship with production of major business, classified as forward and backward integration (Edward & David, 1996; John & Weitz, 1988; Lieberman, 1991), or contributing synergy in major business’s value-added process, also can be categorized into two types: between-stage and within-stage vertical integration, based on when such added value being achieved (Davis & Duhaime, 1992; Zhang, 2013).

In this research, vertical integration is defined as hiring resources in the factor market to internally produce intermediate outputs which are needed in the firm’s production process instead of directly purchasing them from another independent party in the market. Moreover, the number of stages where the firm producing intermediate outputs using command is a direct indicator of the firm’s degree of vertical integration.

1.2 Vertical integration in real estate industry

Vertical integration, as a firm strategy, has also been widely conducted in real estate and construction industry. Producing a real estate project is a process of using factors such as land, capital and labour to develop a real estate consisting of building structures and related services. Typically, the real estate production process includes sequential stages of land acquisition, planning and design, real estate development, investment, construction, engineering services, building materials/components manufacturing, property maintenance, property management. Usually land acquisition is directly conducted by the developer, which is the owner of the project. The intermediate outputs to be used in the following stages are correspondingly provided by consultant, architect, contractor, materials supplier, agent and property manager. If any of those stakeholders are employed by the developer or its subsidiaries, which means some of the intermediate outputs in the firm’s production line are internally produced through command, by making use of the developer’s hiring resources, then the developer is regarded as a vertically-integrated firm. In addition, the number of these stages where the intermediate outputs are provided by developer internally indicates its vertical integration degree.

Real estate companies’ final products are generally homogenous and have similar production process, which is quite a suitable context for conducting empirical studies, since the industry specific characteristics that might interfere the results has been naturally controlled. More importantly, real estate production process always consists of a number of distinct stages where different kinds of intermediate outputs involved. Based on the examination of the annual reports of the listed real estate companies in Hong Kong, we found that they have varying degree of involvements in various activities of producing accommodation spaces (real estate assets), ranging from planning and design, real estate development, investment, construction, engineering services, building materials/components manufacturing, property maintenance, and property management. This provides us with a good opportunity to examine why companies integrate vertically.
1.3 Why do firms vertically integrate

Vertical integration is quite a prevalent strategy being conducted in various industries. There has been a large number of studies trying to figure out the reasons for firms being vertically-integrated, the majority of which are based on context of manufacturing industry (i.e. Bhuyan, 2005; Davies & Morris, 1995; Diez-vial, 2007; Huang & Liu, 2014; Leiblein & Miller, 2003; Lieberman, 1991). Based on the work “The Nature of the Firm” of Coase (1937), Cheung (1983) has generally and theoretically analyzed firm’s vertical integration from the view of firm’s contractual nature. The most influential transaction cost theory explains firm’s vertical integration by focusing on asset specificity and environment uncertainty, under the assumption that market is not perfectly competitive and people can be opportunistic in dealing with economic activities. Derived from transaction cost theory, resource-based view (J. Barney, 1991; J. B. Barney, 1999; Diericks & Cool, 1989; Wernerfelt, 1984) suggests that firms vertically integration with the intention to leverage their unique resources and capabilities, which helps maintain the firm’s competitive advantage in the demand market. Moreover, real options theory (Bowman, 1993; Kim & Kogut, 1996; Trigeorgis, 1996) suggests that sometimes firm’s vertical integration is aimed at maintaining the option to participate in a particular business in the future.

Although several theories have been proposed by plenty of studies, trying to offer an explanation of why firm vertically integrate, a satisfactory answer still remains veiled. The theory of the firm’s contractual nature is quite to the point and really inspiring, but lacks for empirical support. Transaction cost theory, resource-based view and real options theory might be able to explain vertical integration in some industries, but according to the empirical studies have been done, the results are mixed. It should also be noted that, for industries where the final product is not quite specific to a single use, for instance, real estate, the sheltered space with related services, transaction cost theory expects vertical integration barely takes place, which is not the case in reality.

2 Development of Hypothesis

Real estate, consisting of building structures and related services, has more tendency to encounter moral hazards than products of most industries (Chau, Wong, & Yiu, 2007), since properties always have a large proportion of hard-to-observe quality, which comes from the building structure (Wong, Yiu, & Chau, 2012). For instance, customers who are deciding to purchase or rent a property, it is impossible for them to know much about the quality of the house, since some structural or material deficiencies of the building do not appear before being used or even being used for some time (Garmaise & Moskowitz, 2004; Stroebel, 2016). Therefore, buyers always know much less about the quality of housing or related services than the sellers. Information asymmetry severely exists between real estate companies and their customers, which will potentially bring problems of moral hazard and adverse selection (Akerlof, 1970).

For real estate companies, on way that might solve this problem is signaling through their reputation. Due to the immobility of real estate, which is permanently connected with its locality within its whole life cycle, it is of great importance for real estate companies to obtain useful local knowledge and customs, and it is quite beneficial for them to apply it repeatedly in the same or neighbouring locality. Shapiro (1982) has elaborated the idea that in repeated business, consumers could rely on the quality of the firm’s past production to make a judgement and decide whether and how much to pay for it. Thus it should be inferred that one way for real estate companies to resolve the information asymmetry problem is by signaling through building up and maintaining reputations.

Following the logic of the firm’s contractual nature, which is proposed by (Cheung, 1983; Coase, 1937), this process of a firm to establish and maintain its reputation always involves a trade-off between cost of measuring intermediate outputs and cost of monitoring the performance of hired resources. For firms with better reputation, they tend to suffer more from reputation damage due to the loss of a larger number of potential customers, thus they have more intense motivation to protect their reputation, which requires the careful control of their final products’ quality. However, unlike mass production manufacturing products, quality control is difficult for real estate due to its unique nature and in-situ out-door production. This is true for both the final product and immediate outputs since quite a few dimensions of high quality outputs cannot be easily observed by visual inspection. Thus it is usually impossible for a real estate company to produce high quality buildings using the market due to the prohibitively high transaction cost in measuring the quality of purchased intermediate outputs, since measuring higher quality requires more dimensions to be inspected as
well as the cost of searching and negotiating with qualified outsourced firms.

Given the much higher measurement cost in purchasing intermediate output from market, compared with the cost of monitoring the performance of hired resources, firms with better reputation might find vertical integration as an optimal strategy. Hypothesis from the reputation perspective implies that real estate companies with better reputation are more likely to vertically integrate.

3 Research Design

In order to test the hypothesis that real estate companies with better reputation are more likely to vertically integrate, a two-stage regression model is adopted. The first stage aims at estimating firm’s reputation, which will be used as the key variable to test the proposed hypothesis in the second stage.

3.1 Estimating reputation

Previous studies (Chau et al., 2007; Keh & Xie, 2009; Miller, 1988; Shapiro, 1982; Walsh, Mitchell, Jackson, & Beatty, 2009) have suggested that firms’ reputation acts as an important signal for customers of the quality of product or service they produce. Moreover, it has been widely found that a firm’s reputation can be capitalized into the price of its product in plenty of studies across a wide range of industries (Benfratello, Piacenza, & Sacchetto, 2009; Chau et al., 2007; Harald, 2013; Houser & Wooders, 2006; Rindova, Williamson, Petkova, & Sever, 2005; Vasco, Edi, & Samuele, 2011). Particularly, based on investigation in Hong Kong pre-sale housing market, Chau et al. (2007) has empirically proved that market is capable of capitalizing the developer’s reputation into price of properties it sells. Following the conclusions of these studies, the major proxy of firm’s reputation will be estimated in this research is the price premium achieved by each particular developer.

The following hedonic model is established to estimate the price premium achieved by each developer through analyzing the transaction prices of units of residential properties developed by different developers:

\[
\ln(P) = \alpha_0 + \alpha_1 S + \alpha_2 S^2 + \alpha_3 F + \alpha_4 F^2 + \alpha_5 Age + \alpha_6 Age^2 + \alpha_7 Dist + \sum_{j=1}^{J} \beta_j Loc_j + \sum_{i=1}^{I} p_i Com_i + \gamma HPI_t + \varepsilon
\]

Where

\( \ln(P) \) is the natural logarithm of real transaction price of the unit;

\( S \) is the size of saleable floor area;

\( F \) is the floor level;

\( Age \) is the building’s age;

\( Dist \) is the distance from the building to its nearest MTR station;

\( Loc_j \) is a set of location dummy variable which equals 1 if the unit is located in region \( j \) and 0 otherwise.

\( HPI_t \) is the housing price index of Hong Kong’s residential property market, we choose The University of Hong Kong Real Estate Index Series (HKU-REIS).

\( Com_i \) is a set of company dummy variable which equals 1 if the unit of the building is developed by developer \( i \) and 0 otherwise.

\( p_i \), the coefficient of the set of company dummy variable to be estimated, is the price premium correspondingly achieved by each particular developer.

\( \alpha, \beta, \gamma \) are coefficients to be estimated.

3.2 Testing the hypothesis

In the model aimed at testing the hypothesis that real estate companies with better reputation are more likely to vertically integrate, two more proxies of reputation are used to complement with the proxy of price premium. The first is firm’s history. Since building up a good reputation is an accumulative process, which requiring firm’s consistent efforts during a relatively long period, thus firms have good reputation usually have a relatively long history. Also, a long history of survival and development also serves as an indicator of the firm’s high-quality product or service, acting the role of reputation. Therefore, the length of a firm’s history is a suitable proxy for the firm’s reputation. The same logic also goes for the firm size. A firm’s process of building up reputation is usually accompanied with firm’s development and expansion. The accumulation of capital can
also act as reputation based on customer’s perspective. The firm’s large size always seems to be a kind of quality guarantee of its product. Thus firm size is also included as a proxy for reputation in the model.

In the second stage of the two-stage regression, a hedonic model analyzing the potential relationship between firm’s degree of vertical integration and its reputation is established to test the hypothesis in this research:

$$VI_{it} = \alpha + \beta_1 His_{it} + \beta_2 TA_{it} + \beta_3 p_i + \gamma_1 Debt_{it} + \gamma_2 Pro_{it} + \gamma_3 Own_{it} + \gamma_4 Orgin_i + \gamma_5 PV_i + \epsilon_t$$

Where

- $VI_{it}$ is the firm i’s level of vertical integration in year $t$, measured by the total number of products or services firm $i$ produces in year $t$; those counted products and services are bounded by the typical production line of a property development project. In another words, only the businesses producing the intermediate outputs needed in the stages during the production line should be counted. These businesses are limited to land acquisition, planning and design, real estate development, investment, construction, engineering services, building materials/components manufacturing, property maintenance, property management.
- $His_{it}$ is the firm i’s length of history of operating business in real estate industry, measured the year it entered real estate industry, it is a proxy of firm’s reputation;
- $TA_{it}$ is the firm i’s firm size in year $t$, measured by the natural logarithm of its total asset value, it is the second proxy of firm’s reputation;
- $p_i$ is the coefficient of the set of company dummy variable having estimated in first stage, indicating the price premium correspondingly achieved by each particular developer, it is the third but major proxy of firm’s reputation.
- $Debt_{it}$ is the firm i’s capital structure in year $t$, measured by the ratio of the value of total debt to total asset in year $t$;
- $Pro_{it}$ is the firm i’s profitability in year $t$, measured by the ratio of the value of earnings before interest and tax (EBIT) to the firm’s total asset in year $t$;
- $Own_{it}$ is the firm i’s ownership concentration in year $t$, measured by the percentage of its issued shares held by its directors and chief executives in year $t$;
- $Orgin_i$ is the firm i’s first business it operated in real estate industry, consisting of a set of dummy variables: $Orgin_{i_D}$, $Orgin_{i_I}$, $Orgin_{i_C}$, $Orgin_{i_M}$, $Orgin_{i_CM}$ and $Orgin_{i_De}$, separately standing for property development, property investment, construction, property management, construction materials or decoration is the firm’s origin business in real estate industry. (Baseline is the firm starting real estate business from property agency)
- $PV_t$ is the degree of price volatility in real estate market in year $t$, measured by the standard variation of housing price index of previous 36 months’;
- $\alpha$ is the intercept;
- $\beta_{1-3}$ are the coefficients of firm’s reputation;
- $\gamma_{1-5}$ are the coefficients of the control variables.

## 4 Data and Sources

The data sample needed in this research consists of company sample and property transaction sample and the observation period is from year 2006 to 2015.

Hong Kong Real estate developers listed in Hong Kong Exchanges and Clearing Limited (HKEx) are selected as company sample in this research. Their background information including the region they belong to, the time when they entered real estate industry as well as their first business operated in real estate industry will be found in the firm’s website. Then, some of the firms’ financial data from 2006 to 2015 are also needed, including firm’s value of total asset, gear ratio, EBIT and interests of firms’ directors and chief executives. The majority of these data can be collected from Wind Dataset. Complemented with firm’s annual reports, the information about directors and chief executives’ interests and any missing data from Wind Dataset can be collected. Moreover, information about what business in real estate industry has been operated by each firm in every year of 2006 to 2015 should also be collected from firm’s annual reports.

As to property transaction sample, it consists of second-hand transaction records in residential properties, which are produced by developers in the company sample, which can be collected from EPRC. The distance from the building to its nearest MTR station is calculated based on the geographical information on Google.
6 Expected outcomes

If the hypothesis in this research, which is real estate companies with better reputation are more likely to vertically integrate, is correct, then in the empirical regression, the coefficients of the proxy of reputation, which is measured by the price premium achieved by the firm, is expected to be all significant and positive.

References

Keh, H. T., & Xie, Y. (2009). Corporate reputation and customer behavioral intentions: The roles of trust,
Critical Risk Identification in One Belt-One Road Highway Project in Serbia

Andrić, J.M.¹, Wang, J.Y.²*, Zou, P.X.W.³ and Zhong, R.Y.⁴

Abstract: Highway projects are exposed to higher risks due to higher capital amounts and complex site conditions compared to traditional construction projects. The aim of this paper is to identify and classify potential risks on the One Belt-One Road (OBOR) projects and using significant risk index to rank these risks on the particular project. To detect risks, a comprehensive literature review and interviews with participants on the OBOR infrastructure projects were conducted. In total, 43 risks have been identified and classified into categories according to their source and project phase in which they may occur. The significant risk index is applied to a case example, which is the OBOR highway project of Section Surčin – Obrenovac in the Republic of Serbia. This project is of international importance since the highway Section Surčin – Obrenovac belongs to the Highway E-763 which is a part of the China’s OBOR Initiative. The results show that the ten most significant risks are cultural difference, language barrier, safety measures on site, inflation and currency exchange rate, water and soil pollution caused by construction works, majeure force, poor quality of materials, unforeseeable ground conditions, noise pollution, and different religious background.

Keywords: One Belt-One Road, Highway, Risk identification, Risk significant index, Serbia.

¹ Andrić, J. M.
College of Civil Engineering, Shenzhen University, China

² Wang, J.Y., Corresponding Author
College of Civil Engineering, Shenzhen University, China
E-mail: wangjy@szu.edu.cn

³ Zou, P.X.W.
Department of Civil and Construction Engineering and Centre for Sustainable Infrastructure, Swinburne University, Australia

⁴ Zhong, R.Y.
China Center for Special Economic Zone Research, Shenzhen University, China
1 Introduction

OBOR Initiative is China’s greatest economic ambition to assert greater international influence and contribute to the economic development of undeveloped regions in Asia, Europe and Africa [1]. During the visit to Central and South East Asia in September and October 2013, Xi Jinping, the President of People’s Republic of China, raised the initiative of building the Silk Road Economic Belt and the 21st Century Maritime Silk Road. Currently, there are more than 65 countries from Asia, Europe and Africa which are the part of this Initiative [2]. Hence, the crucial component of OBOR is infrastructure projects since the infrastructure plays significant role in development of regional cooperation and connectivity. The OBOR Initiative includes a hundreds of infrastructure (highways, railways, bridges, tunnels, seaports, pipelines) projects which are in different phases, completed, under construction or negotiation.

In the current literature, there is a lack of research related to risk of highway construction projects [3] and risk management of highway projects [4]. Moreover, the OBOR projects are not traditional international infrastructure projects. Compared to traditional international projects, OBOR projects are influenced by more risks. According to the authors best knowledge, the risk identification and management of OBOR projects has not been studied yet. In order to bridge this gap, the aims of this research are to investigate and study the potential risks which could occurred on the OBOR highway infrastructure projects. The tasks of this research include: (1) to identify potential risks on the OBOR highway projects; and (2) to identify most significant risk.

In this paper, risks which influence OBOR highway infrastructure projects are identified by comprehensive literature review and interviews with participants on the OBOR infrastructure projects are conducted. Further, risks are classified into categories according to their origin in order to provide more detailed insight about the risks. Risk significant index is used to rank and identify most critical risks. A case study, the highway construction project Section Surčin – Obrenovac of the Highway E-763 is investigated.

2 Research METHODS

In this research, risks related to the OBOR projects have been studied. The selected methodology for risk identification includes a comprehensive literature review. In addition, stakeholders who have participated on the OBOR projects and construction industry experts have been interviewed about the potential risks on similar projects.

For risk ranking, significant risk index is applied. This method have been proposed by Shen, et al. [5] and Zou, et al. [6]. The risk significant index calculates the significance score for each risk according to the following equation:

$$S_i = \frac{\sum (\alpha_{i,j} \beta_{i,j})}{n}$$

where, $S_i$ – risk significant score for risk $i$, $\alpha_{i,j}$ - the probability of occurrence of risk $i$ assessed by respondent $j$, $\beta_{i,j}$ - the impact of risk $i$ assessed by respondent $j$, $n$ – the number of respondents.

For $\alpha$ and $\beta$, a five-point scale (very low, low, moderate, high, very high) is used to represent the potential values for the probability of risk occurrence and their impact. The participants on the highway project Surčin – Obrenovac are asked to evaluate these factors. In total, five managers, design manager, commercial and procurement manager, Quality Assurance manager, bridge and road construction manager and technical manager have been selected for interview and to fill in
the questionnaires.

The construction of the Highway E-763, Section Surčin – Obrenovac is investigated for this case study. This project is the beginning of the Highway E-763, the corridor which connects Belgrade, the capital of Serbia with the South Adriatic. It is a four-lane highway with additional emergency lanes designed for speed of 120 km/h.

The contractor is Chinese company, the financier is the Government of the Republic of Serbia and the investor is public enterprise “Roads of Serbia”. The total cost of the project is estimated $233 669 280, and duration of the project is three years.

3 Results and discussion

In total, 43 risks related to the OBOR projects have been identified. These risks are sourced from different literature reviews such as journal papers, case studies and interviews (Table 1). Further, risks are classified according to their sources into three levels, OBOR Policy, Construction market and Project. Further, project risks are grouped into four groups: project environment, design process, construction process and staff and management of the project.

The OBOR Policy risk group consists of geopolitical risk, credit risk and cooperation and bilateral relationships between two countries. Since OBOR is a geopolitical project that aims to build infrastructure in order to enable flows of trade and investment [7] and exchange ideas, information, knowledge and philosophies along the countries. This project has the tendency to change the geopolitics in different regions of the world [8]. Hence, the OBOR is influenced by serious geopolitical risk. Further, mostly OBOR countries are developing countries which have insufficient funds for large scale infrastructure projects. In order to complete OBOR projects in their countries, credit from Chinese banks is needed. Credit can be approved or denied depending on country’s ability to pay back loans. Based on this, some countries are at higher risk [9]. Compared to the traditional international infrastructure projects, OBOR infrastructure projects are results of the cooperation and bilateral relationships between China and the member of the OBOR Initiative. Hence, risks which can influence the execution of the OBOR project in the host country are related to cooperation and bilateral partnership between two countries. If some issues or misunderstanding appear in cooperation between China and the OBOR member country, it can slow the implementation of the project.

The second group contains of economic, law and political risks associated to the construction market and social, cultural and religious risk factors which are related to international projects. Currency exchange rate is a significant economic factor since Contractor is Chinese company and sometimes there is a need for import of materials and equipment. Law risks appeared due to changes in rules and regulations. Political risks are related to the political situation, political stability, government effectiveness, bureaucracy and corruption. Language barrier between stakeholders could cause misunderstandings and disputes during the project implementation.

The third category are risks related to project environment such as majeure force, unforeseeable ground conditions, critical weather conditions, noise pollution, and soil and water pollution caused by construction works on the site. In the case of the majeure force and critical weather conditions, some equipment and materials could be damaged and productivity of labor is decreased. Since the construction works of highway are outdoor activities, the produced waste could pollute soil and water on the site.
<table>
<thead>
<tr>
<th>Id</th>
<th>Risk Category</th>
<th>Name of risks</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OBOR Policy</td>
<td>Geopolitical</td>
<td>[8]</td>
</tr>
<tr>
<td>2</td>
<td>OBOR Policy</td>
<td>Credit</td>
<td>[9]</td>
</tr>
<tr>
<td>3</td>
<td>Construction market</td>
<td>Cooperation and bilateral partnership</td>
<td>/</td>
</tr>
<tr>
<td>4</td>
<td>Construction market</td>
<td>Economic – inflation and currency exchange rate</td>
<td>[3, 5, 10]</td>
</tr>
<tr>
<td>5</td>
<td>Construction market</td>
<td>Laws – applicable laws of planning and construction</td>
<td>[5, 10, 11]</td>
</tr>
<tr>
<td>6</td>
<td>Construction market</td>
<td>Political – bureaucracy</td>
<td>[5, 10, 11]</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Social – language barrier</td>
<td>[10, 11]</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Cultural difference</td>
<td>[10-12]</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Religious – different religious background</td>
<td>[10, 11]</td>
</tr>
<tr>
<td>10</td>
<td>Project risks related to environment</td>
<td>Majeure Force</td>
<td>[3, 11]</td>
</tr>
<tr>
<td>11</td>
<td>Project risks related to environment</td>
<td>Unforeseeable ground conditions</td>
<td>[3, 11]</td>
</tr>
<tr>
<td>12</td>
<td>Project risks related to environment</td>
<td>Noise pollution</td>
<td>[6, 13]</td>
</tr>
<tr>
<td>13</td>
<td>Project risks related to environment</td>
<td>Soil and water pollution</td>
<td>[6]</td>
</tr>
<tr>
<td>14</td>
<td>Project risks related to environment</td>
<td>Critical weather conditions</td>
<td>[3, 14]</td>
</tr>
<tr>
<td>15</td>
<td>Project risks related to design process</td>
<td>Design errors</td>
<td>[3, 5]</td>
</tr>
<tr>
<td>16</td>
<td>Project risks related to design process</td>
<td>Inadequate design quality</td>
<td>[11, 15]</td>
</tr>
<tr>
<td>17</td>
<td>Project risks related to design process</td>
<td>Design variations in design for road construction permit</td>
<td>Interview</td>
</tr>
<tr>
<td>18</td>
<td>Project risks related to design process</td>
<td>Design variations in design for road routes</td>
<td>Interview</td>
</tr>
<tr>
<td>19</td>
<td>Project risks related to design process</td>
<td>Design variations in design waterworks</td>
<td>Interview</td>
</tr>
<tr>
<td>20</td>
<td>Project risks related to design process</td>
<td>Design variations in design sewerage</td>
<td>Interview</td>
</tr>
<tr>
<td>21</td>
<td>Project risks related to design process</td>
<td>Design variations in design traffic signalization</td>
<td>Interview</td>
</tr>
<tr>
<td>22</td>
<td>Project risks related to design process</td>
<td>Design variations in electrical installations</td>
<td>Interview</td>
</tr>
<tr>
<td>23</td>
<td>Project risks related to design process</td>
<td>Design variations in telecommunication installations</td>
<td>Interview</td>
</tr>
<tr>
<td>24</td>
<td>Project risks related to design process</td>
<td>Design variations in geotechnical documentation</td>
<td>Interview</td>
</tr>
<tr>
<td>25</td>
<td>Project risks related to design process</td>
<td>Design variations in technical documentation</td>
<td>Interview</td>
</tr>
<tr>
<td>26</td>
<td>Project risks related to design process</td>
<td>Design variations in bridge design</td>
<td>Interview</td>
</tr>
<tr>
<td>27</td>
<td>Project risks related to design process</td>
<td>Design variations in tunnel design</td>
<td>Interview</td>
</tr>
<tr>
<td>28</td>
<td>Project risks related to construction process</td>
<td>Construction site – poor accessibility</td>
<td>[15]</td>
</tr>
<tr>
<td>29</td>
<td>Project risks related to construction process</td>
<td>Construction site – poor organization</td>
<td>[14, 15]</td>
</tr>
<tr>
<td>30</td>
<td>Project risks related to construction process</td>
<td>Equipment – the lack of equipment</td>
<td>[11, 15, 16]</td>
</tr>
<tr>
<td>31</td>
<td>Project risks related to construction process</td>
<td>Equipment – the breakdown of equipment</td>
<td>[5, 15]</td>
</tr>
<tr>
<td>32</td>
<td>Project risks related to construction process</td>
<td>Equipment – delay of equipment delivery</td>
<td>[15, 16]</td>
</tr>
<tr>
<td>33</td>
<td>Project risks related to construction process</td>
<td>Equipment – increase in the cost of use</td>
<td>[5]</td>
</tr>
<tr>
<td>34</td>
<td>Project risks related to construction process</td>
<td>Materials – poor quality of materials</td>
<td>[3, 10, 14]</td>
</tr>
<tr>
<td>35</td>
<td>Project risks related to construction process</td>
<td>Materials – increase of material prices</td>
<td>[5, 10]</td>
</tr>
<tr>
<td>36</td>
<td>Project risks related to construction process</td>
<td>Materials – delay in supplying materials</td>
<td>[10, 14, 15]</td>
</tr>
<tr>
<td>37</td>
<td>Project risks related to staff and management of</td>
<td>Lack of labour</td>
<td>[6, 11, 15]</td>
</tr>
<tr>
<td>38</td>
<td>Project risks related to staff and management of</td>
<td>Poor management skills of project managers</td>
<td>[6, 11]</td>
</tr>
<tr>
<td>39</td>
<td>Project risks related to staff and management of</td>
<td>Lack of coordination between different sectors</td>
<td>[6, 15]</td>
</tr>
<tr>
<td>40</td>
<td>Project risks related to staff and management of</td>
<td>Poor team communication</td>
<td>[11, 15]</td>
</tr>
<tr>
<td>41</td>
<td>Project risks related to staff and management of</td>
<td>Inadequate quality control inspection</td>
<td>[10]</td>
</tr>
</tbody>
</table>
During the design process, highway projects are exposed to many risks such as design errors, inadequate design quality, design variations in different design projects, road construction permit, road routes, waterworks, sewerage, traffic signalization, telecommunication installations, electrical installations, geotechnical and technical documentation, and bridge and tunnel design.

In the construction process, risk related to construction site, equipment and materials could appear. The poor accessibility and organization of construction site contributes to works delay. However, equipment and materials are essential risk elements. The breakdown of equipment, delay of equipment delivery and increase in cost of equipment could cause delay and cost overrun. Also, the poor quality of material, delays of materials supply and increase of material cost should be mitigated in order to avoid potential risks.

The last group of risks is connected with human resources and management of the project. The lack of labor, poor management skills of project managers, lack of coordination between different sectors, poor team communication, inadequate quality control inspections, accident occurrence, and safety measures on the site are analyzed in order to efficiently manage the project. During the construction work, construction workers are exposed to hazardous environment and outside weather conditions. Hence, inefficient safety management could lead to an accident.

After conducting survey and collecting data about the probability of risk occurrence and the impact of risks from managers working on this project, significant risk index for each risk is calculated according to the equation (1). The obtained results and risk ranks are listed in Table 2.

The most critical risk factor on the list is cultural difference \( (V=0.414) \). Cultural difference is the most significant risk for the contractor since they are working in the foreign country. Contractor’s employees, who have Asian cultural background, are engaged to execute the construction works in foreign country, in which Western culture is more dominant. In previous research, it is obtained that differences between Asian and European cultures are likely to result in management issues and conflicts [12]. In order to reduce risk, the contractor can employ consultants from the host country, who will provide him information.

The second and the third rank on the list share social factor related to language barrier and safety measures on the site \( (V=0.351) \). The result highlights that language barrier could cause misunderstandings during project implementation. To overcome difficulties in communication between different participants, translators should be employed. Further, safety measures on the site are high ranked risk since the lack of safety equipment and devices could lead to accidents. Even highway construction sites are exposed to various potential hazardous events, thus safety measures and procedures on the site should be followed.

The fourth ranked risk is inflation and currency exchange rate. The currency exchange rate of Serbian Dinars (RSD) to foreign currencies such as Euro (EU) is followed by steady rising trend. Hence, it is very likely that currency exchange rate would rise in the future since it is expected that would be unstable for longer period of time such as duration of the project.

The results show that soil and water pollution caused by construction work at site are on the fifth place. Water pollution on the site could be caused by different factors: earthworks, storm water runoff, sediment, lack enforcement, compaction, and others. Usually, construction team is responsible for water and soil pollution on the site.
### Table 2 The significant risk index

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>Value</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geopolitical</td>
<td>0.11</td>
<td>41</td>
</tr>
<tr>
<td>Credit</td>
<td>0.138</td>
<td>39</td>
</tr>
<tr>
<td>Cooperation and bilateral partnership</td>
<td>0.106</td>
<td>42</td>
</tr>
<tr>
<td>Economic – inflation and currency exchange rate</td>
<td>0.302</td>
<td>4</td>
</tr>
<tr>
<td>Laws – applicable laws of planning and construction</td>
<td>0.226</td>
<td>15</td>
</tr>
<tr>
<td>Political – bureaucracy</td>
<td>0.218</td>
<td>16-17</td>
</tr>
<tr>
<td>Social – language barrier</td>
<td>0.31</td>
<td>2-3</td>
</tr>
<tr>
<td>Cultural difference</td>
<td>0.374</td>
<td>1</td>
</tr>
<tr>
<td>Religious – different religious background</td>
<td>0.238</td>
<td>9-10</td>
</tr>
<tr>
<td>Majeure Force – earthquakes, floods…</td>
<td>0.266</td>
<td>6</td>
</tr>
<tr>
<td>Unforeseeable ground conditions – insufficient site information</td>
<td>0.242</td>
<td>8</td>
</tr>
<tr>
<td>Noise pollution</td>
<td>0.238</td>
<td>9-10</td>
</tr>
<tr>
<td>Soil and water pollution</td>
<td>0.278</td>
<td>5</td>
</tr>
<tr>
<td>Critical weather conditions</td>
<td>0.17</td>
<td>30-31</td>
</tr>
<tr>
<td>Design errors</td>
<td>0.234</td>
<td>11-12</td>
</tr>
<tr>
<td>Inadequate design quality</td>
<td>0.202</td>
<td>19</td>
</tr>
<tr>
<td>Design variations in design for road construction permit</td>
<td>0.218</td>
<td>16-17</td>
</tr>
<tr>
<td>Design variations in design for road routes</td>
<td>0.198</td>
<td>20-21</td>
</tr>
<tr>
<td>Design variations in design waterworks</td>
<td>0.182</td>
<td>25-26-27-28</td>
</tr>
<tr>
<td>Design variations in design sewerage</td>
<td>0.182</td>
<td>25-26-27-28</td>
</tr>
<tr>
<td>Design variations in design traffic signalization</td>
<td>0.138</td>
<td>36-37</td>
</tr>
<tr>
<td>Design variations in design electrical installations</td>
<td>0.158</td>
<td>33</td>
</tr>
<tr>
<td>Design variations in design telecommunication installations</td>
<td>0.146</td>
<td>35</td>
</tr>
<tr>
<td>Design variations in geotechnical documentation</td>
<td>0.138</td>
<td>36-37</td>
</tr>
<tr>
<td>Design variations in technical documentation</td>
<td>0.118</td>
<td>40</td>
</tr>
<tr>
<td>Design variations in bridge design</td>
<td>0.178</td>
<td>29</td>
</tr>
<tr>
<td>Construction site – poor accessibility</td>
<td>0.23</td>
<td>13-14</td>
</tr>
<tr>
<td>Construction site – poor organization</td>
<td>0.198</td>
<td>20-21</td>
</tr>
<tr>
<td>Equipment – the lack of equipment</td>
<td>0.15</td>
<td>34</td>
</tr>
<tr>
<td>Equipment – the breakdown of equipment</td>
<td>0.162</td>
<td>32</td>
</tr>
<tr>
<td>Equipment – delay of equipment delivery</td>
<td>0.182</td>
<td>25-26-27-28</td>
</tr>
<tr>
<td>Equipment – increase in the cost of use</td>
<td>0.17</td>
<td>30-31</td>
</tr>
<tr>
<td>Materials – poor quality of materials</td>
<td>0.262</td>
<td>7</td>
</tr>
<tr>
<td>Materials – increase of material prices</td>
<td>0.19</td>
<td>23-24</td>
</tr>
<tr>
<td>Materials – delay in supplying materials</td>
<td>0.19</td>
<td>23-24</td>
</tr>
<tr>
<td>The lack of labor</td>
<td>0.194</td>
<td>22</td>
</tr>
<tr>
<td>Poor management skills of project managers</td>
<td>0.13</td>
<td>38</td>
</tr>
<tr>
<td>Lack of coordination between different sectors</td>
<td>0.182</td>
<td>25-26-27-28</td>
</tr>
<tr>
<td>Poor team communication</td>
<td>0.234</td>
<td>11-12</td>
</tr>
<tr>
<td>Inadequate quality control inspection</td>
<td>0.23</td>
<td>13-14</td>
</tr>
<tr>
<td>Accident occurrence</td>
<td>0.214</td>
<td>18</td>
</tr>
</tbody>
</table>
The sixth ranked risk is force majeure such as earthquakes, floods and others. Floods are the most frequent and devastating natural hazards in Serbia [17]. In previous years, several floods have been registered in the Kolubara river basin where the bridge is planned to be constructed.

The poor quality of material is ranked on the seventh place. Good quality of material is essential for the construction durability. In order to provide good quality of material, quality assurance manager and quality engineers are employed to test the used material.

Unforeseeable ground conditions are ranked on the eighth place since uncertainties can arise from subsurface. Geotechnical site characterization is a part of infrastructure projects and data is obtained by different techniques. If contractor found different subsurface conditions from those identified in geotechnical documentations, it could lead to disputes and claims.

According to the significant risk score, the ninth and the tenth risk are noise pollution and different religious background. Noise pollution is triggered by equipment which is operating on the construction site. The consequences of noise pollution can result in health damage of workers. Different religious background as well as different cultural background could influence the project implementation and caused disputes between stakeholders. Also, the religious factor is very important to consider since stakeholders from different religious background will celebrate different festivals, which will result in more non-working days.

4 Conclusion

In this research, a comprehensive literature review on the international highway project is conducted in order to identify the potential risks on the OBOR highway projects. In total, 43 different risk factors have been identified by comprehensive literature review, interview with the participants on the OBOR project and confirmed by a case study. Further, using risk significant index, 10 key risks are identified and practical recommendations for their reduction and prevention is provided.

This research provides insight about the potential risks which could occur on the OBOR projects. Compared to the traditional international projects, OBOR projects are influenced by higher risks related to OBOR Policy, geopolitical, credit and cooperation and bilateral relationships between two countries, China and the member of OBOR country. Also, these results can support future international contractor companies which are planning to operate on Serbian construction market to utilize project management according to key project risks. The results show that the key risks on the OBOR highway projects in Serbia are cultural differences, language barrier, safety measures on the site, inflation and currency exchange, soil and water pollution, majeure force, poor quality of materials, unforeseeable ground conditions, noise pollution, and different religious background. Since contractor’s managers are managing OBOR project in foreign country and they are not familiar with cultural, historical, political, legal and social backgrounds of host country or its nature and environment, it was expected that risks related to construction market and project environment risks could appear as most critical risks.

Acknowledgement

This research was supported by National Natural Science Foundation of China (project ID
References


Land Finance and Urban Diversity: the Empirical Evidence from 289 Prefecture-level Cities in China

Lu Xinhai1*, Ke Shangan2, Kuang Bing3, Jiang Xu4

Abstract: Based on the sample data of 289 prefecture-level cities in China from 2003 to 2015, this paper validates the relationship between land finance and urban diversity. The results showed that the land finance had a significant negative effect on the urban agglomeration characteristics, and the coefficients of eastern and central and western regions were obviously different. In order to promote the diversification of urban development in China, to promote industrial structure upgrading, local government's land financial behaviors should be in institutional norms and the implementation of supervision policies should be carried out.

Keywords: Land Finance; Urban agglomeration characteristics; Absolute Diversification Index

1 Introduction

In the process of the glorious Reform and Opening up near 40 years, the effects of scale economies and the spatial correlation released by cities and the urban agglomeration played a leading role in creating a large number of Urban Wealth (Glaeser, E.L et. al, 1992). A city is generated with the scope of the increasing returns or the accumulation of economic. Thus the different types of gathering will give birth to different cities with different characteristics. The previous studies indicated that the urban spatial forms in China showed the characteristics of coexistence of diversification and profession, not only similar to a few highly specialized cities like Detroit or Toyota but also similar to the diverse cities like New York or Tokyo (Jim and Liu, 2001; Naughton and Yang, 2004; Yu and Ng; Duranton and Puga, 2001).

The diverse urban forms in China are mostly affected by the local strategies of land supply. As the China’s state-owned institution, the local governments control the supply of most land but lack sufficient financial finance for development under the special tax institution. The dual land structure of urban and rural divide in China has given the special status of the "three in one" of the landlord, the donor and the monopolist of the local government. This special identity is consistent with the Chinese fiscal decentralization model and the GDP performance scale system integration, whether it is to make up for the financial gap "forced sell land" of the helpless, or to carry out the inherent impulse of the political tournament, local governments have the "land" to obtain a strong financial power of the huge land. (Lu et. al, 2011).

1 *Lu, X. H.
Corresponding author, Land Resource and Real Estate Research Center, Huazhong University of Science and Technology, China
E-mail: xinhailu@163.com

2 Ke, S. G.
Land Resource and Real Estate Research Center, Huazhong University of Science and Technology, China

3 Kuang, B.
Land Resource and Real Estate Research Center, Huazhong University of Science and Technology, China

4 Jiang, X.
Land Resource and Real Estate Research Center, Huazhong University of Science and Technology, China
And the land as a space carrier of economic activities, industrial layout, and urban agglomeration, the development pattern of local government to the local wealth is bound to affect the internal shape and agglomeration characteristics of the city from birth to maturity. So we want to find out how the land finance affect the characteristics of urban agglomeration under the institution's system with Chinese characteristics? What is the relationship between land finance expansion and urban diversification or specialized clustering? And what is the difference of the effect between the eastern cities, middle and western cities?

Studies have shown that the government's strategic land transfer policy will have an impact on urban agglomeration. The best local land transfer strategy of the local government is to sell the industrial land at a low price and sell the commercial land at a high price to reduce the cost of the enterprise and increase the finance and public expenditure to jointly attract the enterprise, promote the production and promote the purpose of urbanization. And this policy proved to be effective (Lei and Gong, 2014; Arrow and Kurz, 1970; Barro, 1990). Local government's tendency to land finance policy may also play a role in infrastructure construction, public welfare and so on through strategic land supply policy, result in the diverse urban agglomeration forms. Land transfer payments may be to a certain extent, the budget of the budget gap, to fill the budget of public expenditure deficiencies, making the financial investment in public goods increased, and this increase, both for municipal construction projects as the representative of the infrastructure Public goods, as well as the text of the public health care as the representative of the public service category of public goods, are played a positive and effective role in promoting positions (Li, 2013; Eberts, 1986; Glaeser, 2003). These studies are difficult to directly penetrate into the urban industrial structure changes and agglomeration characteristics, and no specific distinction between China's eastern, central and western regions of the land finance on the positive characteristics of the city. Therefore, this paper intends to explore the characteristics of agglomeration within the city, and comprehensively understand the mechanism of agglomeration of the land finance industry. On the whole, the contribution of this paper is to explore the impact of land finance on the characteristics of urban agglomeration, which is of great benefit to the understanding of China's special national conditions.

The third part introduces the measurement model setting, the relevant variable selection, and data description; the fourth part reports the empirical analysis results; the fifth part is the conclusion and discussion. The second part is the analysis of the impact mechanism;

2 Analysis of Impact Mechanism

The impact of market forces on consumer behavior is in stark contrast to the impact of land finance on urban agglomeration, showing a strong government intervention. After the reform of the tax system in 1994, the local government's financial resources became increasingly tense, in the face of political promotion and fiscal finance, the local government's dual incentive measures began to use the monopoly of the land market to seek land finance(Du et.al, 2009; Li et. al, 2013; Sun and Zhou, 2013). Therefore, the inherent financial behavior of the local government in the land of financial impulses will also change the characteristics of urban agglomeration.

First, the expansion of land finance directly increases the income of the local government's extrabudgetary or government funds; secondly, the land transfer income is an important guarantee for the repayment of local government debt, land expropriation as the core of the expansion of land will enhance the local government repayment credit confidence, and thus more motivated to raise the level of debt financing, but also easier local governments to land mortgages, financial guarantees...
to open the door to bank loans (Zhou, 2007). Generally speaking, the general budget income has the "eating finance" rigid expenditure characteristics, so the local government mainly depends on the local debt and land transfer income to carry out large-scale urban infrastructure construction. As the manufacturing products are easier to statistics, and the manufacturing industry's labor productivity is higher than the service industry, nor the rise of the service industry, the development of urban scale and population concentration level of high demand, in the current GDP as the core performance evaluation system. For political tournament purposes, the local government strongly preferred to the development of manufacturing, land finance and its financing-based infrastructure funds mainly into the manufacturing sector to match the infrastructure, public expenditure in urban infrastructure The construction of this biased disposition endogenous to the land finance and related political championships is an institutional distorting act. Overhaul roads, the construction of industrial parks, to attract manufacturing enterprises stationed in the area together to form a manufacturing industry as the leading sector of the industrial structure, and the leading industry has been identified, there will be a strong path dependence and stable rigid feature (Li and Wang, 2015; Tao et. al, 2007; Cao et. al, 2007).

According to the analysis above, we propose a hypothesis: based on the dual incentive of fiscal decentralization and growth competition, the expansion of land finance increases the scale of extrabudgetary income and debt financing of local governments, and further intensifies the area through the partial disposition of urban infrastructure construction. Manufacturing industry as the leading sector of the rigid industrial structure, inhibit the development of urban industries to diversification.

3 Empirical model and identification strategy

3.1 Measurement model settings

In this paper, the empirical model is mainly focused on testing whether the land finance of 289 prefecture-level cities in China will have a significant effect on the urban agglomeration characteristics of the region. The specific measurement model is as follows:

$$ADI_i = \beta_0 + \beta_1 \text{land finance}_i + \delta Z + \epsilon_{it}$$

(1)

In the metrological model (1), $ADI_i$ represents the urban aggregate concentration index in $i$ region of $t$ year, $\text{land finance}_i$ is the land finance in $i$ region of $t$ year, $Z$ is the set of control variables, mainly including the average wage ($\text{wage}$), market potential ($\text{mp}$), the proportion of fixed assets investment to GDP ($\text{faip}$), human capital ($\text{hc}$), per capita road area ($\text{road}$), the number of books per hundred people ($\text{book}$), and the dummy variables reflecting urban political and geographical features. And $\epsilon_{it}$ is a random perturbation term.

Considering the relative stability of urban agglomeration characteristics, the current urban agglomeration characteristics may be affected by the past one or more periods urban agglomeration characteristics. Based on this, in order to make the model set more realistic, reduce the model error, we designed a dynamic autoregressive model.
\[ ADI_t = \beta_0 + \beta_{land\_finance} + \sum_{i=1}^{n} \beta_{i(t-i)} ADI_{i(t-i)} + \delta Z + constant + \varepsilon_t \]  \hspace{1cm} (2)

In the metrological model (2), a hysteresis term \( \sum_{i=1}^{n} \beta_{i(t-i)} land\_finance_{i(t-i)} \) is added to indicate the effect of the previous periods on the current urban agglomeration and constant is the regional fixation effect of the non-observing area.

### 3.2 Variables description

#### Dependent variable.
This paper draws on the ideas of Duranton and Puga (2001), Dong Xiaofang and Yuan Yan (2014), using absolute diversification and absolute specialization to represent the characteristics of urban agglomeration rather than the relative diversification and relative professionalization of the national average adjustment. This is because absolute diversity and absolute specialization are not only relatively diverse, relatively specialized in spatial dimension can be horizontal comparison, more importantly, in the time dimension of the city's own vertical comparison to capture the city's internal industry agglomeration. In this paper, the reciprocal of the most common Herfindahl-Hirschman Index is used as an absolute diversification index (ADI) of the proxy index, calculated by the sum of the square of the employment share of all sectors. Absolute professional indicators (API) is usually chosen to measure the share of the largest share of employment. The API will be used as an alternative to ADI in the significance test. ADI, API calculation required the data of employment share in 19 industries of 289 prefecture-level cities in China from 2003 to 2015. The required data is from EPS DATA in China's regional economic database and China's urban database.

#### Key independent variables.
Land Finance (land\_finance) as the local government's most important extrabudgetary finance, can bring the local government for its discretionary investment funds, which will have an impact on the evolution of industrial structure. There are different views on the definition of land finance. Zuo and Yin (2013) argue that the land finance, including land transfer value-added income and urban maintenance and construction tax, land use tax, and property tax and other related tax finance. However, Lu(211), Li (2013) and Sun and Zhou (2013) argue the land transfer payments as a measure of local government land finance. It should be noted that the land transfer payments from the commercial and industrial land and industrial land and other uses of different land transfer payments, of which industrial land transfer payments for the contribution of land finance is small, but the industrial land transfer behavior on the industrial structure adjustment can produce more direct. However, the urban area of industrial land transfer and transfer area data is difficult to obtain, taking into account the land and land to sell the land-based land transfer payments can better reflect the local government in the face of financial pressure when the financial finance and expenditure behavior choice. Therefore, this article drawing on Li et al. (2013) and Sun and Zhou (2013) and other scholars point of view, use per capita land transfer payments as the proxy indicator of land finance. The data of the land finance are from the China Land and Resources Statistical Yearbook from 2004-2016, and some missing data come from EPS DATA.

Control variables. In order to minimize the resulting deviation from the variable omission in equation (2), the variables we set in the control variable set Z including the follows:

- **average wage (wage).** Regional wage differential is a factor that can not be ignored in the labor flow. At the same time, the higher the wage level, the stronger the purchasing power of the
consumer, the higher the demand level and the demand product category will be higher and richer. As a result, wage increases will increase consumer preferences, and the coefficient is expected to be positive.

b. Market potential (mp). Market potential reflects the needs of the city's available market size or spatial distribution. And how large the market potential plays a key role in the urban development. This paper uses a market potential function to measure market potential. Recent theory on economic geography attributes spatial agglomeration to product-market linkages between regions. This idea is related to Harris’ (1954) market potential function, which equates the potential demand for goods and services produced in a location with that location's proximity to areas of consumer demand, or

$$MP_j = \sum_{k \neq j} \frac{Y_k}{d_{jk}}$$

(3)

where $MP_j$ is the market potential for location $j$, $Y_k$ is income in location $k$, and $d_{jk}$ is the distance between $j$ and $k$. The Recent theory provides a rigorous foundation for this concept.

c. Fixed asset investment to GDP(faip). Fixed asset investment has a technology spillover effect, which has an impact on urban agglomeration.

d. Human capital(hc). Human capital is evaluated with the number of high school students to the total population.

e. Local public facilities. According to the related studies, local public facilities will affect workers' immigration decisions and then change the regional industrial structure. This paper chooses the per capita road pavement area(road) and infrastructure for every hundred people's public libraries(book) to control the influence of local public facilities.

4 Results and discussion

Considering that the model adopts the hysteresis term, the explanatory variables may also have endogenous problems, resulting in errors in the results. This is usually the case with tool variables or GMM dynamic panel. However, due to the choice of strong tool variables, there is a considerable difficulty, which may increase the reliability of the results. GMM dynamic panel model can effectively avoid the problem of weak tool variables, so this paper uses GMM dynamic panel estimation method. Specifically, select the GMM dynamic difference panel, with the dependent variable lag 1 as a tool variable.

4.1 Hypothesis test of land finance 's effect on urban agglomeration

Table 1 reported the GMM Dynamic Panel model on the impact of land finance on the Absolute Diversification Index (ADI). Model 1 reported the test results of the effect of per capita land finance on the Urban Diversification Index (ADI) without considering hysteresis and control variables. The results showed that the per capita land finance had a significant effect on the urban diversification index at 99% confidence level, and the elastic coefficient was -0.0506. The Sargan test result is 0.6571, greater than 0.05, indicating that Zero hypothesis can not be rejected for instrument variables. AR (1) is 0.0000, AR (2) is 0.0098, and AR (2) is too small.

Model 2 reported the test results of the effect of per capita land finance on the Urban Diversification Index (ADI) considering hysteresis. The results showed that the urban diversification index had a positive correlation with the urban diversification index at 99% confidence, and the elasticity coefficient was 0.0849. The per capita land finance was significantly
negatively correlated with the urban diversification index at 99% confidence, and the elasticity coefficient was -0.0712. The Sargan test result is 0.8014, greater than 0.10, indicating that Zero hypothesis can not be rejected for instrument variables. AR (1) is 0.0000, AR (2) is 0.2478.

Model 3 reported the test results of the effect of per capita land finance on the Urban Diversification Index (ADI) considering hysteresis and control variables. The results showed that the urban diversification index had a positive correlation with the urban diversification index at 95% confidence, and the elasticity coefficient was 0.0782. The per capita land finance was significantly negatively correlated with the urban diversification index at 95% confidence, and the elasticity coefficient was -0.0985. The Sargan test result is 0.9248, greater than 0.10, indicating that Zero hypothesis can not be rejected for instrument variables. AR (1) is 0.0000, AR (2) is 0.9698. On the whole, the explanatory variables of Model 3 are tested by significance, and the Sargan test and residual test results are better, and it can be considered that model 3 is reasonable.

### Table 1. The GMM results of the effect of land finance on ADI

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(di(-1))</td>
<td>0.0849*** (3.7741)</td>
<td>0.0782** (2.5282)</td>
<td></td>
</tr>
<tr>
<td>log(land_finance)</td>
<td>-0.0506*** (-2.5979)</td>
<td>-0.0712*** (-3.5320)</td>
<td>-0.0985** (-2.0861)</td>
</tr>
<tr>
<td>log(wage)</td>
<td>-0.0989 (-0.3772)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(mp)</td>
<td>-0.0521 (-0.4512)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(faip)</td>
<td>0.2184 (1.6027)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(he)</td>
<td>-0.1559 (-0.9804)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(road)</td>
<td>-0.2236 (-1.5075)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>log(book)</td>
<td>-0.0799 (0.9767)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>capital</td>
<td>0.4612 (1.5459)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>east</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>port</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sargan test</td>
<td>0.6571 0.8014 0.9248</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.0000 0.0000 0.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.0098 0.2478 0.9698</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>3468 3179 3179</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Parentheses in the table are z statistic; *, **, *** are represented separately 90%, 95%, 99% confidence level; all regression models are GMM differential estimation results, and the followings are the same.

In order to further examine the regional differences of land finance and urban agglomeration, we selected the samples of the eastern and central and western cities from the overall sample and carried out GMM dynamic regression respectively.

Table 2 reported the GMM Dynamic Panel model on the impact of land finance on the Absolute Diversification Index (ADI) of eastern and central and western cities. Model 4 reported the test results of the effect of per capita land finance on the Urban Diversification Index (ADI) considering hysteresis and control variables of eastern cities in China. The results showed that the urban diversification index one period previous of eastern cities had a positive correlation with the urban diversification index at 95% confidence, and the elasticity coefficient was 0.0995. The per capita land finance of eastern cities was significantly negatively correlated with the urban diversification index at 99% confidence, and the elasticity coefficient was -0.1432. The Sargan test result was 0.7270, greater than 0.10, indicating that Zero hypothesis can not be rejected for instrument variables. AR (1) is 0.0000, AR (2) is 0.5698. Model 5 reported the test results of the effect of per
capita land finance on the Urban Diversification Index (ADI) of central and western cities in China when taking the ADI hysteresis and control variables. The results showed that the ADI one period previous of eastern cities had a positive correlation with the ADI at 95% confidence, and the elasticity coefficient was 0.1095. the per capita land finance of eastern cities was negatively correlated with ADI of central and western cities, and the elasticity coefficient was -0.2212. The Sargan test result was 0.9412, AR(1) was 0.0000, AR(2) was 0.9821, were both significant. On the whole, the explanatory variables of Model 4 and 5 are tested by significance, and the Sargan test and residual test results are better, and it can be considered that model 4 and 5 were reasonable.

Table 2. The GMM results of the effect of land finance on ADI of different areas

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 4 (Eastern)</th>
<th>Model 5 (Central and Western)</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(di(-))</td>
<td>0.0995** (2.4860)</td>
<td>0.1095** (2.6170)</td>
</tr>
<tr>
<td>log(land_finance)</td>
<td>-0.1432*** (4.6136)</td>
<td>-0.2212*** (4.7157)</td>
</tr>
<tr>
<td>log(wage)</td>
<td>-0.1124*** (-6.0536)</td>
<td>-0.1424*** (-5.5039)</td>
</tr>
<tr>
<td>log(mp)</td>
<td>-0.0712(-0.4215)</td>
<td>-0.0621(-0.6512)</td>
</tr>
<tr>
<td>log(fai)</td>
<td>0.4411*** (7.6840)</td>
<td>0.5211*** (6.7548)</td>
</tr>
<tr>
<td>log(hc)</td>
<td>-0.1157*** (-3.2493)</td>
<td>-0.2417*** (-3.0427)</td>
</tr>
<tr>
<td>log(road)</td>
<td>-0.2367*** (-6.8502)</td>
<td>-0.1851*** (-5.2512)</td>
</tr>
<tr>
<td>log(book)</td>
<td>-0.0076 (0.2827)</td>
<td>-0.0102 (0.3807)</td>
</tr>
<tr>
<td>capital</td>
<td>0.4612 (1.5459)</td>
<td>0.3611 (1.4419)</td>
</tr>
<tr>
<td>port</td>
<td>-0.0416(-0.4823)</td>
<td>-0.0610(-0.4132)</td>
</tr>
<tr>
<td>Sargan test</td>
<td>0.7270</td>
<td>0.9412</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>AR(2)</td>
<td>0.5698</td>
<td>0.9821</td>
</tr>
<tr>
<td>Observations</td>
<td>528</td>
<td>2651</td>
</tr>
</tbody>
</table>

Note: The eastern cities include the prefecture-level cities in the 11 eastern provinces of Liaoning, Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan, and the rest of the city for the central and western regions.

The scale of the financial expansion of the local government through the distorted urban infrastructure, the construction of the city, to prevent the diversification of the city, initially proved the hypothesis proposed in this article. The effect of fiscal expansion on the characteristics of urban agglomeration has obvious regional bifurcation. Although the expansion of eastern urban land finance is still logical to the city. The characteristics of the sample are negative, but the coefficients are not significant and the absolute value is much smaller than that of the central and western cities. The reason may be: First, the higher the level of economic development, the lower the dependence on land finance, the better economic endowment to the eastern region of the financial gap is smaller than the central and western regions, especially after 2003, this differentiation is more obvious, the eastern city development Second, the institutional environment is directly related to the local government public expenditure structure of the degree of bias configuration, the eastern city is more mature, good, open and transparent institutional environment can effectively reduce the land finance and its Debt financing as the core of the local government in the construction of urban infrastructure in the public expenditure structure of the degree of distortion.

In order to ensure the robustness and reliability of the model conclusion, the API is used as the dependent variable to replace the ADI model calculation, and a similar conclusion can be drawn. The analytical method is the same as above. Due to limited space, only the results of the overall
The GMM results of the effect of land finance on API

<table>
<thead>
<tr>
<th>Variables</th>
<th>Model 6</th>
<th>Model 7</th>
<th>Model 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\log(api(-1))$</td>
<td>0.1040*** (4.4531)</td>
<td>0.0969*** (2.8434)</td>
<td></td>
</tr>
<tr>
<td>$\log(land_finance)$</td>
<td>-0.0564*** (2.8158)</td>
<td>-0.0828*** (4.0307)</td>
<td>-0.1047** (2.2612)</td>
</tr>
<tr>
<td>$\log(wage)$</td>
<td>0.2286 (0.8842)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\log(mp)$</td>
<td>-0.0645 (-0.4512)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\log(faip)$</td>
<td>-0.2328* (-1.8033)</td>
<td>0.1133 (0.7338)</td>
<td></td>
</tr>
<tr>
<td>$\log(road)$</td>
<td>0.2412 (1.8000*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\log(book)$</td>
<td>0.1033 (1.1655)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{capital}$</td>
<td>-0.4799 (-1.5002)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{east}$</td>
<td>0.0506 (0.2876)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{port}$</td>
<td>-0.0246 (-0.1643)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sargan test 0.6527 0.9154 0.9877
AR(1) 0.0000 0.0000 0.0000
AR(2) 0.0128 0.5743 0.4108
Observations 3468 3179 3179

5 Conclusions

"High fever" land finance constitutes an important part of the development of the Chinese-style city and distinctive features. This paper introduces the mechanism of land finance on behalf of the will of the government, constructs the influence mechanism of land finance and urban agglomeration, and adopts the panel system GMM estimation method to analyze the 289 prefecture level and above cities in China from 2003 to 2015.

The main conclusions of this paper are as follows: First, under the dual incentive of fiscal decentralization and growth competition, the expansion of land finance strengthens the rigid structure of industrial structure and restrains the diversification of cities through the biased disposition of urban infrastructure construction. Second, due to the huge difference between the level of economic development and the institutional environment, the difference of the effect of land finance on the characteristics of urban agglomeration is obvious in the eastern and central regions.

Therefore, in the process of urban development, we should refine, standardize and supervise the use of local governments to prevent the land finance distorting the behavior of local governments, and thus hinder the evolution of urban agglomeration characteristics.

References:


Using Mobile Phone Data for Social Infrastructure Planning

Long, F.J.1*, Shi, L.2, Tang, H.3, and Yang, Y.4

Abstract: In China, traditional social infrastructure planning based on the experience of city planners lags behind the rapid urbanization process. From a new perspective, this paper involves mobile phone data in the planning of social infrastructure. First, we select Guiyang Riverside Park located in Guiyang City as the object of our research and identify its users based on the spatial-temporal information provided by mobile phones. By tracking the mobile signaling of these users, we obtain the spatial distribution of their residences. Then, service radius and service penetration rate are defined and calculated to reflect the actual service condition of social infrastructure, based on which planning suggestions are put forward to improve the level of current social services. Last but not least, inspired by the gravity model, we find that the number of people who have visited the park in a particular scope is negatively related to the distance. The discovery of distance decay phenomenon takes the first step to reveal the service law of social infrastructure, which will provide a reference for city planners to forecast the service scope of the social infrastructure under planning. In general, as an attempt to combine big data with social infrastructure planning, this paper is of great value for urban planning under the background of China’s new urbanization.

Key Words: Social infrastructure, mobile phone data, service radius, service penetration rate, distance decay

1* Long, F.J.
Corresponding author, Department of Construction Management, Tsinghua University, China
E-mail: longfj@tsinghua.edu.cn

2 Shi, L.
Department of Construction Management, Tsinghua University, China

3 Tang, H.
Guizhou Institute of Technology, China

4 Yang, Y.
Guizhou Institute of Technology, China
1 Introduction

China is currently undergoing urbanization at a scale and speed that is unprecedented in human history. Urbanization has made significant achievements in China’s social and economic development, in the meanwhile, the cost of rapid urbanization is enormous. The blind expansion of cities, gradual degradation of soil and water resources, destruction of the ecological system and other factors have led to many problems of an uncomfortable city environment. Both officials and scholars are paying increasing attention to the quality of urbanization rather than just pursuing the scale or speed. "National new urbanization plan (2014-2020)" issued by the central government marks a significant transformation of China’s urbanization development, the core of which is to emphasize the urbanization of people and to create harmonious, livable, energetic and modern cities.

As a subset of the infrastructure sector, social infrastructure refers to assets that accommodate social services (NZSIF, 2009). Examples of social infrastructure include schools, universities, hospitals, parks, community housing, etc., which all aim at promoting the health, education or cultural standard of the population (DBSA, 1988). In recent years, intensive urban sprawl has added to the demand for social infrastructure in most Chinese developing cities, where social infrastructure is being utilized over and above the design capacity (Ahmed et al., 2008). Worse still, traditional methods for social infrastructure planning to a great extent based on the experience of city planners lacks of scientific basis and public participation (Cheung and Leung, 2007), which can hardly adapt to the needs of various groups of inhabitants living in the city, thereby not conducive to social equity and sustainable development of China’s new urbanization.

In general, the defects of traditional method for social infrastructure planning lies in the weak data availability (Short and Kopp, 2005). Fortunately, in the age of information, big data has brought a revolution for urban planning. In this paper, we propose a novel idea by involving mobile phone data in the planning of social infrastructure. The paper is organized as follows. In Section 2, we introduce the mobile phone data and study methods we adopt. Section 3 describes the results of our study and Section 4 discusses what we find and puts forward some suggestions on planning. The viewpoints and meanings of this paper are summarized and highlighted in Section 5.

2 Data and Methods

2.1 Mobile Phone Data

2.1.1 Data Description
In recent years, the mobile phone has become one of the necessities of people’s daily life, in the meanwhile, it brings opportunities for urban planning as a result of the spatial-temporal information of people they provide. There are various kinds of mobile phone data, of which mobile signaling data is the most detailed. Any active use of a mobile phone (switch on and off, call and text message in and out, Internet access, etc.) and automatic base station switching of the mobile phone are recorded in log files and stored by mobile operators (Rein, 2010).

The mobile signaling data used in this paper are provided by China Mobile Communication Corporation Guizhou Branch Office, who accounts for nearly 70% of the market share, making the data we use close to covering the full sample. Besides, all the mobile activities happened within the urban area of Guiyang City from December 3, 2016, to December 11, 2016, are recorded in the data.
There are 2 billion pieces of mobile signaling data, 271.9GB in the aggregate, which is worthy of the name big data. Each piece of data includes the following parameters (see Table 1): 1) the processed constant ID number (for privacy issue) of mobile subscribers; 2) the code of the city in which mobile activities happen (“851” refers to Guiyang City); 3) the unique ID number of the mobile base station and its longitude and latitude; 4) the start time and duration of a mobile activity; 5) the type of mobile activities, including call, 4G, GPRS, etc.

<table>
<thead>
<tr>
<th>User_id</th>
<th>City_code</th>
<th>Base_id</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Start_time</th>
<th>Stay_time</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>100263014</td>
<td>851</td>
<td>140568577</td>
<td>106.666647</td>
<td>26.627810</td>
<td>2016/12/10</td>
<td>57s</td>
<td>Call</td>
</tr>
<tr>
<td></td>
<td></td>
<td>141182210</td>
<td>106.722961</td>
<td>26.609531</td>
<td>2016/12/8</td>
<td>2288s</td>
<td>4G</td>
</tr>
</tbody>
</table>

2.1.2 Data Processing

With these attributes, mobile signaling data can be used to track a mobile subscriber’s location by positioning the base station near which one’s mobile activity happens. Typically, the base station to be recorded when a mobile activity happens shall be the nearest one to the corresponding mobile phone. The precision of positioning results normally depends on the density of mobile base station network. In our study area, the average distance between mobile base stations is approximately 300 meters, which can meet the requirement of our research.

Firstly, we input the location data of each mobile base station to geographic information system (GIS). Thiessen polygons are then generated, and the cells that cover the social infrastructure we investigate along with their interior base stations can be directly observed through the screen. Afterwards, we extract the mobile signaling data which contain the ID number of these target base stations, and with the model to be introduced in Sect. 2.3.1, the users of social infrastructure can be recognized. Finally, all of these users are located based on the method in Sect. 2.3.2 and their residential locations are mapped on GIS. After these steps, the spatial distribution of the social infrastructure’s users is visualized. Both the research on actual service condition and the discovery of distance decay phenomenon are based on these results.

2.2 Study Area and Research Object

Guiyang City, as the capital of Guizhou Province, is not only a hub for politics, economy and culture in Guizhou but also one of the central cities in Southwest China. Like many other cities in China, Guiyang has encountered many urban problems in the process of rapid urbanization, of which the insufficient supply of social infrastructure in urban area caused by the fast population growth is severe.

As a major kind of social infrastructure, the park provides a space for the public to recreate, to relax, to participate in scientific and cultural activities as well as to do physical exercise. In this paper, we choose Guiyang Riverside Park which is located in the central area of Guiyang City as the object of our research. The park was renovated in 2002 by the government, covering an area of 170,000 square meters. As a place aiming at promoting the living standard of the population, Guiyang Riverside Park opens to the public free of charge all day.
2.3 Study Methods

2.3.1 Recognizing the Users of Social Infrastructure
After targeting the cells and extracting the signaling data as instructed in Sect. 2.1.2, what we need to do next is to recognize the users of social infrastructure we investigate. The study period is from December 3, 2016, to December 11, 2016, covering five weekdays and four holidays (two weekends). In this paper, people whose mobile signaling appears in the base station within the area of Guiyang Riverside Park are divided into three groups: 1) people working in the park, including operation and maintenance staff of the park, retailers in the park, etc.; 2) users of the park, including the citizens who do physical exercise in the park every day, visitors who go sightseeing to the park on holidays, etc.; 3) people passing by the park, mainly referring to those happen to appear in the vicinity of the park. Three groups of people can be distinguished by their diverse mobile activity patterns. People in Group 1 typically spend most of the daytime in the park. Some of them may be on night duty, but they are in the minority and not within our consideration. Therefore, considering the working hours of the people in Guiyang and the occasional interruption of mobile signaling, we regard the people whose mobile signaling stays within the area of the park longer than 5 hours for more than 4 days as the staff of the park. People in Group 2 spend less time in the park by contrast, and they may not appear in the park many times in 9 days. As for the people in Group 3, the duration of their mobile signaling staying within the area of Guiyang Riverside Park is the shortest. After taking the area and surroundings of the park, we filter out the people whose mobile signaling stays within the field of the park shorter than 2 hours altogether in 9 days to avoid interference by Group 3.

<table>
<thead>
<tr>
<th>Group No.</th>
<th>Filter Criteria (5 a.m-9 p.m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Whose mobile signaling stays within the area of the park longer than 5 hours for more than 4 days</td>
</tr>
<tr>
<td>Group 2</td>
<td>Eliminate Group 1 from the people whose mobile signaling stays within the area of the park longer than 2 hours altogether in 9 days</td>
</tr>
<tr>
<td>Group 3</td>
<td>Whose mobile signaling stays within the area of the park shorter than 2 hours altogether in 9 days</td>
</tr>
</tbody>
</table>

2.3.2 Identifying the Residence of Users
Referring to the previous literature (Becker et al., 2011; Kung et al., 2014; Niu and Ding, 2015), we adopt the method that is commonly used to identify the residence of people. Taking the mobile subscriber with ID number 100261102 who has been identified as the user of Guiyang Riverside Park as an example, we first extract the mobile signaling data which record his or her ID number. Then, we search the base station around which his or her mobile activities happen during the period from 12 p.m. to 6 a.m. in 9 days. The same base station with ID number 141172340 recurs for more than 4 days, which has reached the minimum requirement we set. Thus we regard the area covered by this base station as the place where he or she lives.

2.3.3 Evaluating the Actual Service Condition of Social Infrastructure
First, we adopt the concept of core radiation circle which is commonly used in the field of commercial analysis into our research. The word core means that in one hand, the area of the circle is where the main users of Guiyang Riverside Park are concentrated; in another hand, Guiyang Riverside Park should be the primary choice for the inhabitants living within the area to recreate, to
enjoy, to join in scientific and cultural activities as well as to do physical exercise. Previous methods for identifying the core radiation circle are evolved from classical models or theories. In this paper, with the mobile phone data, we can know who the users of Guiyang Riverside Park are and where they are distributed in the city exactly, based on which the core radiation circle can be mapped quickly and precisely.

After the identification of core radiation circle, two indicators service radius and service penetration rate are implemented to reflect the current service scope and utilization efficiency of the park respectively. The service radius which refers to the radius of the core radiation circle can be directly calculated through the spatial analytical module of GIS. The service penetration rate is defined as the proportion of the users to all inhabitants living within the core radiation circle.

2.3.4 Distance Decay of the Service

Distance decay is commonly analyzed in the study of spatial interactions in geography, which means that the interaction intensity is weakened with the increase of the distance (Liu et al., 2014). In this paper, we adopt the concept of Distance decay to reflect the impact of distance on the service capability of social infrastructure. There have been various functions used to describe the distance decay phenomenon, such as power law, exponential equations and Gauss function (Wu and Bao, 2005). Liu et al (2014) evaluated these functions and concluded that the power law function could reveal the inherent distance impacts behind spatial interactions. Thus the interaction formula becomes the gravity model which is widely used in geography and regional economics. According to the model, the intensity of interaction between locality i and locality j (G_{ij}) can be calculated by the following equation:

\[ G_{ij} = k \times \frac{P_i P_j}{d^\alpha}, \quad (1) \]

where \( P_i \) and \( P_j \) represent the size or scale of locality i and locality j, between which the distance is \( d \), and \( k \) denotes a constant coefficient whereas \( \alpha \) denotes a parameter to reflect the effect of distance decay. The larger the parameter \( \alpha \), the greater the hinder impact of distance on the interaction. According to Gao et al. (2013), Eq. 1 can be deformed into:

\[ G_{ij} \propto d^{-\alpha} . \quad (2) \]

Therefore, what we need to do is to confirm that there is a linear correlation between \( G_{ij} \) and \( d^{-\alpha} \) and to calculate the distance decay parameter. In this paper, locality i represents Guiyang Riverside Park and locality j represents the areas with a distance \( d \) to the park. The number of \( G_{ij} \) depends on the number of park’s users on locality j.

3 Result

3.1 Actual Service Condition of Guiyang Riverside Park

Based on the methods introduced in the preceding chapter, residential locations of the users of Guiyang Riverside Park are mapped on GIS (see Fig. 1). There are 1022 people identified as the users of the park, and 98 as the staff. The results are close to the field observation number of visitors, indicating that the filter criteria in this paper are valid. The According to the distance between each mobile base station in our study area and referring to the previous study (Gao et al., 2013), the users are binned in 1 km intervals, and the number of them in each range is counted (see Table 3). Then the core radiation circle is identified based on the criteria that the number of users in the circle shall
account for 50% of all. After calculation, the park mainly provides social service for inhabitants living within a radius of 1.8 km, and in this scope, less than one out of every 100 people has visited the park in 9 days.

![Image](image.png)

Fig. 1 Spatial distribution of the users and core radiation circle of the park

Table 3 Number of users in each range

<table>
<thead>
<tr>
<th>Range (km)</th>
<th>0~1</th>
<th>1~2</th>
<th>2~3</th>
<th>3~4</th>
<th>4~5</th>
<th>5~6</th>
<th>6~7</th>
<th>7~8</th>
<th>8~9</th>
<th>9~10</th>
<th>10~11</th>
<th>11~12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>205</td>
<td>347</td>
<td>165</td>
<td>102</td>
<td>59</td>
<td>50</td>
<td>36</td>
<td>26</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

3.2 Regression Results

The data in Table 3 is shown in a log-log plot. As can be seen from Fig. 2, the service capability based on the number of users decreases along the distance, and there is a linear correlation across the distance between 1 km and 8 km, which reveals the phenomenon of distance decay. To calculate the distance decay parameter, we select the above seven points to be regressed based on the power-law. The regression result shows that the number of users decreases along the distance with a scaling exponent 1.84, of which the R-squared reaches 0.996, meaning there is a high degree of the power-law fitting.
4 Discussion

4.1 Suggestion on the Park Planning

With the current service condition of Guiyang Riverside Park clarified, some findings deserve to be focused on. First, as one of the few parks located in the central area of Guiyang City, Guiyang Riverside Park bears the responsibility to provide a recreational place for the inhabitants living in this area. However, the service radius of the park is only 1.8 km, meaning that there are a large number of blank areas downtown which lack of the service from the park. Second, the low penetration rate reflects that in one hand, the attraction of Guiyang Riverside Park to its potential users is inadequate; in another hand, inhabitants living in the vicinity do not regard visiting the park as their primary choice for relaxation.

To solve these problems, city planners shall find ways to improve the service scope and utilization efficiency of Guiyang Riverside Park. A renovation is needed to raise the citizen’s interest in the park, and building more fitness equipment may attract old and young to participate in physical exercise and be beneficial for promoting the health standard of the public. In the meanwhile, some new parks are in demand to fill the vacancies of the social service and adapt to the high population density of the central area of Guiyang City.

4.2 Explanations for the Distance Decay Phenomenon

What can be found in Sect. 3.2 includes that: 1) the number of users in the range of below one kilometer is relatively small; 2) the farthest user is nearly 12 km away from Guiyang Riverside Park whereas the service radius of the park is only 1.8 km; 3) the goodness of model fit clearly deteriorates beyond the distance of 8 km.

The explanation for the first phenomenon is that the density of residences near the park is relatively low and there is a river next to the park, causing fewer users being located in the south of the park. The second finding indicates that the scope in which the park provides social service is concentrated. That is to say, people who live far away are not a park’s main service objects. As for the third issue, we speculate that it may result from the decisive role of distance when the
accessibility to social infrastructure is beyond a particular value.

4.3 Further Studies

As an exploration of involving big data in social infrastructure planning, this paper raises various interesting issues to be explored in the future.

First, we confirm that the service capability of the park is negatively related to the distance in this paper, but the study of verifying if the service law of social infrastructure is characterized by the gravity model hasn’t been completed yet. It means that we should clarify the correlation between the service capability and the size or scale of social infrastructure in the next step.

Second, we only select one kind of social infrastructure as the research object in this paper. It will be interesting to research and compare the distance decay parameters of more. We speculate boldly that the distance decay parameter of the hospital may be smaller than that of the park, the reason for which is that most people are willing to go further to see a doctor in the top hospital, making the hinder impact of distance decrease.

Third, when city planners intend to make an overall planning of a particular kind of social infrastructure such as the park, they just need to take all the parks in the city into consideration like what we have done in this paper. The blank service areas of the parks will be clearly observed through the map, based on which site selection and capacity design are easy to be decided.

5 Conclusion

Under the background of China’s new urbanization, scientific and human-centered planning of social infrastructure is in an urgent demand as is the social infrastructure itself. Fortunately, the development of big data has brought opportunities to the innovation of planning methods. As an attempt to involve big data in social infrastructure planning, this paper puts forward the research on actual service condition of Guiyang Riverside park and discovers the distance decay phenomenon for the first time. The results of research work can not only push the government to improve the current level of social service, but also provide a reference for the future planning. When the service law of social infrastructure is confirmed to be characterized by the gravity model, city planners can make a rational forecast on the future service capability of the social infrastructure to be planned. Moreover, with the popularity of mobile phones, mobile phone data which carries valuable information of people is playing an important role in urban research and urban planning. By introducing the data and the work of data processing in detail, this paper provides a reference for further urban studies based on mobile phone data.

Reference

sustainable urban land use and spatial development. Procedia Environmental Sciences, 12, 491-498.
The Study of the Economic Balance in Urban Village Transformation in China under the Guidance of Policy

——A Case Study of Guangzhou, Guangdong, Province

Mengtian Cao\textsuperscript{a}, Minting Cai, Canling Zheng\textsuperscript{a}, Ziyi Cao\textsuperscript{a}, Zhigang Wu\textsuperscript{a}\textsuperscript{*}

\textbf{Abstract:}

Urban village is a unique phenomenon in the process of urbanization in China. Urban village transformation is the solution to the shortage of construction land and the construction of inefficient construction land, to improve the supply of urban housing and to improve the urban environment. This research starts from the evolution of urban villages’ policies and reviews the development stages of urban village transformation in Guangzhou. Moreover, it conducts the in-depth analysis and a series of formula derivation and calculation of the economic balance relations that the UV transformation cost in Guangzhou is equal to the financing need, obtaining the main factors affecting the economic balance. The results of the study show that: Through the analysis and decomposition of the comprehensive volume ratio after transformation and the floor price, which are the important indicators affecting urban villages’ transformation, it is seen that the key to achieving the economic balance is to grasp the residential floor price and the commercial floor price as well as to identify the ratio of the commercial floor price to the residential floor price.

\textbf{Keywords:} Urban villages; Policy envolvement; Transformation pattern; Economic balance; Guangzhou.

\textsuperscript{a} School of Tourism management, South China Normal University, Panyu district, No.378 Waihuan West Road, Guangzhou, 510000, Guangdong, P.R.China.

\textsuperscript{*} Corresponding author. Tel.: +86 13922238800. E-mail addresses: zhigangwu@scnu.edu.cn (Z. Wu).

Other authors. E-mail addresses: caomt@m.scnu.edu.cn (M. Cao), minty915@126.com (M. Cai), Zhengcl@m.scnu.edu.cn, (C. Zheng) caozy@m.scnu.edu.cn (Z. Cao).
1. Introduction

Urban village (UV) is a unique phenomenon in the process of urbanization in China. Since the reform and opening up in 1978, the built-up area of cities in some economically developed areas has expanded rapidly, and the original rural area around the city has been surrounded by the city, becoming UV. At present, there are urban villages in almost all of the cities in China, especially in large and medium-sized cities. Wherein, the phenomenon is the most obvious in the Pearl River Delta, the Yangtze River Delta, the Circum-Bohai Sea Economic Zone and other economically developed areas. As of 2016, according to the data released by the Urban Renewal Bureau of Guangzhou, China, in UV, there were 10521 transformation plots, which covered an area of 320.12km² and accounted for 54.25% of the urban renewal plots in Guangdong Province[1]. Meanwhile, the internal problems of UV are becoming more and more serious. For instance, the low utilization rate of construction land, the old buildings, the serious environmental pollution and the high population density have restricted the development of cities.

As UV is a unique urban phenomenon in China, there are few foreign articles specializing in the study of UV, and city villages, slums and other self-service residential areas in foreign countries are similar to UV, but the studies focus on two aspects, namely floating population residence and land use of UV[2-7]. In China, the research on UV phenomenon mainly involves concept definition, characteristics and types, evaluation and causes, etc. UV is a benefit community, which collects urbanized villagers, immigrants living in low-rent housing and urban spontaneous grass-roots units, while in UV, the land property rights are vague, and the laws and regulations of the leasing market are not sound[8]; UV characteristics are studied from the four aspects of the spatial patterns, demographic characteristics, economic strength and social characteristics; the types of UV are classified by using qualitative analysis and mathematical methods; the evaluation is mainly based on the positive and negative effects[9].

With regard to the research on UV transformation, Chinese scholars mainly carry out the study from transformation model thinking, multi-lateral interest relationship and coordination, transformation planning, transformation benefit analysis and other aspects[10-13]. The research contents are mostly studied from multiple perspectives, and from the perspective of UV villagers, the study content focuses on the living conditions of UV villagers, the changes of organization forms (such as family education, citizenship, social security, etc.), exploring on sub-culture of UV, community integration and cultural reconstruction of "changing village into community", citizenship and identity[14].

In UV transformation, complex stakeholders’ power relations and long governance structures are usually involved, and in terms of different scale development and re-development UV, the balance of different power relations would bring about promoting or preventing UV transformation. Urban-rural dual system is not only the foundation of UV generation and spread but also the obstacle of UV transformation[15-16]. The core of UV transformation is the redistribution of the benefits of land increment among key stakeholders, and the common commitment established through cooperative relations is the key to the successful implementation of the project[17]. In the study of China's UV transformation, it is seen that local government policies and top-down hierarchical management methods are the most influential in developed cities. In view of this, firstly, taking Guangzhou as an instance, this study starts from the evolution of UV policies and reviews the development stages of UV transformation in Guangzhou. Meanwhile, it discusses the favorable direction of UV transformation through comparing the changes of the new and old policies in the process of UV transformation in Guangzhou. Moreover, it conducts the in-depth analysis and a series of formula derivation and calculation of the economic balance relations that the UV transformation cost in Guangzhou is equal to the financing need, obtaining the main factors affecting the economic balance, so as to be able to regulate the UV renewal and transformation at the macro policy level, make it develop toward a healthy
direction and provide reference for UV transformation in other areas of China.

2. Changes in the policy development in the process of UV transformation in Guangzhou

2.1 Initial stage

In 2000, Guangzhou comprehensively promoted the conversion of UV. Specifically, villagers’ agricultural accounts were all changed into the resident accounts ("changing from agricultural to non-agricultural status"), and the collective economic organizations of villages (EOV) were converted into joint-stock enterprises (companies), but the UV problems were not substantially solved. In 2002, with regard to the problems of UV conversion, the municipal government put forward the UV transformation thinking of "conversion before transformation" and "one policy for one village".

2.2 Development stage

After UV conversion, in 2008, the government further improved the relevant policies concerning "changing from agricultural to resident status" and "UV" transformation, actively and steadily solving various contradictions and problems in the process of "changing from agricultural to resident status" and "UV" transformation. In 2009, Guangzhou promulgated "Opinions on Accelerating the ‘Three Old’ Transformation" (Document No. 56), which opened a new milestone for the overall progress of the transformation of old towns, old villages and old factories. Document No. 56 divided two models of renovation and transformation, namely the overall transformation model based on the overall demolition and reconstruction as well as the comprehensive renovation model aimed at improving the living environment. In terms of transformation subjects and operation modes, the overall transformation projects can take UV self-transformation model or open land transfer financing model. The overall plan must be approved through the consent of more than 80% of the village collective members. Regarding revenue sharing, the ratio of the government to village is 4:6. The favorable policies towards village are conducive to improving the enthusiasm of the transformation, and restrict the use of retained part of the district government as well.

To further accelerate the transformation of UV, in 2012, the Guangzhou municipal government put forward "Supplementary Opinions on Speeding Up the ‘Three Old’ Transformation" (Document No. 20). With regard to transformation subjects and operation modes, the leading role of the district government was enhanced, and the transformation model selection was changed from encouraging the EOV self-transformation model to encouraging the investment financing model through open land transfer. The proportion of villagers’ voting was revised, increasing from 80% to 90%, and greater emphasis was given on the villagers' right to know and participate. However, to some extent, the transformation difficulty was increased, and the implementation barriers were greater. Revenue sharing ratio remained unchanged. By the end of 2014, a total of 37 old village transformation projects, with a total area of 1718hm², had been approved in Guangzhou.

2.3 Adjustment stage

In 2015, Guangzhou promulgated the "Urban Renewal Measures in Guangzhou" and the supporting methods (hereinafter referred to as the Measures), and the urban renewal management standards were heightened to the regulation level. It was proposed that the renewal and transformation of old villages included two modes, namely overall transformation and micro-transformation. The concept of "micro-transformation" was put forward for the first time, containing renovation remediation and local transformation. Overall transformation was summarized as the following three models: collection reserve, self-transformation and cooperative transformation. The proportion of village collective members’ voting was down to 80%. Regarding benefit sharing, the benefit sharing project, namely the surplus construction area, was
added in the old village renewal methods. In the approved and determined transformation program, the total construction area needed for achieving the economic balance was compared with the current regulatory total construction area within the scope of the village transformation, and the surplus construction area was distributed by the municipal government, the district government and the village collective in accordance with the proportion of 4:3:3, which meant the ratio of the government to EOV was 7:3. In actual operation, many transformation projects would break through the planned construction area, and this initiative is conducive to controlling the construction area of projects and improving the enthusiasm of participation. Specific periodic policies are detailed in Fig.1.

3. Changes and applicability analysis of UV transformation models in Guangzhou under the guidance of policy

3.1 Changes of UV transformation models in Guangzhou under the guidance of policy

According to Document No. 56 in 2009 and Document No. 20 in 2012, UV transformation models consist of the comprehensive renovation model and the overall transformation model. The comprehensive renovation model is suitable for the UV with the poor environment and the imperfect public service facilities, and the purpose of improving the living environment is achieved by violation clearance and construction reduction.

The overall transformation model is mainly aimed at the overall demolition and reconstruction of 52 urban villages, which are located in the urban key functional areas. According to different ways of financing, there are the following three overall transformation models: I. the overall transformation implemented through open transfer financing (the urban village is comprehensively reconstructed, and the transformation funds are obtained through the open transfer financing plots); II. the overall transformation implemented through self-transformation and agreed transfer financing (the urban village is transformed by itself, and after the transformation program is determined, the transformation funds are obtained through the agreed transfer financing plots, so as to achieve the overall transformation); III. the overall transformation implemented through self-transformation and rolling development (through dividing the transformation periods and rolling development methods, the early development investment can get a quick return, so as to be able to invest in the next period of development, so the capital investment is relatively small).

"The Measures" released in 2015 put forward that the renewal and transformation of old villages contained micro-transformation and overall transformation. On the basis of maintaining
the current status, micro-transformation is to dismantle, construct and repair the local architecture or change the use function, improve the infrastructure and so on, so as to achieve the purpose of renovation, improvement, protection or activation. At this time, the overall transformation can be summarized as the following three models: Ⅰ. collection reserve (public transfer or municipal public facility construction shall be implemented after land consolidation); Ⅱ. self-transformation (the village collective shall carry out the demolition, compensation and resettlement according to the approved transformation programs, and the financing plots are obtained through the agreed transfer methods, so as to conduct the development and financing); Ⅲ. cooperative transformation (after the programs are approved, developers are introduced by public tender, to carry out the cooperation, or the village collective shall apply for transferring to cooperative enterprises consisting of the village collective and the market subjects by agreements, or cooperative enterprises are introduced by the open transfer financing plots, to carry out the cooperative transformation).

3.2 Applicability analysis of the latest overall transformation model

In terms of the applicable scope, collection reserve is applicable to the project involving major infrastructure construction or the project with complex ownership that cannot implement the joint transformation or the same subject transformation after determining the basic information of the land. If the ownership is single, and more than 80% of the EOV members agree to transform, it is possible to carry out the cooperative transformation or self-transformation. Collection reserve can transform UV with complex ownership and construct major infrastructure, which is conducive to the overall planning, but EOV does not participate in land transfer revenue sharing, which causes that the enthusiasm of collection reserve is less than that of self-transformation and cooperative transformation.

With regard to the participation subjects, the subjects of collection reserve and self-transformation are the government and EOV, respectively, whereas the subjects of cooperative transformation are EOV and market cooperation enterprises. Self-transformation requires V with strong economic strength. For the UV with general development or poor economic strength, there will be some barriers.

Concerning transformation revenue, UV participating in collection reserve can only get the basic villagers’ housing and village collective property rehabilitation resettlement compensation, and does not participate in land transfer revenue sharing. However, self-transformation and cooperative transformation can share revenue sharing, and self-transformation revenue sharing can fully belong to EOV. Therefore, urban villages involving the major infrastructure construction or with complex ownership are applicable to the collection reserve model; urban villages with strong economic strength can choose the self-transformation model; other urban villages can choose the cooperative transformation model.

4. Analysis on the economic balance of UV transformation in Guangzhou

4.1 Economic balance relationship

As the benefit game of UV transformation mainly focuses on the flow, exchange and distribution of the two elements, which are land and capital, to operate, while land and capital have become the core of the balance of the benefit game[18]. Thus, the economic balance relation of UV transformation in Guangzhou can be summarized as the following formula:

\[ TC = FN \] (1)
\[ FN = FCA \cdot CFP \] (2)
\[ FCA = CVR \cdot LA \cdot VA \] (3)

(TC: UV transformation Cost; FN: Financing Needs; FCA: Financing construction Area; CFP: Comprehensive floor price; CVR: the comprehensive volume ratio after transformation; LA: land...
Area of transformation plots; $VA$: villagers’ resettlement and rehabilitation construction area.

Among them, according to different transformation models, the financing need can be from the financing, transfer and village collective self-raising. Based on different transformation models, the economic balance will be different, but the principle is the same.

Therefore, we can use formula (1), (2), (3) to get formula (4) and formula (5):

$$\begin{align*}
TC &= (CVR \cdot LA - VA) \cdot CFP \\
CVR &= \frac{VA + TC}{LA + CFP}
\end{align*}$$

4.2 The main factors affecting economic balance

In general, in a UV transformation program, the land area of transformation plots can be obtained through the field survey, and villagers’ resettlement and rehabilitation construction area can be obtained by measuring the current construction area and calculation, while the transformation cost is calculated through the relevant policy documents, so they are relatively stable. Therefore, the economic balance focuses on how to determine the comprehensive volume ratio after transformation and the comprehensive floor price.

It can be seen from the formula that the comprehensive volume ratio after transformation is correlated with villagers’ resettlement and rehabilitation construction area, the land area of transformation plots, the transformation cost and the floor price. Villagers’ resettlement and rehabilitation construction area, the land area of transformation plots and the transformation cost can be obtained through the calculation, so the comprehensive volume ratio after transformation is mainly related to the comprehensive floor price. In the case of the relative stability of other factors, the comprehensive volume ratio after transformation is negatively correlated with the comprehensive floor price, and if the floor price is higher, the comprehensive volume ratio after transformation will be smaller.

5. Conclusions and Discussions

Policy changes are accompanied by the development and changes of the whole UV transformation, and the dominance of the government plays a greater role in the economic balance. The government dominates UV transformation, indicating that the government needs to assume more responsibility for distribution.

The floor price is an important indicator affecting the economic balance. Through the analysis on the internal economic balance relation of UV in Guangzhou, it is found that the important indicator affecting the stability is the floor price. The value of the floor price has a direct impact on the determination of the financing construction area, so as to affect the subsequent benefit sharing.

UV transformation is carried out under the background of urbanization, having certain significance of the epoch. Numerous urban villages are widely distributed in Guangzhou. After several years of transformation, some results have been achieved, and the urban renewal measures which are promulgated on the basis of summing up the experience have further refined the implementation procedures of the transformation. The continuous development and change of the policies results in different characteristics and applicability of different transformation models, so UV transformation needs to select the appropriate transformation model in accordance with the actual situation of UV. Through the analysis and decomposition of the comprehensive volume ratio after transformation and the floor price, which are the important indicators affecting UV transformation, it is seen that the key to achieving the economic balance is to grasp the residential floor price and the commercial floor price as well as to identify the ratio of the commercial floor price to the residential floor price.

In the future UV transformation, the government should arouse the transformation enthusiasm of developers and village collectives and regulate the benefit balance of stakeholders in urban
villages. Through the specific calculation and analysis of the interests of the three parties, it is possible to provide the operational reference for the government to regulate and control the benefits of land increment. In the face of the equilibrium game of long management and numerous stakeholders, it is necessary to establish a unified networked UV transformation information base, so as to provide the detailed basic information for the future urban renewal and provide more opportunities for rural household livelihood choices in urban villages.

References:
Research on the Transformation Path from Traditional Construction Method to Off-site Construction - Taking Chinese Enterprises as Example

Liu, G.W ¹, Xie, F.Y ², Mao, C.³*

Abstract: As one of the important directions for the transformation and upgrading of the construction industry, the off-site construction has advantages of low energy consumption, low pollution, high efficiency and high quality, which prompts more and more enterprises to change from the traditional construction to the off-site construction. However, not all companies are able to change successfully and achieve the desired goal, which is closely related to the transformation of enterprises and adopted. Therefore, this paper aims to obtain the best transformation path of various enterprises, and introduce a correct direction for the enterprises who are follow-up to be engaged in the off-site construction, by (1) collect the successful enterprises in the transformation of the off-site construction in china; (2) deeply excavate and analyze the transformation process of these enterprises; (3) summarize the transformation path, and analysis the utility of various transformation path. The research shows that there are five kinds of transformation paths in Chinese off-site construction enterprises, among which linear and homogeneous transition are the common paths. At the same time, due to the different business characteristics, there is often the best transition path for different types of enterprises.

Keywords: off-site construction; construction enterprises; transformation path

¹ Liu, G.W
Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: gwliu@cqu.edu.cn

²* Xie, F.Y
Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: xiefangyun@cqu.edu.cn

³* Mao, C
Corresponding author, Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: maochao1201@cqu.edu.cn
1 Introduction

For the global construction industry, off-site construction has long been a new concept. The emergence of the industrial revolution makes the construction industry began to initiation of the trend of industrial construction, and the Second World War is really the construction industry to become a new type of construction industry with the impact of the production mode. Since the 1930s, the United States, Japan, Sweden and other countries have begun to explore the construction industry in-depth study, and Singapore, Australia and China's Hong Kong region followed, the construction of these countries, industrial systems, whether from production technology or The development of production relations has been relatively mature. However, not all countries have begun to think about the transformation of their construction industry to the direction of industrialization, and not all countries that have started construction industrialization have already completed the construction of the construction industry system, such as China. In the 1950s and 1960s, China began to flourish in the construction industry, until the end of the 20th century, really see the start of the construction industry.

As we all know, the traditional construction mode which build by hands on-site has the existence of high energy consumption, low production efficiency, unsustainable development, poor production methods, low informatization and so on. The off-site construction mode compared to the traditional way, can effectively save water 40-50%, reduce 90% of the garbage emissions, reduce the energy consumption 20-30%, saving 30-40% of the labor force. And it is an inevitable direction of construction industry transformation and upgrading.

The transformation of the traditional construction method to off-site construction need take production technology and production relationship into consideration. Nowadays it has a lot of researches about production technology due to it is the basis for the realization of the off-site construction, mainly in the production of prefabricated components, connection technology, installation technology, production machinery and equipment innovation, construction process informatization and so on. However, the research on the production relations which will affect the long-term development and progress of off-site construction is limited compared with the production technology. And the research on the transformation and upgrading of stakeholders is much rare. Therefore, this article focuses on the production relations changes when traditional construction method transforms to off-site construction, and the way stakeholders adopted in transition process which makes transform successfully. So this article wants to provide a certain reference to follow-up enterprises and help them achieve transformation.

2 Literature review

2.1 Definition of off-site construction

Off-site construction not a fresh concept for the global construction industry. Starting from the first industrial revolution, the idea of off-site construction began to germinate (Zhou Chao, 2007). And the Second World War make the off-site construction really become a new production mode of construction industry with great influence. Since the 1930s, the United States, Japan, Sweden and other countries have begun to carry out in-depth exploration of off-site construction, Singapore, Australia and Hong Kong also followed. The origin of China's off-site construction can be traced back to the earliest 50, 60 years, and the State Council introduced the first policy related to the off-site construction--"Decision on Strengthening and Developing the Construction Industry", it has determined that China's construction industry needs to transition to the direction of off-site construction. However, the off-site construction has been developed nearly a hundred...
years, but it still has not been a unified concept and definition, and with the socio-economic and technological level of continuous development, off-site construction is also constantly given the new connotation of the times.

Mehrdad Arashpour et al (2015) pointed out that off-site construction means the way of industrial production apply in the construction area, by taking part of the construction work to the factory environment and forming the components production line. Sparksman (1999) and Zhengdao Li (2014) think off-site construction same as prefabricated building, and it is a manufacturing process that integrates a wide variety of building materials and connectors in a special plant to form a component. Roger-Bruno Richard (2005) points that off-site construction can be divided into five levels: prefabricated, mechanized, automated, artificial intelligence and replication, and now it just reached the degree of mechanization. Lara Jaillon (2009) and C.S. Poon also think the off-site construction is prefabricated building, which represented the process of building produced in the factory, and they also pointed out that the not all of the building components were produced in the factory and it could be produced in the open air.

Thus, from a narrow perspective, the off-site construction can be divided into mechanical construction and factory manufacture. The factory manufacture refers to the decomposition of the building into a single component, and the components produced in the prefabricated factory, then transported to the construction site for assembly, like the production of cars or toy bricks. It includes five aspects: (1) production of components is done in the factory; (2) all activities in the factory production line to complete; (3) prefabricated components means the modular building parts, such as the external walls, staircase board, beams, columns, balconies, the overall kitchen and so on; (4) prefabricated components need to be transported to the project site; (5) prefabricated components are laid and assembled in the construction site. The structure of off-site construction includes light steel structure, wood structure, concrete structure and so on. It is also can be divided into semi-prefabricated, full prefabricated, the overall module. From a broad perspective, the off-site construction can also include the information technology and intelligent during the construction process.

2.2 Enterprises Transformation

The meaning of transformation often involves three levels, namely, structural changes, operation mode changes and ideas changes. From a broad point of view, the most fundamental change in an enterprise's transformation is its change in the competitiveness of the enterprise in the whole environment, by changing the organizational structure, management system and process. So that the enterprise can keep up the pace with the market, which can get more long-term competitiveness and vitality. However, from a narrow perspective, the enterprise transformation is more emphasis on changes in business, through open up the new business types and scope to improve the competitiveness of enterprises.

Not all enterprise transformation can be successful, the successful transformation can be understood as an enterprise upgrade. Enhance the underlying technology is a necessary condition of enterprises upgrade, improve and promote all aspects of the entire value chain of the enterprise is the ultimate performance of enterprise upgrade. Existing studies suggest that enterprises transition from high pollution, high energy consumption, extensive production mode to low pollution, low energy consumption and intensive production mode is an inevitable trend. Kong Yan's (2016) studied the transformation and upgrading of China's construction industry, and think that the workers within the skill training, team construction and other related content to provide a basic platform for the industrial upgrading. Zhou Jianliang (2014) point that the promotion of BIM technology can promote the transformation of China's construction industry. Yao Zhiqin (2013) said the current China's construction industry is facing low earnings, high pollution, lack of talent and
other problems, so it is necessary to promote the construction industry transformation and upgrading. And she adopts the smile curve to analyze the transformation and upgrading, aims to put forward new ideas and suggestions.

Industrial transformation as a macro-level analysis, but also combined with the transformation of enterprises. A transformation of an industry, is bound to affect the changes in the industry, and the transformation of enterprises to a certain extent can lead to the entire industry changes. On the definition and connotation of enterprise transformation, there has been a big controversy. Adnals thinks that the transformation of enterprises is a more thorough change in the ideals and behavior. And Shhaeen (1994) said the enterprise transformation is the enterprise make a strategic changes in organizational structure, corporate strategy, corporate behavior and other aspects, in order to obtain stronger business competitiveness. No matter what kind of definition, are that the transformation of enterprises is a behavior that enterprise take a series of initiatives to gain better competitive advantage and market share. And whether the transformation of enterprises or industrial, there are certain rules and paradigms to follow, it can be better service for the subsequent transformation.

3 methodology

The development of things in nature or social environment often has a universal law, so if the traditional construction enterprises like developer, designer to the off-site construction also has some general rules? The study of this paper begins with such a problem.

In order to solve this kind of problem, the induction method is often adopted. And this article mainly chooses the Chinese construction enterprise as the object. Because the construction industry has been a pillar industry and enriching industry in China's national economy. It has made outstanding contributions in stimulating domestic demand, raising the GDP and local economic output. As can be seen from Table 1, China's construction industry output has been increasing, and it accounted for the proportion of GDP has also increased. Thus, the industry or construction enterprises transformation will cause a huge impact in China's society and economy. What's more, China has a certain development basis of off-site construction, as early as 1960s or 1970s, China has begun construction of the seeds of off-site construction. In 2015, the Chinese government proposed that "the off-site construction area will be 30% of the total construction area by 2020", while the current off-site construction just accounts for only 1%. Huge market gap and demand continue to stimulate the Chinese construction enterprises to think about how to transform to off-site construction to meet the needs of the new trends of industry. And China's construction enterprise transformation has an irregular way to follow, there have been a number of enterprises making a lot of attempts, and these attempts accumulated valuable experience can effectively guide the follow-up enterprise transformation.

Table 1: China's construction industry accounted for the proportion of GDP (2006-2015)

<table>
<thead>
<tr>
<th>Years</th>
<th>GDP (Billion)</th>
<th>Gross value of construction industry (Billion)</th>
<th>Accounting</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>219438.5</td>
<td>41557.16</td>
<td>18.94%</td>
</tr>
<tr>
<td>2007</td>
<td>270232.3</td>
<td>51043.71</td>
<td>18.89%</td>
</tr>
<tr>
<td>2008</td>
<td>319515.5</td>
<td>62036.81</td>
<td>19.42%</td>
</tr>
<tr>
<td>2009</td>
<td>349081.4</td>
<td>76807.74</td>
<td>22.00%</td>
</tr>
<tr>
<td>2010</td>
<td>413030.3</td>
<td>96031.13</td>
<td>23.25%</td>
</tr>
<tr>
<td>2011</td>
<td>489300.6</td>
<td>116463.32</td>
<td>23.80%</td>
</tr>
<tr>
<td>2012</td>
<td>540367.4</td>
<td>137217.86</td>
<td>25.39%</td>
</tr>
<tr>
<td>2013</td>
<td>595244.4</td>
<td>160366.06</td>
<td>26.94%</td>
</tr>
<tr>
<td>2014</td>
<td>643974</td>
<td>176713.42</td>
<td>27.44%</td>
</tr>
<tr>
<td>2015</td>
<td>689052.1</td>
<td>180757.47</td>
<td>26.23%</td>
</tr>
</tbody>
</table>

The article collected 55 construction enterprises in Chinese 22 provinces, all of these enterprises are from the traditional construction methods to the off-site and be successful (Table 2). In order to collect the
basic information of 55 enterprises to carry out research, including the enterprise nature, name, location, established time, the time enterprise carry on traditional construction business, the business type before the transformation, the time enterprise carry on off-site construction business.

And then the article uses a historical analysis method, the analysis process for Figure 1. At first, it is basic data collection, including collect annual reports, enter the corporate website to collect the enterprise development process, development memorabilia and corporate news. Then, screening of a large number of basic documents by keywords to find information which related to the basic data. In the process of in-depth analysis, this paper focus on enterprises nature and the main business before and after enterprise engaged in off-site construction. Such as Vanke Group, which work on construction project development in the beginning, and also to do off-site construction project development after transformation. And the China State Construction International Investments (China) Ltd. (“CSCII”) transform to carry on development of industrial parks of off-site construction and components manufacture. Analysis of all the text data, about 54,853 characters, get the seven basic information. And attribute the nature of the enterprise to the following nine categories: developers, contractors, designers, materials suppliers, off-site construction service providers, machinery and equipment manufacturers, building parts producers, component producers, investment enterprises and researchers. Then the article began to summarize all the enterprises, adopt the correlation between the enterprise nature before and after the transformation as the induction of the standard to summarize the general laws of its inner development. The results of induction analysis show that 55 enterprises from the traditional construction method to off-site construction has a certain law and direction.

![Figure 1:55 enterprise history analysis chart](image)

### 4 Discussion

#### 4.1 The induction results of China’s construction industry transformation path

Through sorting the transformation path of 55 enterprises, it can sum up the five transformation path (Figure 2). First of all, all 55 companies can be divided into linear extension enterprise and non-directional development enterprise, and non-directional development enterprises can be divided into comprehensive development enterprises and part of the expansion enterprises, part of the expansion enterprises then can be divided into homogeneous transition enterprise, technical practice enterprise and business-led enterprise.
(1) Linear extension enterprise: it refers to the enterprise from the traditional construction to the off-site construction is still engaged in the original business type, and did not change the enterprise nature. There are 20 companies to adopt a linear extension way transform to the off-site construction, of which 12 for the contractors, six developers and two designers.

(2) Comprehensive development enterprises: belong to the non-directional development, mainly refers to the enterprise is no longer engaged in the original type of business and became an off-site construction service provider, aim to provide a complete set of off-site construction solutions from the initial building development to the final building finish. There are five companies using a comprehensive expansion of the way, of which three for the contractors, a materials supplier, a developer.

(3) Homogeneous transition enterprise: mainly refers to the enterprises, although no longer engaged in the original type of business, but engaged in the similar business in the off-site construction, such as machinery and equipment manufacturers start to do components production or building parts production. There are 21 enterprises using a homogeneous transitional approach, of which eight machinery and equipment manufacturers, thirteen materials suppliers.

(4) Technical practice enterprise: mainly refers to the enterprise is no longer engaged in the original business type, but the transform to the technical business in the off-site construction. At the same time enterprise actively explore the practice of off-site construction, master the advanced technology, so that it can enjoy the advantages brought by technology and practice. There are three enterprise using a technical practice, including a manufacturing, a researcher, a materials supplier.

(5) Business-led enterprise: mainly refers to enterprise carry on the innovative, pioneering and leading business segments in off-site construction, these businesses are generally more challenging and more profitable. There are six enterprise using the new business-led mode, of which three contractors, an investment enterprise, two real estate enterprises.

4.2 Analysis on the Transformation of Chinese Construction Enterprises

Through the further analysis of the transformation path of 55 construction enterprises, matched 7 types of construction enterprises with five transformation paths, it can be more clearly found some differences when China's construction enterprises from the traditional construction methods to the off-site construction. These differences are strongly related to the characteristics of China's construction industry, enterprises and the off-site construction.
4.2.1 Most of transformation enterprises are developers, contractors and materials suppliers

As can be seen from Table 2, in 55 enterprises, the number of contractors accounted for up to 32.73%, the second for the materials suppliers accounted for 27.27%, followed by developers accounted for 16.36%, machinery and equipment manufacturers also occupy 16.36%. On the Chinese construction industry chain, developer has been in a dominant position, is also a key role in China's construction industry from the traditional construction methods of transition to industrialization. Developers do not have their own strong technical strength, its function in the industrial chain is mainly to find market demand and create construction business, in order to achieve the linkage of the entire industry. As in China, the high cost of off-site construction will make the enterprise lose a large profit, so there is no large number of developers spontaneous transforming to off-site construction, and part of the transformation developers mainly to respond to national policies to obtain other aspects of policy preferences, or in order to gain leadership advantage, so that compared to the contractors and building materials suppliers, the developers performance is poor.

Unlike developers, the contractors are more market-driven. The Chinese government is paying more and more attention to the transformation of the construction industry, and taking the off-site construction as an important direction, which will bring greater market demand. The contractors are less affected by the construction cost, and the key problem in the transformation lies in the industrial construction technology. Compared with market, the off-site construction technology has been relatively mature, the contractor’s transformation is easier to achieve. The reason about transformation of materials suppliers is the production relationship changes, In the off-site construction industry chain, the emergence of component manufacturers, building parts producer to reduce the direct demand which developers, contractors for raw materials. With the continuous improvement of the pre-manufacturing rate, developers, contractors more docking component manufacturers and building parts producer, so for materials suppliers, the appearance of component suppliers and building parts producer not only a shock but also a business opportunity, and much more stimulating the transformation of materials suppliers.

Compared with the above four types of enterprises, designers, researchers and investment units hardly to do transformation, because researchers and investment enterprises don’t have strong technical characteristics in the off-site construction industry chain, so that the transformation just have a small influence on them. When entire market environment is not mature enough, transition is not the best way to survive for them. Although the designer is a key link in the construction industry chain, but it is not affected by the off-site construction added cost due to the designer is still in the auxiliary service for the developer, and get design fees before building is complete. Thereby, designers always lack of the mastership and motive.

<table>
<thead>
<tr>
<th>Types</th>
<th>Paths</th>
<th>linear extension</th>
<th>comprehensive development</th>
<th>homogeneous transition</th>
<th>technical practice</th>
<th>business-led</th>
<th>Total</th>
<th>Accounting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td>6</td>
<td>1</td>
<td>--</td>
<td>--</td>
<td>2</td>
<td>9</td>
<td>16.36%</td>
<td></td>
</tr>
<tr>
<td>Contractor</td>
<td>12</td>
<td>3</td>
<td>--</td>
<td>--</td>
<td>3</td>
<td>18</td>
<td>32.73%</td>
<td></td>
</tr>
<tr>
<td>Designer</td>
<td>2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>2</td>
<td>3.64%</td>
<td></td>
</tr>
<tr>
<td>materials suppliers</td>
<td>--</td>
<td>--</td>
<td>13</td>
<td>1</td>
<td>--</td>
<td>15</td>
<td>27.27%</td>
<td></td>
</tr>
<tr>
<td>machinery and</td>
<td>--</td>
<td>--</td>
<td>8</td>
<td>1</td>
<td>--</td>
<td>9</td>
<td>16.36%</td>
<td></td>
</tr>
<tr>
<td>equipment manufacturers</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>1.82%</td>
<td></td>
</tr>
<tr>
<td>Investment enterprise</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1</td>
<td>1</td>
<td>1.82%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>5</td>
<td>21</td>
<td>3</td>
<td>6</td>
<td>55</td>
<td>100.00%</td>
<td></td>
</tr>
<tr>
<td>Accounting</td>
<td>36.36%</td>
<td>9.09%</td>
<td>38.18%</td>
<td>5.45%</td>
<td>10.91%</td>
<td>100%</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: 55 China's construction industry transformation path distribution
force of transformation. Moreover, the traditional designers are generally considered if adopt off-site construction will miss the individuality and artistry result from industrialized mass, large-scale construction features, it is one of the reasons why they do not want to promote the off-site construction.

### 4.2.2 Linear extension and homogeneous transition is the main use of the transformation path

From the 55 enterprises data, there are 21 enterprises using the homogeneous transition mode to achieve transformation, accounting for about 38.18% of the total. And there are 20 enterprises with linear extension mode, accounting for 36.36% of the total. Compared with other transformation modes, the use of homogeneous transition mode can develop some new business, but it will bear a relatively small risk, access to new profit points. It is not difficult to find that materials suppliers and machinery and equipment manufacturers prefer to use homogeneous transitional mode, and they are mainly transformed into components manufacturers and building parts producer. Component manufacturers and building parts producer as two new roles, from the product characteristics, they are secondary processing of building materials units. Thus, for materials suppliers and machinery and equipment manufacturers, the transformation to components manufacturers or building parts producer have a certain resource advantages, while there is a certain degree of similarity between the two technology, can use less cost to master new technology, so it is the best transition path for them.

Linear extension is the most conservative transition mode in all 5 transition paths, with lower transition costs and no need to change the strategic deployment and organizational structure of the enterprise. And developers, contractors and designers often use this transformation. Compared to other enterprises, these three types of enterprises are the most critical enterprises, but also the enterprises whose business and technology are most independent. At the same time, if they want to shift from the original business scope to other business areas, often need to pay a higher price. Whether new technology learning, strategic adjustment, organizational structure and staffing, it will take a long time to deploy and change, as the light assets enterprise, they emphasis on the business is short and fast cycle, and it not suitable for long-term operations.

Fully expand the type, technology practice, new business-led mode often have large business changes, it is unrealistic to try a new business section and give up the original stable business sector for the old enterprises when the market is not mature enough. Although there is a big business opportunity in new business areas, but the risk also is too higher, so enterprise scarcely any choose these three types of transformation only when the enterprises have strong financial strength to cope with risks. However, from the perspective of the development of the industry, there must always be some brave to promote the progress of the industry.

### 5 Conclusion

Construction enterprises as the main body of the construction industry transformation and upgrading, will determine the speed and extent of the transformation. For China, due to the impact of enterprise characteristics and market environment, different types of construction enterprises have different possibility when transit to off-site construction from the traditional construction method, materials suppliers and machinery and equipment enterprises than developers and other enterprises are more willing to transition and expansion of new business. In the way of selecting a transition path, conservative transformation path more favored by construction enterprises, 75% of enterprises will choose a linear extension and homogeneous transition mode. Therefore, in order to promote the further development of construction industry, it need to promote from two levels:

1. Governance

In formulating the policy of off-site construction, the government should give full consideration to the
differences between different types of enterprises. From the perspective of the development of China's off-site construction, the key roles include the component manufacturers and building parts manufacture (New role, the basis for the development of off-site construction). So that promoting the transformation of traditional construction enterprises to components manufacturers and building parts manufacture, which is conducive to the rapid improvement of the industrial chain of off-site construction. From the point of result, materials suppliers and machinery and equipment manufacturers have the greatest potential to transition to component manufacturers and building parts manufacture, so government policies can be biased towards both. For developers, contractors and designers, the market is the fundamental driving force, only if expanding the income point, stimulate demand, the transformation of these enterprises can be achieved fundamentally.

(2) Enterprise

For enterprises, before transformation of off-site construction, it is need to clear the purpose of transformation at first. And then assessing their own conditions, including the nature of the enterprise, business conditions, financial situation, anti-risk ability. Next, analyzing the entire industry and socio-economic environment, making a full understanding of market dynamics and policy. The enterprises can first adopt a more conservative way to explore the off-site construction, when they have some experience and foundation, they can engage in thoroughgoing reform and changes.

Article uses historical data analysis and inductive analysis methods, take the development of China's off-site construction as an example, to analyze the path of construction enterprises transition to off-site construction. But the article also has more shortcomings and limitations, in the future, more countries and more enterprise transformation path can be analyzed, thus refining more transformation of the law. Although China's situation can't represent the rest of the countries, but the article provides a set of transformation path analysis ideas.

Reference


Industrial ecosystem evolution of off-site construction industry: based on a multiple case study

Jiang, R.¹, Mao, C.²* and Wu, C.³

Abstract: Off-site construction has proven potential to improve construction efficiency and quality and reduce both the amount of carbon emissions and construction wastage. While off-site construction has been widely constructed in many nation and jurisdictions, it is still in its infancy in China. Many cities in China are exploring ways to develop OSC, limited progress has been made though. There is a need to gain the experience of developed nations and jurisdictions to guide these cities. However, few researches have analyzed their development history or explored the inherent laws of their development. This paper aims to fulfill this knowledge gap and to offer some implications for future OSC development in China based on the industrial ecosystem theory. A multiple case study method was adopted in this study. By observing the OSC promotion facts of Japan and Shenzhen in different stages, the government and enterprises role in each stage was compared in a dynamic manner. It is concluded that there are two ways of evolution in OSC industrial ecosystem, namely, hetero-organization evolution and self-organization evolution. For hetero-organization, the government is in charge and do the research and development work in the beginning but its function weakens gradually. For self-organization, giant enterprises spontaneous implement the research and development work and drive the entry of other practitioners without guide from the government at first. The government’s role strengthens gradually.

Keywords: off-site construction; industrial ecosystem; evolution; self-organization; hetero-organization

¹ Jiang, R.
Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: jiangrui@cqu.edu.cn

²* Mao, C.
Corresponding author, Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: maochao1201@126.com

³ Wu, C.
Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: chengke.wu@curtin.edu.au
1 Introduction

Offsite construction (OSC), otherwise known as off-site manufacturing, prefabrication, modern methods of construction, industrialized building systems and manufactured construction, refers to a process which incorporates prefabrication and pre-assembly [1-2]. Successful OSC implementations from several developed countries have indicated that OSC can significantly improve construction efficiency and quality. It also facilitates in reducing both the amount of carbon emissions and construction wastage [3-4]. With these benefits, OSC has been used worldwide. For example, Japan produces over 70,000 manufactured homes a year; over 30% of the new homes built in the UK today are prefabricated and; in Sweden, the prefabrication rate has exceeded 80% [5-9]. However, OSC in China is still in its infancy. Less than 10% of completed domestic housing projects adopted OSC in the past 10 years [10].

Fortunately, the Chinese government has realized the advantages of OSC and introduced several policies to encourage the adoption of OSC throughout mainland China [11-12]. It is required that more than 15% of new buildings should be built using OSC by 2020. To echo these policies, many cities are trying to make a move. However, the progress is tardy in most cities owing to the lack of knowledge of how other countries or jurisdictions promoted OSC. Previous studies [10, 13-18] have extensively explored the key factors that impedes or drives offsite production both in and outside China. Although several strategies have been recommended in these researches, these recommendations are on the macro-level and cannot guide the practices of specific cities. On the other hand, there have also been a few reports [8-9] that introduce the state of the art around the world, including the prefabrication rate, market penetration, important practitioners, etc. It is regretful to see that these analyses are static rather than dynamic and therefore fail to reveal the internal laws of development. Therefore, there is an urgent need to summarize the experiences and development course of successful practices, namely, how many stages to go through, what role the government played in various stages, etc.

To fulfill the knowledge gap, this paper aims to analyze and understand the OSC development process of developed countries or jurisdictions based on the theory of ecology, in order to give an insight into the inherent law of the OSC development and to further provide a reference for future development of OSC in China.

2 Theoretical foundation

2.1 Organizational ecosystem theory

Industrial ecology (IE) can be a rewarding metaphor for facilitating the understanding of industrial systems based on the principles of system development of ecosystems. IE describes manufacturing complexes as “industrial ecosystems”, and industrial processes related to the manufacturing draw the boundary of an industrial ecosystem [19-20]. In this perspective, the manufacturing process of buildings can also be regarded as an industrial ecosystem. Such OSC industrial ecosystem can evolve similar to the natural ecosystems. The whole lifecycle of an industrial ecosystem consists of four stages, namely, start-up, growth, maturity and decline. In the start-up phase, there are only a few pioneer enterprises in the ecosystem. The system is sufficient in resources with almost no competitions and the economies of scale are not formed yet. During the growth stage, the ecosystem expands and the number of enterprises increased rapidly. The supply chain gets
improved and the economies of scale come into being. Meanwhile, the competition for limited resources began to emerge. In the period of maturity, the ecosystem seeks for the highest efficiency and the enterprises with lower competitiveness began to withdraw from the market. The result is the market becomes more standardized and the economies of scale reach or approach the maximum. In the final stage, the industry gradually loses its vitality and the enterprises in the ecosystems start fading away from the stage.

2.2 Two basic ways of industrial evolution

The industrial ecosystem evolves in two basic ways, that is, self-organization and hetero-organization. Self-organization means that an ecosystem can autonomously form a structured and ordered system through self-creation, self-evolution, and self-ordering without external instruction. Hetero-organization evolution refers to the passive process that the ecosystem relies on specific instructions of the outside world to evolve from disorder to order. The specific instructions are mainly given by the government, such as the compulsory policies and preferential policies. The self-organization and hetero-organization can be apparently observed in the OSC industrial ecosystem. For instance, Japan and Singapore are typical examples of hetero-organization evolution, which developed OSC through a series Five-year Plans and mandatory requirements for “buildability”, respectively. On the other hand, the preference of recreational vehicles stimulated the spread of OSC in the United States due to their pursuit of freedom. Shenzhen China began the exploration of OSC mainly because of the innovative culture of Vanke Group. They can be regarded as representative for self-organization evolution. It should also be pointed out that unlike natural ecosystems, even evolving through self-organization, the industrial ecosystems still need management. That is, the government always plays a role in the evolution process.

3 Method

To the best of the authors’ knowledge, few studies have investigated the dynamic development of OSC. By contrast, such researches are fruitful in the field of industrial clusters. Fang [21] conducted a case study on the titanium industrial cluster and studied its developing stages and industrial network evolution mechanism. Baoji Lu [22] adopted a multiple case study method to analyze the natural, cultural, economic, political and technological environment and their developing tracks. Based on the comparison of the two developing modes, several conclusions and implications are elaborated. It can be concluded that case study method is effective in analyzing development course and evolution mechanism of an industry. Thus this paper adopts multiple case study as the main approach to understand the evolution mechanism of different regions and to gain their similarities and differences.

Owing to the short history and the immature development status in mainland China, it is necessary to analyze the OSC developing laws of developed countries. Currently, Sweden, the UK, Singapore and Japan are accredited to be developed in OSC adoption. These countries all experienced the process of post-war reconstruction and have similar stages of development. Therefore, this paper only chose Japan as the representative of hetero-organization evolution to carry out in-depth analysis. The reason for choosing Japan as a reference is that it is located in the same continent as China, and it was historically influenced by Chinese culture. Furthermore, many
of the OSC techniques were introduced from Japan. Therefore, there are more similarities between Japan and China than the other countries in terms of the political, natural, technological and cultural environment.

Despite of all the similarities, there are more differences of macro environment between two countries. As a result, this paper also chose one of the Chinese cities as a representative of self-organization evolution. At present, Shen, Shanghai and Beijing are the most experienced cities in developing OSC in China, among which Shenzhen is the first OSC demonstration city. Shenzhen is also the home of Vanke Group which is one of the most powerful and influential pioneer practitioners in China. With a long history of OSC implementation, the policy system and market of Shenzhen are both well-established. It is reasonable to take Shenzhen as a representative of self-organization development. In addition, as the purpose of conducting the case study is to provide references for other cities, it is also advisable to combine nation-level and region-level analyses to obtain more information. Data used in this paper are derived from corporate official websites, relevant papers, government reports, and several other resources, for example data released by the industry associations.

4 Findings and discussions

4.1 Hetero-organization evolution of Japan

Generally, OSC in Japan has experienced four stages: germination, growth, maturity and sustainable development.

- The germination stage: 1940s – 1950s
  
  The germination of OSC was government-led. In 1945, the Japanese government set up a specialized OSC promotion organization to implement postwar reconstruction, and formulate a series of policies, regulations and technical standards. The research and development work of precast component standardization was done by the government. In the 1950s, the government built a huge number of houses according to the requirement of national housing technical standards. To insure large-scale construction, the government set up a “housing corporation” in 1955 and drew up a 10-year plan for housing construction. After the ten-year postwar reconstruction, OSC market gradually established.

- The growth stage: 1960s – early 1970s
  
  During the 1960s and the 1970s, OSC in Japan grew rapidly under the leadership of the government. Owing to the expanding urban population and rising urban house demand in the 1960s, the government put forward a 5-year plan. To echo the plan, a set of workable measures were explored, namely, organization establishment, policy making, financial support and technical research and development. Since then, OSC began to spread nationwide. In this stage, approximately 10% of the newly built buildings adopted OSC and each family can live in their own home [23]. This fact that the housing demand was met marked that the requirement of consumers shifted from quantity to quality.

- The maturity stage: 1970s – early 1990s
  
  In the third stage, the market dominated while the government only played a guiding role. As the basic living demand was fulfilled, higher quality and aesthetic requirements were proposed. A large number of joint groups formed by giant enterprises began entering the market. Various boxes and units were used and the layouts started to diversify. By contrast, the government nearly
stopped houses provision but implemented a certification system to regulate the market instead. In the middle of the 1980s, the market share of OSC reached 15%-20% and few new houses used the traditional manual construction methods, marking the maturity of the OSC market [23].

- The sustainable development stage: 1990s - now

In the 1990s, the residential market of Japan has been saturated and began to focus on the transformation of old houses and further enhancement of housing quality. On the one hand, the concept of sustainable development is widely spread and recognized worldwide. Eco-friendly, energy-efficient and sustainable houses became the trend. On the other hand, with the development of digital technology, residential products also became more functional and intelligent. This stage can be regarded as a self-creation of the OSC industrial ecosystem. The legal framework, policies and institutions have all been adjusted accordingly. The government was mostly providing services to the ecosystem.

4.2 Self-organization evolution of Shenzhen

- Germination stage: 1999 - 2006

The OSC industry in Shenzhen originated at the end of the 1990s. In 1999, Vanke Group set up a construction research center in Shenzhen, which opened the prelude to OSC research and development. Four years later, the standardization work began. As a result, Vanke built its own standardized prefabricated component library and released 8 enterprise standards [24]. In 2004, a factory center was set up by Vanke and relevant OSC research work officially launched. In the next two years, Vanke finally transformed the research achievements into concrete implementation by building two test buildings. In this stage, the government almost didn’t play a role in the OSC development.

- Promotion stage: late 2006 – 2014

In November 2006, Shenzhen was titled the first “national OSC pilot city”. Since then, OSC started to be used in affordable houses construction. The most well-known project was one developed by the Vanke Group, which also drove the Huayang International Engineering Design and Pengcheng Construction to be involved in the design and construction, respectively. In 2011, the local government of Shenzhen worked out several work procedures [24] to regulate the evaluation of residential performance and the recommendation of superior residential prefabricated components. After that, the application of OSC in projects expanded. Till 2014, the OSC projects totaled more than 200 square meters (including projects under construction), which were mostly provided by the Vanke Group.

- Accelerated development stage: late 2014 - now

After 8 years of pilot research and exploration, Shenzhen strengthened the guiding role of government in the promotion of OSC. The government enacted the Guiding opinions on Housing Industrialization in Shenzhen [25] in November 2014, explicitly requesting that new residential land sales projects and affordable housing projects with government investment in Shenzhen should all adopt OSC from 2015 onwards. The release of this document is to accelerate the OSC development in Shenzhen. This was mainly because the central government had increased its efforts to promote OSC. Since then, more companies entered the market, such as Jiada Hi-tech, China Construction International, Huarun, etc. At present, Shenzhen Vanke has basically formed a relatively OSC supply chain and more than 3 million square meters of OSC projects are being built or planned. The economies of scale of OSC finally came into being.
4.3 Discussion

Whether it is self-organization or hetero-organization, the OSC development will both experience the stages of germination and promotion, which is consistent with the theory of industrial ecosystem. In the germination stage, R & D, standardization and certification of prefabricated components are important in both two ways. The difference is that the research and development of hetero-organization evolution is mainly led by the government, while that of the self-organization evolution is mainly completed by the enterprise.

In both two ways of evolutions, the government and the market both play a role at the same time, but their functions are different. For hetero-organization evolution, government plays a leading role at first and gradually turns into the function of guiding or even serving; for self-organization evolution, the market played a leading role at first and enterprises spontaneously take on the corresponding research and development work. Later on, with the expansion of the scale of the industry, the government's regulation and control will gradually strengthen.

5 Conclusion

This paper conducted a multiple case study of the OSC development process of Japan and Shenzhen based on the industrial ecosystem theory, verifying the phased evolution of the OSC industrial ecosystem and summarizing the inherent developing laws of the OSC industrial ecosystem. These results can offer guidance for cities in developing strategies in the future. For example, cities with greater government support can draw on the evolution process of Japan, which is dominated by the government at the beginning. The enterprises led to enter the market some public projects. When a certain scale is reach, the government turns to regulate or serve the industry instead of playing a leading role so as to give full play to the self-organization function of the market. For cities lacking government support, they can learn from the evolution mode of self-organization evolution of Shenzhen. The large-scale enterprises take the lead at first, and gradually drive the participation of other enterprises. When the industry reaches a certain scale, the government enters and plays a guiding or serving role.

But there are also limitations in this study. The number of cases analyzed in this paper is small, therefore there may be some accidental facts that can be observed. For example, Shenzhen is adjacent to and so the development of Shenzhen is influenced by Hong Kong. Because of the high local production costs, many OSC projects in Hong Kong have purchased prefabricated components from Shenzhen, which led to the development of many component manufacturing factories in Shenzhen. Such factors should be considered when other cities choose their own development mode.

This study also provides several further directions for future research. For example, subsequent studies can take more nations and cities into consider and increase the number of cases to further find some universal regularities. In this study, only the government’s and enterprises’ roles in different stages are discussed.

References


Supplier selection model in construction

Tran, L.T.1*, Nguyen, T.S.2, Mohamed, S.2 and Panuwatwanich, K.2

Abstract: This paper aims at developing a supplier selection model in the construction field. The proposed model considers a non-homogeneous decision-making group in the supplier selection process. It applies the analytical hierarchy process (AHP) in determining the influence weightings of the non-homogeneous group. The importance weighting of criteria, which are used to evaluate potential suppliers, are determined by the non-homogeneous group. Potential suppliers are evaluated based on criteria by using a linguistic terms set. A linguistic ordered weighted averaging (LOWA) operator is applied to aggregate the linguistic term assessments of the non-homogeneous group. Finally, the scores of potential suppliers are calculated by applying a mathematical algorithm.

Keywords: Supplier selection; Construction; Decision-making; LOWA operator.

1 Introduction

Supply chain management has become the main dimension that has implication for efficient and effective management of industrial relationships[1]. It is an essential concern for organisations to achieve competitive advantages[2]. In supply chain management, supplier selection can be seen as one of the most important activities of purchasing management[1]. It is a vital constituent of logistics and production management for many different industries[3]. In the modern business competitive environment, it is impossible to succeed with high-quality and low-cost products without appropriate suppliers[4]. Therefore, selecting the appropriate supplier plays an essential role in an organisation success or failure.

Supplier selection can be seen as a multiple criteria group decision-making process. Group decision making that is a multi-expert is typical, where the intrinsic uncertainty and complexity necessitate the involvement of many experts in the decision-making process[5]. The consensus of the group plays an essential role in the level of group agreement and the reliability of the group result. Research has been undertaken to propose an approach for a succession of decisions to reach a high level of consensus[5, 6].

Hence, this paper proposes a hybrid supplier selection model for construction professionals by combining the widely used AHP method, and LOWA operator considering a non-homogeneous decision-making group in order to select the best supplier to satisfy the purchaser’s requirements.

2 Methodology

In our proposed model, the AHP is applied to determine the influence weightings of experts who participate in the selection process, whereas the LOWA operator is used to overcome the issues of

1*Tran, L.T.
Corresponding author, Hanoi National University of Education
E-mail: whiterose1282002@gmail.com

2 Nguyen, T.S., Mohamed, S., Panuwatwanich, K.
Griffith School of Engineering, Griffith University, Australia
achieving consensus in a non-homogeneous decision-making group. The total score of the supplier is calculated by applying the weighted sum (WS). Methodology details are described in the following sub-sections.

2.1 Analytic hierarchy process

The AHP is broadly applied in the decision-making analysis across a wide range of fields, including supplier selection. The application of AHP to a complex problem involves six important steps, and three of these are applied in our proposed model\[7, 8\]: 1) employing pairwise comparisons among decision elements and form comparison matrices; 2) using the eigenvalue method to estimate the relative weights of the decision elements; and 3) checking the consistency property of matrices to ensure the judgments of decision makers are consistent.

2.2 Fuzzy linguistic terms and linguistic ordered weighted averaging operator

2.2.1 Fuzzy linguistic terms

Linguistic terms have been seen as intuitively easy to use in expressing subjective and imprecise assessments of decision makers\[9\]. The fuzzy linguistic method, which allows dealing with qualitative aspects that are represented in qualitative terms by means of linguistic variables, provides an important technique for solving decision-making problems in different fields\[9\]. Herrera, et al.\[10\] pointed out that in each fuzzy linguistic approach, appropriate linguistic descriptions for the term set and their semantics have to be selected. The semantics of linguistic terms is represented by the fuzzy numbers as defined in \([0, 1]\) interval that is described by the membership functions.

Table 1 presents, for example, two sets of five linguistic terms represented by triangular fuzzy numbers that will be used for fuzzy assessment and the crisp outputs of these fuzzy numbers. A 1 to 9 ratio scale is used since it has been demonstrated that it is an effective measurement scale for reflecting the qualitative information of decision problems\[11\]. The linguistic terms sets were also applied in supplier selection\[12\].

<table>
<thead>
<tr>
<th>Table 1 Two linguistic terms sets</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linguistic terms set 1</strong></td>
</tr>
<tr>
<td><strong>Linguistic terms set 2</strong></td>
</tr>
<tr>
<td>Membership Function</td>
</tr>
<tr>
<td>Crisp output</td>
</tr>
</tbody>
</table>

2.2.2 Linguistic ordered weighted averaging (LOWA) operator

Herrera, et al.\[13\] developed the LOWA operator for aggregating non-weighted linguistic information. In this scenario, only one set of linguistic value is available for aggregation. The application of the LOWA operator in supplier selection is revealed by Nguyen, et al.\[14\]. A definition of the LOWA operator and an example of how to use its operator, is referred to by Herrera, et al.\[13\].

2.3 The proposed model

To reflect the real group decision-making in supplier selection that is a commonly non-homogeneous, the new structured approach is developed as shown in Figure 1. The proposed model
can be described, through a scenario, as follows:

A top manager of an organisation identifies the experts who are responsible for the supplier selection process. The importance of experts, which are reflected by their skills, knowledge, influence, and power, are determined by the top manager using the AHP. The group, which includes these experts, identifies criteria that are used in the supplier selection process. They use a linguistic terms set to determine the importance weighting of the criteria. After that, the LOWA operator is applied for aggregating the linguistic terms that are the assessments of a criterion from the group into a single linguistic term. The aggregated linguistic terms are transferred to fuzzy numbers for calculating the crisp outputs to compute the importance weighting of criteria. Next, the experts evaluate potential suppliers based on these criteria by using another linguistic term set. Again, applying the LOWA operator, transferring the aggregated linguistic terms to fuzzy numbers, the crisp outputs that represent the evaluation of the potential suppliers, based on the criteria, are calculated. Based on the importance weighting of criteria and the values of evaluation suppliers based on the criteria, the WS operator is used to compute the score of suppliers for supplier ranking. The following section presents, step-by-step, the way the proposed model is implemented.

**Figure 1. Proposed model considering non-homogeneous decision-making group in supplier selection**

**Step 1: Experts identification**

A top manager identifies the experts, who participate in a supplier selection process. The influence weighting of the experts are determined by the manager using the AHP.

**Step 2: Criteria identification**

The evaluating criteria are identified through a group decision made by the experts by applying a brainstorming session. After that, the experts, using the linguistic terms set 1 (see Table 1), determine the importance weighting of the criteria. The linguistic assessments by the experts are
aggregated by applying the LOWA operator. Then, the aggregated linguistic term results are transferred into fuzzy numbers leading to crisp outputs, by using Table 1. Finally, the important weighting of each criterion is calculated by applying the weighted averaging (WA).

**Step 3: Criteria-based supplier evaluation**

Experts, using the linguistic terms set 2 (see Table 1), evaluate the potential suppliers based on the identified criteria. Similar to step 2, the linguistic assessments by the experts are aggregated by applying the LOWA operator. The aggregated linguistic terms results are transferred into fuzzy numbers. The crisp outputs which represent the evaluation of suppliers based on criteria, are determined.

**Step 4: Supplier ranking**

The score for each supplier is calculated using the WS. Then, the suppliers are ranked in order, based on the calculated scores of suppliers.

### 3 Empirical application

HNC is a construction company in Vietnam that regularly acquires equipment and raw materials for their implementation. In HNC’s procurement policy, the responsibility for supplier selection is a committee comprising representatives from different functional departments within HNC. There are no fixed memberships in the committee. The committee members are selected depending on purchase type and value. Committee members, therefore, tend to have unequal influence and powers in the decision-making process, relating directly to their positions in the company. The main purpose of the committee is to select the best appropriate supplier that satisfies the purchaser.

The proposed model has been applied, herein, to demonstrate its applicability. Four experts who are from functional company departments at HNC participated in this empirical practice. Five criteria ‘price’, ‘quality’, ‘delivery’, ‘service’, and ‘technology’ were identified for evaluation of the six potential suppliers.

**Step 1: Experts identification**

The four executive heads (experts) were selected to participate in this process. The influence weightings of the experts are determined by using the AHP. Regarding the AHP strategy, the pairwise comparison matrix $A$ was constructed. From a pairwise comparison matrix, a normalised pairwise comparison matrix $A'$ was formed. Based on the normalised pairwise comparison matrix, a column vector $C$ that presents the influence weighting of four experts was constructed. To verify the consistency, a weighted sum vector $\overline{C}$ was formed. After that, the maximum eigenvalue $\lambda_{\text{max}}$ of matrix $A$, consistency index $CI$, and consistency ratio $CR$ were calculated.

\[
A = \begin{bmatrix}
1 & 1/3 & 1/2 & 2 \\
3 & 1 & 1 & 3 \\
2 & 1 & 1 & 1 \\
1/2 & 1/3 & 1 & 1
\end{bmatrix};
A' = \begin{bmatrix}
0.154 & 0.125 & 0.143 & 0.286 \\
0.462 & 0.375 & 0.286 & 0.429 \\
0.308 & 0.375 & 0.286 & 0.143 \\
0.077 & 0.125 & 0.286 & 0.143
\end{bmatrix};
C = \begin{bmatrix}
0.177 \\
0.388 \\
0.278 \\
0.158
\end{bmatrix};
\overline{C} = \begin{bmatrix}
4.299 \\
4.305 \\
4.236 \\
4.143
\end{bmatrix};

\lambda_{\text{max}} = 4.246; \ CI = 0.082; \ CR = 0.091.

The consistency ratio $CR = 0.091 < 0.1$, therefore, the influence weightings of expert 1, 2, 3 and 4 are 0.177, 0.388, 0.274, 0.158, respectively.
Step 2: Criteria identification

In this step, five criteria ‘price’, ‘quality’, ‘delivery’, ‘service’, and ‘technology’ were identified for evaluating potential suppliers through a brainstorming session. After that, the four experts were asked to participate in a simple survey to determine the importance weighting of criteria by using a linguistic terms set 1 (see Table 1). The results are presented in Table 2.

Table 2 Criteria and their important weighting

<table>
<thead>
<tr>
<th>Experts</th>
<th>Price</th>
<th>Quality</th>
<th>Delivery</th>
<th>Service</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregated</td>
<td>H</td>
<td>VH</td>
<td>H</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Fuzzy number</td>
<td>(5,7,9)</td>
<td>(7,9,9)</td>
<td>(5,7,9)</td>
<td>(3,5,7)</td>
<td>(5,7,9)</td>
</tr>
<tr>
<td>Crisp output</td>
<td>7</td>
<td>8.33</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Weighting</td>
<td>0.204</td>
<td>0.243</td>
<td>0.204</td>
<td>0.146</td>
<td>0.204</td>
</tr>
</tbody>
</table>

To aggregate four linguistic terms into one linguistic term, authors applied the LOWA operator. In this study, we produced a program running in Matlab to calculate the LOWA operator. For example, examining the criterion ‘price’ (shown in Table 2), and by using the mean as determined by the LOWA operator, we require to aggregate the following labels \{H, VH, H, H\} with the influence weighting vector (influence weighting of experts) \(W = [0.177, 0.388, 0.274, 0.158]\).

Aggregation of the labels \{H, VH, H, H\} with the weighting vector \(W = [0.177, 0.388, 0.274, 0.158]\) using the LOWA operator provides the mean H (see Table 2). Aggregated linguistic terms are shown in Table 2. The aggregated assessments are transferred to fuzzy numbers as cited in Table 1. The crisp outputs are calculated from fuzzy numbers. Finally, the importance weighting of criteria, which are shown in Table 2, are calculated by applying WA.

Table 3 Criteria-based supplier evaluation by experts

<table>
<thead>
<tr>
<th>Supplier 1</th>
<th>Supplier 2</th>
<th>Supplier 3</th>
<th>Supplier 4</th>
<th>Supplier 5</th>
<th>Supplier 6</th>
</tr>
</thead>
</table>

Step 3: Evaluate supplier based on criteria

The four experts were asked to assess suppliers based on the five criteria using the linguistic terms set 2 (see Table 1). Table 3 shows the linguistic terms assessments of suppliers based on the five criteria. The linguistic terms given by the four experts are aggregated by applying the LOWA operator. The aggregated linguistic assessments are presented in Table 4. The crisp outputs of evaluation suppliers based on the criteria are determined in the same fashion covered in the previous step (see Table 5).
Table 4 Aggregated linguistic assessments of potential suppliers based on the criteria

<table>
<thead>
<tr>
<th>Supplier</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>VG</td>
<td>F</td>
<td>G</td>
<td>F</td>
<td>P</td>
<td>G</td>
</tr>
<tr>
<td>Quality</td>
<td>G</td>
<td>G</td>
<td>VG</td>
<td>F</td>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>Delivery</td>
<td>G</td>
<td>F</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>Service</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>F</td>
<td>F</td>
<td>G</td>
</tr>
<tr>
<td>Technology</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>P</td>
<td>F</td>
</tr>
</tbody>
</table>

Step 4: Supplier ranking

The suppliers’ scores are calculated based on the criteria weighting and the assessment values. The results, which are computed by applying WS, are presented in Table 5.

Table 5 Supplier scores

<table>
<thead>
<tr>
<th>Supplier</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>7.271</td>
<td>6.184</td>
<td>7.323</td>
<td>5.816</td>
<td>4.592</td>
<td>6.592</td>
</tr>
</tbody>
</table>

In the above application, the influence level of experts, who are from different departments at HNC, have proven to be different. The influence weighting of the four experts are 0.177, 0.388, 0.274, and 0.158, respectively. This result indicates that the influence level of each department in the selection process differs.

‘Quality’ was identified as the criterion with the highest important weighting (0.243), followed by other criteria for example; ‘price’, ‘technology’, ‘delivery’, and ‘service’ with weights of 0.204, 0.204, 0.204, and 0.146, respectively. By deduction, the outcomes indicate HNC requires a slight premium on the quality. Also, it puts the same weighting on ‘Price’, ‘Technology’, and ‘Delivery’ criteria and less on ‘Service’ criterion.

Overall, it can be observed that Supplier 3 is the highest ranked supplier gaining a total score of 7.323. Interestingly, Supplier 1 has offered a more competitive price than that offered by Supplier 3 but, its overall ranking is second. Despite, its relatively higher price, Supplier 3 seem to compete strongly on the ‘quality’ criterion.

4 Conclusion

This study has proposed and reported on a new hybrid model for non-homogeneous group decision-making in supplier selection in a construction field that best satisfies the purchaser. This study illustrated a structured procedure in proposing the hybrid model based on the AHP, fuzzy set theory, and LOWA operators. The applicability of the developed model was demonstrated numerically. This study is the first study combining the AHP and LOWA operator and reflecting the non-homogeneous decision-making group in supplier selection in the construction field.

This paper has drawn attention to the following areas potential for future study. Further study may look into increasing number of criteria. Another study could discover the weighted ordered
weighted averaging (WOWA) operator in calculating the total score of suppliers instead of using the WS operator.

References

The Significance of the Life Cycle Embodied Energy in Shopping Centres in Australia

Weththasinghe, K.K.1*

Abstract: Shopping centres, which represent 38% of total retail floor space, are being increasingly developed in Australia to service the demographic growth and consumer demands. 227,008 m² of new sub-regional shopping centre floor spaces are planned to complete from 2017 to 2020 in new metropolitan suburbs and regional areas. Shopping centres have a unique life cycle with typically short service lives and exceptionally high refurbishment frequency. Thus, materials are replaced in shopping centres before the end of their service lives due to economical, functional and social obsolescence. This frequent material replacement ultimately results in increased Life Cycle Embodied Energy (LCEE). Thus, careful material selection is needed in order to reduce recurrent material and embodied energy use in shopping centres. The aim of this paper is to demonstrate the significance of LCEE of sub regional shopping centres through a review of relevant literature and empirical data from the Australian retail real estate industry. Findings of this review divulge the significance of LCEE in shopping centres and the need to have a better material selection approach to reduce the environmental impacts. The paper concludes with details of a proposed PhD study, which will be undertaken over the next 2 years.

Keywords: Life Cycle Embodied Energy; Material selection; Sub regional shopping centres of Australia.

1* Weththasinghe, K.K.
Corresponding author, Faculty of Architecture, Building and Planning, The University of Melbourne, Australia
E-mail: kweththasing@student.unimelb.edu.au
1 Introduction

Shopping is an essential component of the consumerist model adopted by many societies. Shopping centres are a built form that provides an amenity utilized by a large number of persons and provide benefits to the local community (Goodman & Coiacetto, 2012). These centres are considered the face of the built cities (Feinberg & Meoli, 1991). The first shopping centre in Australia was developed in Brisbane in 1957 with 25 retailers and a department store (Shopping Centre Council of Australia, 2015). Since then, Australia has witnessed a rapid growth in its number of shopping centres with an average of 24 new centres or expansions every year (Shopping Centre Council of Australia, 2015).

Shopping centres currently represent 38% of the total retail floor space in Australia (Urbis, 2015). Suburbanization has created a growth in the retail property market with 1,753 shopping centres now in Australia. Thus, shopping centres represent a significant proportion of the Australian real estate market. 286 of these centres are sub regional shopping centres (Urbis, 2015). Sub regional shopping centre is defined as a centre with at least one major super market, one discount department store and around 40 specialty stores with a gross lettable area (GLA)\(^2\) of 10,000 m\(^2\) to 30,000 m\(^2\) (Property Council of Australia, 2008). Continuing the growth, 227,008 m\(^2\) of sub regional shopping centres are planned to complete in the next three years (Jones Lang LaSalle, 2017).

Shopping centres are an innovative format, with an ever-changing cycle of design developments following the consumer requirements and fashion trends (Mesher, 2010). The most complex component of these is the interior designing, which demonstrates the brand and identity of a retail construction (Coleman, 2007). Therefore, shopping centre developers and designers aim to tempt, enthuse and attract the consumers by producing “an experience”, which they feel related rather than constructing just a building (Gibbs, 2012). In order to simulate the “one off experience”, the retail developers often use unique design strategies, construction techniques and materials for construction, which are comparatively costly and energy intensive (Sinha, 2011). Moreover, shopping centres have a significantly shorter replacement frequency with replacements in every 2-10 years is considered essential in order to make the place attractive to customers (Aktas, 2011; Hayles, 2015; Kocaili, 2010). Thus, materials are replaced in shopping centres before expiring their service lives due to economical, functional and social obsolescence (Holtzhausen, 2007; Sinha, 2011).

The frequent replacements ultimately result in an excessive use of natural resources, as well as increased energy use for the manufacture of the replacement materials. Moreover, frequent tenant turnover is also a cause of excessive material and embodied energy (the energy associated with raw material extraction, manufacturing, construction and sometimes demolition of a building (Stephan, 2013)) use in shopping centres. Each time a tenant leaves and a new tenant move in the shop fit out is typically replaced in order to fulfill the new tenant’s requirements (Carter & Allen, 2012; Scott, 2006; Wakefield & Baker, 1998). Replaced materials are rarely reused and new materials are used for this retrofitting. Mostly the interior finishing materials (wall, floor and ceiling) are vulnerable to these frequent changes. Thus, the mounting recurrent embodied energy\(^3\)

---

\(^2\) Total area available for leasing including storage and other miscellaneous spaces (International Council of Shopping Centers, 2001)

\(^3\) Energy incurred for repairs and replacements during a building’s operational phase (Ramesh, Prakash, & Shukla, 2006)
of shopping centres over the years ultimately cause a significant increase in the Life Cycle Embodied Energy (LCEE)\(^4\) (Chebat, Michon, Haj-Salem, & Oliveira, 2014) which can outweigh the operational energy use. Materials being the primary source of embodied energy therefore become vitally important in LCEE reduction in shopping centres as careful material selection can account for significantly reduced environmental impacts (Kim & Rigdon, 1998).

As shopping centres development has no abated in Australia, there is a growing need to focus on the LCEE and understand excessive material use and its effect on embodied energy. Therefore, the aim of this paper is to demonstrate the significance of the LCEE of shopping centres in Australia and to discuss the need for an approach to select materials taking into account the LCEE impact. This paper combines an analysis of literature with the empirical data from the Australian shopping centre industry to demonstrate the need for a better material selection approach for shopping centres in Australia in order to mitigate their environmental impacts. The paper concluded with an outline of some proposed research to be undertaken in this area.

2 Sustainable shopping centres

According to Yudelson (2009) retail matters to sustainability. In the past few decades, the construction industry has had an increased focus on sustainability (Kibert, 2013; Robichaud & Anantatmula, 2011; Yudelson, 2009). Yet, the retail sector has lagged behind the trend until recent times due to several economic and social challenges and obstacles. Green Star certified the first retail project in Australia in 2008, namely the Mirvac Group’s Orion Springfield Shopping Centre in Southeast Queensland with 6 star Green Star. This can be considered as comparatively behindhand compared to other building types which commenced registering and obtaining certification from 2004 (Green Building Council of Australia, 2017). However, the mounting appreciation of green buildings in the society and the government legislations has encouraged retail developers towards corporate sustainability. Table 1 presents the Green Star certified shopping centres in Victoria, Australia.

Table 1: Green Star certified retail buildings in Victoria

<table>
<thead>
<tr>
<th>Centre Name</th>
<th>Rating Tool</th>
<th>Green Star</th>
<th>Year</th>
<th>NLA/ GLA</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridgehaven Neighbourhood Centre</td>
<td>Retail Centre Design 1</td>
<td>4 Star</td>
<td>2011</td>
<td>6,500 m(^2) GLA</td>
<td>Stockland</td>
</tr>
<tr>
<td>Stockland Highland Centre</td>
<td>Retail Centre As Built 1</td>
<td>4 Star</td>
<td>2012</td>
<td>9,820 m(^2) GLA</td>
<td>Stockland</td>
</tr>
<tr>
<td>Chadstone West Mall</td>
<td>Retail Centre Design 1</td>
<td>5 Star</td>
<td>2009</td>
<td>20,945 m(^2) GLA</td>
<td>Vicinity Centres</td>
</tr>
<tr>
<td>Westfield Doncaster</td>
<td>Shopping Centre Design PILOT</td>
<td>4 Star</td>
<td>2008</td>
<td>28,000 m(^2) NLA</td>
<td>Scentre Group</td>
</tr>
<tr>
<td>Chadstone Shopping Centre Stage 40 – North</td>
<td>Retail Centre Design 1</td>
<td>5 Star</td>
<td>2015</td>
<td>47,186 m(^2) GLA</td>
<td>Vicinity Centres</td>
</tr>
<tr>
<td>Craigieburn Central</td>
<td>Retail Centre Design 1</td>
<td>4 Star</td>
<td>2013</td>
<td>76,000 m(^2) GLA</td>
<td>Lendlease</td>
</tr>
</tbody>
</table>

NLA – Net Lettable Area  
GLA – Gross Lettable Area  

\(^4\) Combination of initial, recurrent and sometimes demolition embodied energy (Stephan, 2013)
The growing interest of retail developers in green certification has led to the creation of a specific green rating systems for retail, which considers its complex nature and unique characteristics (Yudelson, 2009). The major environmental concerns of a green rating system involves elements of sustainable site development, water conservation, energy conservation and use of renewable energy, materials and resource conservation, indoor environmental quality, transport energy use and emissions from operations (Green Building Council of Australia, 2017). LEED for Retail Commercial Interiors and LEED for Retail New Constructions in the US, BREEAM Retail and BREEAM Retail Interiors in the UK and Green Star - Retail Centre in Australia are the retail specific rating systems (Yudelson, 2009).

The green rating systems measure performance against criteria based on a given level. In all the retail building green rating systems, energy is given the highest credit or the weighting as a single component varying from 35-37% in LEED, 19-21% in BREEAM and 24% in Green Star. Green Star Retail Centre v1 version has points under 8 major criteria as follows (Refer Table 2).

Table 2: Green Star Retail Centre v1 credits and weightings

<table>
<thead>
<tr>
<th>Category</th>
<th>Credit</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Indoor Environment Quality</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Energy</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>Transport</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Water</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Materials</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>Land use and Ecology</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Emissions</td>
<td>16</td>
<td>7</td>
</tr>
</tbody>
</table>

The number of stars awarded to a project is based on the weighted scores achieved (Refer Table 3).

Table 3: Green Star certifications

<table>
<thead>
<tr>
<th>Weighted Score</th>
<th>Star Rating</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>45-59</td>
<td>4 star</td>
<td>Best practice</td>
</tr>
<tr>
<td>60-74</td>
<td>5 star</td>
<td>Australian excellence</td>
</tr>
<tr>
<td>75-100</td>
<td>6 star</td>
<td>World leadership</td>
</tr>
</tbody>
</table>

Green Building Council of Australia (2017) figures reveal that since 2008 only 39 retail centres have been Green Star certified in Australia until 2017.

Table 4: Number of Green Star certified office and retail buildings in Australia

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Rating tool</th>
<th>Number</th>
<th>Total</th>
<th>Green Star certified buildings percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office</td>
<td>Office Interiors v1.1</td>
<td>161</td>
<td>691</td>
<td>4500</td>
</tr>
<tr>
<td></td>
<td>Office Interiors v1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Office Design v3</td>
<td>143</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Office Design v2</td>
<td>206</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Office Design v1</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Office As Built v3</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building Type</td>
<td>Number of Green Star certified projects</td>
<td>Total number of buildings</td>
<td>Green Star certified buildings percentage</td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------------------------</td>
<td>--------------------------</td>
<td>------------------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office As Built v2</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Office As Built v1</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retail</td>
<td>Retail centre As Built v1</td>
<td>11</td>
<td>39</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>Retail centre Design v1</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shopping Centre Design PILOT</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 Material selection for shopping centres

Buildings, consume massive quantities of extracted raw materials, which are later processed into building materials, used and finally generate waste (Cole & Auger, 1996). Thus, sustainable material selection requires concern of environmental impacts over the life cycle phases of materials. The environmental implications associated with materials include resource depletion, greenhouse gas emissions, depletion of bio diversity and environmental deterioration (Bribián, Capilla, & Usón, 2011). Embodied energy\(^5\) that implies the overall environmental impacts of materials is therefore considered a realistic measure for sustainable material selection for buildings.

Materials used for different types of buildings differ based on the functional requirements of the building. Unlike many other commercial buildings material selection for shopping centres is a critical process, which require better understanding of the social, functional and economical requirements of the development (Finn & Louviere, 1996; Ogunkah & Yang, 2012). Shopping centres are designed in a manner in order to attract new customers while keeping the regular ones and increase foot traffic (Kocaili, 2010). However, nowadays shopping centres are considered as not only a place to shop but also a social gathering space for many people in Australia (McGreevy, 2016). Thus, the public spaces of shopping centres are designed to be leisure or recreational areas (Aktas, 2011; Reimers & Clulow, 2004).

Therefore, material selection for these public spaces and their interior finishes influence on the amount of foot traffic a shopping centre attracts (Aktas, 2011; Hayles, 2015; Mesher, 2010). Materials used for shop interiors have also become important in shopping centres given the tenant replacement frequency and the tenant mix (Carter & Allen, 2012; Scott, 2006; Wakefield & Baker, 1998). The conditions for small tenant leases in sub regional shopping centres in Australia is normally a maximum lease period of 5 years, where as for anchor tenants (such as supermarkets and discount department stores) it is usually 25 years. Therefore, every time a samll tenant leaves and a new tenant arrives the shop fit out is rebuilt (Anselmsson, 2016; Chebat et al., 2014; Chui, 2004). This cycle of tenant replacements, therefore cause excessive material use for shop fit outs over the shopping centre life cycle (Chebat et al., 2014). Thus, materials need to be selected considering tenant replacements as well as maintaining the social attraction or the appearance of the public spaces of the shopping centres (Chen & Zhong, 2016; SergeFerrari, 2016).

However, material selection becomes critical where the environment and finance has to be balanced while considering design constraints of the shopping centres (Akadiri, 2015; Franzoni, 2015; Stephan, 2013).

---

\(^5\) Energy required for the raw material extraction, manufacturing, construction and sometimes demolition of a building (Stephan, 2013)
In shopping centres, material selection becomes more difficult due to the higher design requirements of the owners and investors (Coleman, 2007). In Australia, the continuous growth in retail sector real estate developments have created a competition between property owners and investors driving them towards developing a unique shopping space which can attract customers (Bailey, 2011; Braslavsky, Wall, & Reedman, 2015; Buxton, Goodman, & Moloney, 2016). This higher design expectation has ultimately made material selection decision more complex for the designers, architects and quantity surveyors (McGreevy, 2016).

4 Life cycle embodied energy of shopping centres

Residential buildings are often constructed for a longer life span (from 50 to 100 years) whereas commercial buildings common design life is 60 years or less (Riley & Cotgrave, 2014). According to Fieldson and Rai (2009) retail buildings have an exceptionally shorter life span with a refurbishment cycle of 2 to 10 years. Thus, retail buildings are significant in the construction sector in terms of refurbishments and replacement frequencies. Shopping centres therefore have a unique life cycle with short life spans and exceptionally short refurbishment frequencies. Regular renovations and refurbishments are seen as essential for shopping centres in order to draw customers and retain foot traffic. Thus, materials are replaced in shopping centres before expiring their service lives due to economical, functional and social obsolescence. These frequent replacements, renovations and refurbishments ultimately cause an excessive use of natural resources, as well as increased energy use for the manufacture of replacement materials. Thus, recurrent embodied energy of shopping centres mounts up over time causing a significant increase in the LCEE, which can outweigh the operational energy use.

For instance, assume a sub regional shopping centre in Victoria, Australia with GLA of 15,000 m² with 2 anchor stores and 60 specialty shops. According to the property planning and development guidelines for shopping centres in Australia 40% of GLA is given to specialty shops. Area of specialty stores $= 15,000 \text{ m}^2 \times 40\% = 6,000 \text{ m}^2$.

<table>
<thead>
<tr>
<th>Area of specialty stores</th>
<th>15,000 m² × 40% = 6,000 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of specialty stores</td>
<td>60</td>
</tr>
<tr>
<td>Average area of one store</td>
<td>6,000 m² / 60 = 100 m²</td>
</tr>
</tbody>
</table>

Assume a wall height $= 5$ m

The minimum tenant lease period for small tenants in shopping centres is 5 years in Australia. Consider a hypothetical situation where all specialty tenants leave the centre at the end of each 5 years and new tenants move in or they remain but refurbish their shops. Then all specialty shop fit outs need to rebuilt (in most cases interior finishes of floor, wall and ceiling are replaced). Assuming the life span of shopping centre is considered 50 years and based on the embodied energy coefficients by Crawford (2011). Hypothetical internal finishing materials used and replaced are as follows.

<table>
<thead>
<tr>
<th>Element</th>
<th>Item</th>
<th>Material</th>
<th>Unit</th>
<th>Embodied energy coefficient (GJ/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>Carpet</td>
<td>Nylon</td>
<td>m²</td>
<td>0.683</td>
</tr>
<tr>
<td>Walls</td>
<td>Paint</td>
<td>Water based paint</td>
<td>m²</td>
<td>0.096</td>
</tr>
<tr>
<td>Ceiling</td>
<td>Paint</td>
<td>Water based paint</td>
<td>m²</td>
<td>0.096</td>
</tr>
</tbody>
</table>

6 Energy incurred for repairs and replacements during a building’s operational phase (Ramesh et al., 2010)
Number of replacements occur over 50 years

<table>
<thead>
<tr>
<th>Material quantities replaced each time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
</tr>
<tr>
<td>6,000 m²</td>
</tr>
<tr>
<td>Wall</td>
</tr>
<tr>
<td>(10*4)m * 5m * 60= 12,000 m²</td>
</tr>
<tr>
<td>Ceiling</td>
</tr>
<tr>
<td>6,000 m²</td>
</tr>
</tbody>
</table>

Total quantity of materials replaced over 50 years

| Floor carpet                           |
| 6,000 m² * 10 = 60,000 m²              |
| Wall finish                            |
| 12,000 m² * 10 = 120,000 m²            |
| Ceiling finish                         |
| 6,000 m² * 10 = 60,000 m²              |

Total recurrent embodied energy of interiors

| Carpet                               |
| 60,000 m² * 0.683 GJ/ m² = 40,980 GJ  |
| Wall finish                           |
| 120,000 m² * 0.096 GJ/ m² = 11,520 GJ |
| Ceiling finish                        |
| 60,000 m² * 0.096 GJ/ m² = 5,760 GJ   |

These figures demonstrate the importance of recurrent embodied energy in shopping centres which has been neglected to date. However, continuous material replacements occur throughout the life cycle of shopping centre due to various reasons mounting up the LCEE, which may have been insignificant at the initial stage.

5 Need for a materials and assemblies matrix for shopping centres

According to the example provided above, it is evident that LCEE is crucial in shopping centres. Materials as the primary source of embodied energy are therefore important in LCEE study. Material selection directly affects the LCEE of shopping centres and thus careful selection can lead to reduced environmental impacts. Literature study reveals material selection for shopping centres is a unique process. Researchers have developed many approaches to assist this material selection process for buildings as a common platform using several approaches such as optimization methods (Castro-Lacouture, Sefair, Florez & Medaglia, 2008), analytic hierarchy process (Akadir, Olomolaiye, & Chinyio, 2012) and computer aided software tool (LCADesign of Australia) (Seongwon, Tucker, & Ambrose, 2007). Even though several material selection approaches are available they are not considering the exceptional replacement frequencies of shopping centres which is a significant variable in determination of LCEE. Yet, the existing studies in Australia demonstrate the absence of a matrix of sustainable materials and assemblies for shopping centres, assessing LCEE aspects and considering design constraints.

6 Conclusion

The growth of urban developments or the suburbanization has created a sustained growth in the retail property market in Australia (Shopping Centre Council of Australia, 2015). As a result, subregional shopping centre developments are growing rapidly. Regular renovations, refurbishments and replacements are essential in shopping centres life cycle (Chebat et al., 2014; Chui, 2004). Shopping centres are met with significant upgrades once every 2 to 7 years or less (Shopping Centre Council of Australia, 2015). As a result of this shorter refurbishment frequency material replacements occur before expiry of their expected service life (Holtzhausen, 2007) due to economical, functional or social obsolescence (Silva, de Brito, & Gaspar, 2016). This cause in excessive resource and recurrent embodied energy use resulting in negative environmental
(Goodman & Coiacetto, 2012) impacts as well as higher costs to the developer. Stephan and Stephan (2014) stated that the recurrent embodied energy could be reduced if high quality durable materials are used. Materials being the primary source of embodied energy is therefore important in LCEE reduction as careful material selection can account for significantly reduced environmental impacts (Kim & Rigdon, 1998).

Further research is therefore needed to identify the materials with lower LCEE impact for shopping centres in Australia. The proposed research will scope the LCEE aspects as outlined in Figure 1 of materials used in shopping centres and develop a matrix of materials and assemblies, which have lower LCEE impact as well as financially viable. Nonlinear optimization modelling would be used in deriving optimum material and assemblies combinations with the variable of material replacement frequency in shopping centres. The research will investigate the availability of materials in developing the matrix and will propose the most acceptable materials and assemblies combinations for sub regional shopping centres in Australia.

Figure 1: Embodied energy over life cycle stages of a building (Adapted from Crawford (2011))

References


International Council of Shopping Centers. (2001). ICSC's dictionary of shopping center terms:
[includes French, German, Portuguese, and Spanish translations]: International Council of Shopping Centers.


Critical Factors Affecting the Implementation of Urban Renewal Projects: Case Study in Shenzhen

He, H.Y.¹*, Liu,G.W.², Yi, Z.Y.³

Abstract: after an extensive and rapid urbanization, some metropolis have been in the stage of urban renewal due to the land limits, decline of construction industry and Chinese buildings lifespan. As the typical city for urban renewal in china, Shenzhen underwent successful and failed projects. This paper identified the determinants affecting the implementation of urban renewal projects with the 32 cases in Shenzhen and demonstrated that industrial and small sites with a large developers will be more likely to be redeveloped successfully.

Keyword: Urban renewal; Critical factors; Project implementation; Case study

¹* He, H.Y.
Corresponding author, Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: hehaiyang@cqu.edu.cn

² Liu, G.W.
Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: gwliu@cqu.edu.cn

³ Yi, Z.Y.
Faculty of Construction Management and Real Estate, Chongqing University, China
E-mail: yzyldm@hotmail.com
1. Introduction

China had experienced immense urbanization and rapid development of construction before 2010[1]. From 1989 to 2010, the average growth rate of construction industry in China is about 22%. However, after the rapid development in last 20 years, the gross output of construction industry has shifted gear from its previous high speed to low one. Especially in 2015, the growth rate of construction industry is 2.3%. Meanwhile, China’s urbanization rate has reached 57.35%. The urbanization growth in conjunction with the pursuit of more comfortable living environment has resulted in great amount of new housing demands and consequent huge number of construction projects [2]. The demands can come to fruition through urban sprawl and urban renewal strategies. As urban sprawl has limits due to the strategy is at the expense of the loss of agricultural and ecological land, urban renewal strategy plays a major role in the process of urbanization [3].

Notwithstanding the declined construction industry and limited urban sprawl, another three phenomena appeared in china, which included the clearance of slum, land supply and Chinese buildings’ life span. During the “13th Five-Year” period, China renovated 20 million housing units in slum. The second phenomenon is that Chinese metropolis like Shanghai, Shenzhen etc. are in over-exploitation, and the left space can’t support the imminent development. For example, in Shenzhen there is only 59.3 km² reserved land in 2014, which account for 3% of all the land. Meanwhile there is a fact drawing our attention that is for the metropolis like Beijing, Shenzhen, Shanghai, the construction land supply is declining, but the stock construction land supply is increasing gradually. Consequently, the proportion of stock construction land is increasing rapidly. Thirdly, Chinese reconstruction lifespan and maintenance lifespan is 43 years old and 20 years old prospectively according to Liu’s paper [4], which means there will be numerous buildings to be innovated. It seems that the urban renewal will be the main stream in China.

With the development of urban renewal, more and more urban renewal projects have ensued by governments. However, not all the projects are implemented successfully and there are almost 60% of the projects cannot going well. Meanwhile we should insist that all the projects have been included in the urban renewal unit plan. Even in the case that governments try to promote the process of urban renewal with the power of regulation, it is noticeable that the effect of the projects is not ideal. So we would ask some questions, what’s the crucial factors accelerating the implementation of urban renewal projects?

At present, considerable articles are conducted in the determination of demolition and evaluation for implementation of the urban renewal projects. All these papers enable government to determine the area to be updated and improve the sustainability of the projects. However, inadequate attention has been paid to the process of urban renewal projects and there are relatively few papers on the implementation of urban renewal projects.

As an effort contributing to effective implementation of urban renewal projects, the focus of this paper is to find the critical factors which can determine whether the projects will be carried out effectively with a case study of Luohu District, Shenzhen City. The reminder of this paper is organized as follows: an overview of research on implementation of urban renewal projects are introduced in Section 2; data and result are explained in Section 3; and some conclusions are presented in Section 5.
2. Literature review

Previous studies have ever investigated the reason for demolishment and reconstruction in urban renewal projects [4, 5, 6, 7], indicating that the determinants for urban renewal are comprehensive and systematic.

Most researchers indicated that the physical condition of building would accelerate the process of urban renewal strongly. Andrew demonstrated building age is the most strongly significant determinants, while a low-density houses are more likely to be demolished with an empirical analysis on 435,534 buildings [6]. David proved that building over 57 years will not be easily renovated due to the substantial exorbitant capital [7]. William B concluded that households are seen to be less likely to move out of old buildings for the preference of maintenance.

Previous studies reveal that a site with a better location has a more chance to be renovated. Laiyali confirmed that location including sites’ access to transportation and city Centre and existing rents to be the key determinants of the redevelopment of sites based on the theory of rent-gap [1]. Location is an essential factor to be considered for the decision-making process which determines the priority of sites for redevelopment [8]. Michael P found that strategic values of property can differ in systematic ways depending on the types of amenities and dis-amenities, such as school, hospital, railway station, park etc. [9].

Some researchers value the influence of site attribution. Wanghao described that land-ownership is readily to be taken into consideration in urban renewal projects [10]. A multi-ownership or lack of ownership is usually regarded as a challenge for urban renewal [11, 12] and the complexity of land ownership varies from different land use. Besides, it is proved that FAR (floor-area-ratio) has insignificant effect on urban renewal in China, which differs from that of previous empirical studies in Western countries [13].

Environmental situation may also put an effect on urban renewal projects and has been taken into consideration by scholars so as to improve the sustainability of the district [8, 14]. Hamed made a multi-criteria evaluation including air quality, preservation of the environment etc. to identify the priority of the sub-projects [15]. And Lucie Dolešelová classified the brownfields and found that only 12 of 81 sites belong to category A (self-developing sites) and 59 site belong to category C (reserve sites) [16]. This paper would not stress the environment of the projects for all the projects in this study have been included in annual urban renewal program and the purpose of this paper is to identify the determinants for effective implementation.

However, little research emphasizes the effect of the developers. Developers of different types and scale may also influence the implementation of the urban renewal projects. Hence we identify the factors influencing the implementation according to the literature and interview with the developers, as shown in Table 1.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Factors</th>
<th>specific</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>site</td>
<td>construction area</td>
<td>area for reconstruction(m³)</td>
<td>urban renewal plan</td>
</tr>
<tr>
<td></td>
<td>regulated FAR</td>
<td>regulated floor area ratio</td>
<td>urban renewal plan</td>
</tr>
<tr>
<td></td>
<td>previous use</td>
<td>resident/commercial/industrial</td>
<td>urban renewal plan</td>
</tr>
<tr>
<td></td>
<td>regulated use</td>
<td>resident/commercial/industrial</td>
<td>urban renewal plan</td>
</tr>
</tbody>
</table>
3. Data and analysis

3.1 data

Sample description
The survey was conducted in Luohu District, Shenzhen City. Shenzhen is regard as the most active city in China in terms of urban renewal and the land supplied by urban renewal will account for 76% of the whole land supply during the period of 13th Five-Year. Due to the high density of population and badly short supply of land, Shenzhen has been at the stage for a comprehensive urban renewal. Hence it is meaningful to take Shenzhen as the study area.

There has been 32 urban renewal projects listed in the Urban Renewal Unit Planning in Luohu District since 2011 and the latest included project is listed in 2015. However, only 15 projects have been implemented successfully and the other 17 projects remain unimplemented. Among the 17 unimplemented projects, the data of 6 projects cannot be investigated because they are not listed in the Shenzhen annual urban renewal program.

Up to now, the most successful project has been operating and start earning such as the project: Golden Exhibition International Jewelry Plaza. For the unsuccessful projects, some projects are trapped into the negotiation with the owners and some still remains static for no reason. Except for the 6 projects without information, 26 urban renewal projects have been taken as the cases to find the critical factor influencing the implementation. Table 2 presents the basic information of projects.

<table>
<thead>
<tr>
<th>status</th>
<th>number</th>
</tr>
</thead>
<tbody>
<tr>
<td>implemented</td>
<td>15</td>
</tr>
<tr>
<td>unimplemented</td>
<td>11</td>
</tr>
<tr>
<td>null information</td>
<td>6</td>
</tr>
<tr>
<td>all</td>
<td>32</td>
</tr>
</tbody>
</table>

Table 2: Basic information of the cases

3.2 analysis and result

Industrial sites are more likely to be developed successfully
First we need conduct a structure analysis for the classified variables due to the variables in survey is divided into 2 category: classified variables and continuous variables. The variables of land use have been proposed in Table 3. From the table, we can know that resident sites are difficult to be redeveloped, only 2 sites have been renovated. Industrial sites are the easiest projects to be redeveloped, 76.92% of which have been successfully redeveloped. The main reason for this phenomena is that the resident sites have multiple and complex ownership which would cost a lot of time and money in the process of land acquisition. Meanwhile, due to the simple and single ownership, industrial site are more popular for the government and developers to be developed.

Besides, from the perspective of regulated use there is not distinct difference between the implemented and unimplemented. The only similarity is that the commercial land are the most popular regulated land use, which mainly because the commercial real estate would be easier to get a profit.

**Table 3: Comparison of land use for the urban renewal projects**

<table>
<thead>
<tr>
<th></th>
<th>previous use</th>
<th>regulated use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>resident</td>
<td>commercial</td>
</tr>
<tr>
<td>unimplemented</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>implemented</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

Projects developed by large enterprises can progress better

The influence of developers on the process of urban renewal is usually ignored by most researcher but developers do affect the process of projects. To analysis the relationship between developers and implementation, Table 4 is proposed. There is no distinct influence from the type of developer on the project implementation. However, in terms of scale of developers, 17 large developers conducted the projects and 58.82% of them can successfully implement urban renewal. The other 9 developers are medium-sized or small. An interesting phenomenon is that the successful implementation rate from the non-large developers reached 55%. By investigation on these 5 success implemented by non-large developers, we found that these redeveloped properties are owned by the developer and are small sites, which can avoid the land acquisition and shorten the developing life-cycle.

**Table 4: Comparison of developers for the urban renewal projects**

<table>
<thead>
<tr>
<th>type of developer</th>
<th>scale of developer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Large</td>
</tr>
<tr>
<td>local developer</td>
<td>implemented</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Local real estate developer</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

Small plot can contribute more to the implementation

To determine which other factors do have a strong effect on the implementation of urban renewal projects, a T-test is used to compare the factors in these two different groups. The t-test formula is as follows:
\[ t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2} \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}} \]

Where: \( \overline{X}_i \) = mean of group \( i \)

\( S_i \) = standard deviation of group \( i \)

\( n_i \) = sample size of group \( i \)

T-tests were applied to the means site, neighborhood variables listed in Table 1. The results show which variables will be significantly distinct between implemented and unimplemented projects. The result is shown in Table 5.

### Table 5: Independent variables test

<table>
<thead>
<tr>
<th></th>
<th>implementation</th>
<th>N</th>
<th>means</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>construction area</td>
<td>no</td>
<td>11</td>
<td>51515.72</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>23504.35</td>
<td></td>
</tr>
<tr>
<td>regulated FAR</td>
<td>no</td>
<td>11</td>
<td>9.03</td>
<td>0.605</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>7.03</td>
<td></td>
</tr>
<tr>
<td>price for resident real estate</td>
<td>no</td>
<td>11</td>
<td>4.45</td>
<td>0.576</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>3.88</td>
<td></td>
</tr>
<tr>
<td>price for commercial real estate</td>
<td>no</td>
<td>11</td>
<td>5.97</td>
<td>0.725</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>5.88</td>
<td></td>
</tr>
<tr>
<td>ratio of profitable area</td>
<td>no</td>
<td>11</td>
<td>.89</td>
<td>0.712</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>.92</td>
<td></td>
</tr>
<tr>
<td>distance to railway station</td>
<td>no</td>
<td>11</td>
<td>559.09</td>
<td>0.522</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>826.67</td>
<td></td>
</tr>
<tr>
<td>distance to park</td>
<td>no</td>
<td>11</td>
<td>513.64</td>
<td>0.895</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>618.67</td>
<td></td>
</tr>
<tr>
<td>distance to lake</td>
<td>no</td>
<td>11</td>
<td>913.64</td>
<td>0.956</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>1030.67</td>
<td></td>
</tr>
<tr>
<td>distance to school</td>
<td>no</td>
<td>11</td>
<td>458.09</td>
<td>0.079</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>524.00</td>
<td></td>
</tr>
<tr>
<td>distance to hospital</td>
<td>no</td>
<td>11</td>
<td>450.91</td>
<td>0.612</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>15</td>
<td>754.67</td>
<td></td>
</tr>
</tbody>
</table>

The result indicates that the construction area is significantly different between implemented and unimplemented as the sig. is 0.006 and the construction area of implemented projects is distinctively smaller than that of unimplemented, which is 23504.35 to 51515.72. For urban renewal projects, as the area of a redeveloped site is smaller, the demand for developers and government will be lower because there are less ownerships in smaller site and the requirements for capital will not be so strict as a large site.

Besides, we need to point out that all the other factors are not significantly different. With the
indifference of location factors including distance to railway station, park, lake, school, hospital, the indifference of price for resident and commercial real estate shows that most urban renewal projects are located in the place with similar location condition. Meanwhile the means of the price for commercial real estate indicates that most urban renewal projects are in a prosperous region. The factor ratio of profitable area for implemented and unimplemented projects are indifferent and both of them reach about 90% and this is mainly due to a high ratio of profitable area will contribute to attract developers.

4. Conclusion

By now, the existing studies on urban renewal projects are ambiguous on the implementation, especially for the projects which have been encouraged to be redeveloped. This paper can contribute to fill the gap in the literature. From the cases study in Luohu District, Shenzhen City, it is demonstrated that due to the simple and distinct ownership, small plot and industrial sites are easier to be redeveloped successfully, identifying the ownership should be attached considerable importance. So for the government, it is essential to confirm the property for stimulating urban redevelopment. Meanwhile, government should strengthen the review of the funds and take the large enterprise with development experience as the priority selection as they can provide high quality products and increase the success rate of implementation of urban renewal projects.

Due to the limited access to the micro-data of the projects, this papers only covers the data from the 2011. Accordingly, some effect can’t be reflected in this study, such as the effect from another urban renewal project. Projects can affect each other and a spatial analysis should be proposed so as to analysis the internal relations between the projects.

References


Gender Equality in Singapore’s Construction Industry

Zhang, Z.1*, Ling, F.Y.Y.2 and Lim, C.J.I.3

Abstract: Gender inequality is a pressing issue that is affecting the manpower pool in the construction industry for settlement building. The ratio of male to female employees within the industry remains skewed towards the male, and thus results in an imbalance. The aim of this research is to explore the perceptions of both men and women with regard to the role of women in the construction industry. A literature review was carried out and it was used to design the questionnaire. The data were collected via e-mail, telephone calls and face-to-face meetings with the respondents, after which the SPSS software was used to analyse the results. The statistical tests include ANOVA and the one-sample t-test. Research findings showed that there are significant differences in how the two genders perceive issues like conditions of the workplace, issues faced at work and the suitability of some positions for women. Recommendations were made to improve communication through ways like informal meetings, gatherings and seminars. It is suggested that women take a more proactive stance towards communication and men show greater support and encouragement to the women in their jobs.

Keywords: Gender equality; Construction industry; Female; Male; Perception; Questionnaire survey

1* Zhang, Z.
Corresponding author, Research Assistant, Department of Building, National University of Singapore, Singapore
E-mail: bdgzzhe@nus.edu.sg

2 Ling, F.Y.Y.
Professor, Department of Building, and Associate Provost, Office of the Provost, National University of Singapore, Singapore

3 Lim, C.J.I.
Assistant Contracts Manager, Land Transport Authority, Singapore
1 Introduction
The construction industry is one of the largest employing industries. However, the issues of gender inequality and male domination have been plaguing the construction industry for decades [1]. The aim of this study is to investigate the perceptions of women working in the construction industry and the issues they face. The first objective is to investigate, from the female perspective, the work environment and jobs that women prefer, and the HR issues they face at their workplace. The second objective is to examine men’s perception of women in the construction industry. The final objective is to give suggestions that would encourage women to stay in the construction industry. The purpose of this study is to inform firms operating in the construction industry on how to attract and retain more female employees through crafting appropriate HR policies, offering them appropriate jobs and creating a work environment that is conducive for them.

2 Literature Review
The construction industry in many countries is characterised by an imbalanced gender ratio. Women comprise 9.1% [2], 10% [3] and 11.6% [4] of US, UK and Australia’s construction workforce respectively. In Singapore, the male-to-female gender ratio is about 76:24 [5]. The lack of diversity in the construction industry has left it predominantly male and thus greater female participation should be encouraged.

2.1 Work environment
The male-dominated culture is representative of the construction industry’s work environment. Females working in such a male-dominated and -oriented environment have to deal with issues such as sexual discrimination and being treated hostilely by senior male managers [6]. The work culture, including long working hours, heavy workload, stressful work environment [7], inflexible working practices [8], which are contradicting women’s family responsibilities [9], is unsupportive of women and thus they do not perceive it as a desirable workplace [10]. Working on-site may pose several difficulties for women [11] as the construction site is considered dirty, dangerous, noisy and harmful to health.

Based on the review on work environment issues, the research questions are set as follows:

1. Do women who work in the industry prefer to work in an office rather than on-site?
2. Do women who work in the construction industry prefer to work regular hours?

2.2 Careers for women
The construction industry is portrayed as a workplace that is physically demanding, disorderly and unsafe, with frequent clashes between work and personal commitments. All these factors lead to limited female participation in the industry [12]. Women are perceived as being less capable than men or that they could only do administrative work in the construction industry [11].

It is not clear to what extent each of the professions is suitable for women and whether women and men view women’s suitability in the same way. Therefore, the research question is:

3. What professions in the construction industry are more suitable for women?

2.3 HR matters
2.3.1 Gender discrimination
Gender discrimination is a barrier for women to work in the construction sector [13]. Discriminative and negative attitudes towards women exist in the construction industry, especially on-site [9; 11].

2.3.2 Salary levels of men vs women in the same jobs

Gender segregation is observed where women are paid generally lower than men [1]. Women working in the construction sector are paid 8.7% and 16.6% lower than men in Germany and UK [14].

2.3.3 Promotion standards for men vs women in the same jobs

In the construction industry, it generally takes a longer time for women to be promoted compared to their male counterparts [15]. Being a minority, women need to perform better than men to be considered for promotion [7]. Some evidence of a ‘glass ceiling’ may be present for women attempting to make a career in construction [11].

2.3.4 Women altering behaviour when working with men

Construction site jobs expect entrants to be physically tough, and able to endure the harsh outdoor working environment and coarse language [16]. Women working in such a male-dominated environment may feel compelled to change their behaviour. For example, they may behave more like men so that they would be accepted and be able to thrive in such an environment [16].

2.3.5 Equal opportunities for men and women in the workplace

Equal opportunities for both genders are not always apparent in the construction industry. Dainty et al. found that there are limited promotion opportunities for women, mismatch between construction work and women’s expected social roles, and a culture that limits women’s equal participation [17]. There is also lack of gender diversity and fairness of opportunity in the industry [16].

2.3.6 Reasons for leaving the construction industry (Voluntary termination)

A few factors are driving women to leave the construction industry. These include the male-dominated environment, long working hours, inflexible work practices and unequal opportunities [17].

The literature review discovered a few issues that women working in the construction industry face. However, a systematic examination of all the issues that women indeed are facing is lacking. Meanwhile, it is not clear whether women and men perceive these issues differently or otherwise. It is important to reconcile the views of both men and women so that fairer policies can be crafted to correct the significant gender imbalance and encourage women to stay in industry.

The research questions are as follows:

4. Do women who work in the construction industry face gender discrimination?
5. Are women who work in the construction industry paid lower than men for the same job?
6. Do women who work in the industry alter their behaviour when working with men?
7. Do women who work in the construction industry have equal opportunities as the men?

The research hypothesis is set out below:

H1: There is a significant difference in the way men and women perceive the roles that are suitable for women in the construction industry and the issues faced by women.

3 Research Method
A two-pronged approach was adopted for the research design: a questionnaire survey based on literature review and semi-structured interviews. There were two different sets of questionnaires: one to gather the men’s perspectives and the other the women’s perspectives. Each questionnaire comprised two main sections: demographics and details of the respondent; and the men’s and women’s preferences and their respective perceptions of job-related issues faced by women. Responses to the questions are either a ‘yes’/ ‘no’, or a rating of 1 to 5 on the Likert scale, where 1 = very low extent; 3 = moderate; and 5 = very high extent.

Pilot studies were conducted. In the formal study, the target population was all professionals working in Singapore’s construction industry. An e-mail was sent to randomly selected professionals, with the questionnaire attached.

Descriptive and inferential statistics analysis was conducted using the Statistical Package for Social Sciences (SPSS) software. The one-sample t-tests were used to find out if the respondents agreed with the issues listed to a significant extent and the test value was set at 3 (neutral). One-way analysis of variance (ANOVA) was conducted to compare if the means of both male and female respondents were significantly different.

In the second prong of the research, in-depth interviews were conducted to validate and substantiate the statistical findings, and to explore the reasons behind certain findings from the survey. Semi-structured face-to-face, telephone and e-mail interviews were conducted. Open-ended questions were posed.

4 Characteristics of Respondents
A total of 156 questionnaires were sent out and 72 responses were received, of which 68 were usable, giving a response rate of 43.6%. Thirty-one male and 37 female professionals in the construction industry responded to the survey. The majority of the male respondents are middle management. Slightly more than half of the female respondents are junior staff while close to half are middle management. The construction experience of the female respondents ranged from one year to 26 years, with an average of 9.9 years. The construction experience of the male respondents ranged from one year to 40 years, with an average of 14.3 years.

Semi-structured interviews were conducted with five interviewees. Their experience ranged from two years to 40 years, with an average of 17 years. The majority hold senior positions in their firms, and work in the public sector.

5 Results and Discussion
5.1 Work environment
The t-test results in Table 1 indicate that women show a significant preference to work in an office setting with regular working hours. Men shared a similar perception that women significantly desire to work in the office. However, the ANOVA result shows that men think women’s desire to work on-site is less than what women themselves actually desire. Therefore, women may be more receptive to work on-site than men think. The work environment analysis results support Lingard and Francis’ finding that women tend to work in an office setting with regular working hours[8].

<table>
<thead>
<tr>
<th>Description</th>
<th>Female Mean</th>
<th>t-value</th>
<th>1-tail Sig.</th>
<th>Male Mean</th>
<th>t-value</th>
<th>1-tail Sig.</th>
<th>ANOVA F-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 5.2 Careers for women

<table>
<thead>
<tr>
<th>Description</th>
<th>Female Mean</th>
<th>t-value</th>
<th>1-tail Sig.</th>
<th>Male Mean</th>
<th>t-value</th>
<th>1-tail Sig.</th>
<th>F-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desire to work in an office setting</td>
<td>3.57</td>
<td>4.742</td>
<td>0.000**</td>
<td>3.90</td>
<td>5.330</td>
<td>0.000**</td>
<td>2.739</td>
<td>0.103</td>
</tr>
<tr>
<td>Desire to work on site</td>
<td>2.65</td>
<td>-2.324</td>
<td>0.013*</td>
<td>2.16</td>
<td>-4.655</td>
<td>0.000**</td>
<td>4.362</td>
<td>0.041#</td>
</tr>
<tr>
<td>Desire to have regular office hours(8.30-18.00)</td>
<td>3.89</td>
<td>6.705</td>
<td>0.000**</td>
<td>3.94</td>
<td>6.400</td>
<td>0.000**</td>
<td>0.049</td>
<td>0.826</td>
</tr>
</tbody>
</table>

### HR matters

<table>
<thead>
<tr>
<th>Description</th>
<th>Mean</th>
<th>t-value</th>
<th>1-tail Sig.</th>
<th>F-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face gender discrimination</td>
<td>2.27</td>
<td>-4.920</td>
<td>0.000**</td>
<td>5.322</td>
<td>0.024#</td>
</tr>
<tr>
<td>Paid lower than men for same position &amp; work</td>
<td>2.73</td>
<td>-1.351</td>
<td>0.093</td>
<td>0.188</td>
<td>0.666</td>
</tr>
<tr>
<td>Subject to higher promotion standards than men for the same position</td>
<td>2.24</td>
<td>-5.334</td>
<td>0.000**</td>
<td>2.330</td>
<td>0.132</td>
</tr>
<tr>
<td>Alter their behaviour when working with men</td>
<td>2.84</td>
<td>-0.845</td>
<td>0.202</td>
<td>1.635</td>
<td>0.205</td>
</tr>
<tr>
<td>And men have equal opportunities</td>
<td>3.43</td>
<td>3.151</td>
<td>0.002**</td>
<td>0.117</td>
<td>0.734</td>
</tr>
<tr>
<td>Leave the industry because they are affected by the abovementioned issues</td>
<td>2.38</td>
<td>-3.745</td>
<td>0.000**</td>
<td>11.206</td>
<td>0.001#</td>
</tr>
</tbody>
</table>

### Display behavior compared to men

<table>
<thead>
<tr>
<th>Description</th>
<th>Mean</th>
<th>t-value</th>
<th>1-tail Sig.</th>
<th>F-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>As aggressive and assertive</td>
<td>3.08</td>
<td>0.650</td>
<td>0.260</td>
<td>0.581</td>
<td>0.449</td>
</tr>
<tr>
<td>As able to tolerate stress</td>
<td>3.46</td>
<td>3.643</td>
<td>0.000**</td>
<td>1.873</td>
<td>0.176</td>
</tr>
<tr>
<td>As competitive and ambitious</td>
<td>3.24</td>
<td>2.165</td>
<td>0.019*</td>
<td>0.450</td>
<td>0.505</td>
</tr>
<tr>
<td>Put work responsibilities before family duties</td>
<td>2.97</td>
<td>-0.215</td>
<td>0.415</td>
<td>0.816</td>
<td>0.370</td>
</tr>
<tr>
<td>Have similar sense of humour</td>
<td>2.97</td>
<td>-0.177</td>
<td>0.430</td>
<td>0.091</td>
<td>0.764</td>
</tr>
<tr>
<td>As tolerant of coarse language</td>
<td>3.11</td>
<td>0.612</td>
<td>0.272</td>
<td>4.615</td>
<td>0.035#</td>
</tr>
<tr>
<td>As tough</td>
<td>3.11</td>
<td>0.702</td>
<td>0.244</td>
<td>0.540</td>
<td>0.465</td>
</tr>
<tr>
<td>As able to tolerate outdoor conditions</td>
<td>3.00</td>
<td>0.000</td>
<td>0.500</td>
<td>0.606</td>
<td>0.439</td>
</tr>
<tr>
<td>As able to handle criticism</td>
<td>3.08</td>
<td>0.534</td>
<td>0.298</td>
<td>0.006</td>
<td>0.941</td>
</tr>
</tbody>
</table>

Notes: 1. Mean: calculated from rating on 5-point scale, where 1 = very low, 3 = moderate, 5 = very high extent.
2. * significant (p < 0.05) extent; ** significant (p < 0.01) extent
3. # significant (p < 0.05), ## significant (p < 0.01) difference both genders rated that particular question.
The t-test results in Table 1 show that the female respondents feel they are significantly suited to work in the construction industry, while the ANOVA result shows a significant difference in men’s perception of women’s suitability to work in the construction industry and women’s desire to work on site. This may be attributed to the following perceptions of the construction industry – a male-dominated culture, inflexible working practices, possible discrimination issues and men’s reservations about women working in this industry. However, for women who have worked in the construction sector, they know that they are capable of working in this industry.

Table 1 shows that both the male and female respondents feel that women are suited for jobs at the different management levels, ranging from administrative and professional to mid and upper management. The female respondents feel that women are suited for a myriad of professional jobs in the construction industry. They are neutral on the suitability of the safety officer and site supervisor jobs for women, while men feel that the position of site supervisor is unsuitable for women. The female respondents feel that they are significantly suited to be contractors and project managers. However, the male respondents are neutral on these positions and gave a lower rating on their suitability for women. The results on careers for women reconfirm men’s misconception that women are significantly not suited for the construction industry [16].

5.3 HR matters

Table 1 shows that women face significantly low gender discrimination. The ANOVA result shows there is a significant difference in the perception of this issue, with the men feeling there is a moderate extent of gender discrimination against women. One male interviewee had come across women facing a high extent of gender discrimination in this line of work.

Women being paid lower than men (x3ii) is felt to a moderate extent by the female respondents, while the men perceived that women face this to a significantly low extent. This may be because the male respondents are privy to the women’s salaries.

Both groups do not feel that women are subjected to a significantly higher standard than men in order to be promoted (x3iii), corroborating the finding that equal opportunities exist to a significant extent (x3iv).

The t-test results in Table 1 show that the HR issues do not significantly affect women’s decision to leave or stay in the construction industry. However, the t-test and ANOVA results for the men show that there is a significant difference in the way the male and female respondents rated this item, suggesting there are differing views. Men feel that these issues affect women to a moderate extent, which is significantly more than what the women themselves actually feel.

5.4 Behaviour expected of women

The t-test results in Table 1 show that the female respondents feel they are significantly more able to tolerate stress and are more competitive and ambitious than men. However, the male respondents feel that women do not need to behave significantly different from men. Women working in the construction industry are still a minority. They may feel that they need to be better able to tolerate stress and be more competitive and ambitious than men to succeed in the industry.

The male respondents expect women to have a significantly lower tolerance of coarse language. However, the female respondents feel they need to be no different from men in
tolerating coarse language. The ANOVA result also shows the difference in perceptions between the two genders. Men may feel they need to be more careful with the use of coarse language when communicating with women, and hence women feel they do not need to have a similar tolerance level. However, women appear to understand the norm of using coarse language, and therefore feel they can tolerate coarse language to the same extent as men. The findings confirm Agapiou’s study that women are as just as able to tolerate coarse language[16].

Three male interviewees admitted to altering their behaviour when interacting with women. It can be shown that men’s control over their use of coarse language has achieved some effect. However, the difference in perception of this issue as revealed in the survey suggests that effort is still needed to lessen the use of coarse language at the construction workplace.

Table 1 shows that both men and women feel that women put work responsibilities before family duties to a similar extent as the men. The result confirms Agapiou’s study that women devote time and energy to work, and are unlikely to give family duties significantly more priority than the men[16].

5.5 Validation of hypotheses

Hypothesis H1 states that there is significant difference in the way men and women perceive women’s role, position and suitability in the construction industry. It was found that there are significantly different views pertaining to workplace conditions, suitable positions for women, issues women face at work and women’s behaviour in construction. The hypothesis is supported.

6 Recommendations

Based on the findings of the survey and interviews, suggestions are now given that would encourage women to stay in the construction industry. Employers can engineer greater opportunity for both male and female employees to interact. This may include gatherings, informal meetings, seminars and workshops where staff of both genders can bond and forge stronger relationships, allowing communication channels to be created. Improved relationships and communication can help to clear any existing misconceptions as well as prevent new ones from forming.

It is recommended that female professionals take a more proactive stance to interact and communicate more with their male colleagues on the issues they face at work. This will help to clear misconceptions and establish healthier working relationships which will encourage female professionals to stay in the construction industry.

For male professionals, it is recommended that they be more careful with the use of coarse language. They can also encourage and support women in the construction industry. This is because women are still a minority in the industry, and they need their colleagues’ encouragement to build up their confidence and perform better.

7 Conclusion

Using a questionnaire survey, which was supplemented by in-depth interviews, this study investigated women’s preferences and the issues they face when working in the construction industry. The first objective found that women prefer to work regular hours, and in an office environment. Women feel they are suited for the construction industry in general, and capable of handling a variety of jobs that include quantity surveyor, contractor, engineer, architect, project manager and contracts manager.
The second objective found that by and large, men generally do not have many misconceptions about female professionals. However, in certain aspects such as workplace conditions, issues faced at work, behaviours and attitudes, and the suitability of women in the construction industry, significant misconceptions exist. These misconceptions should be clarified as they can affect communication and working relationships in the construction industry. The results show that men’s perception of women’s desire to work on-site is less than what the women themselves actually desire. In general, men are neutral on women’s suitability to work in the construction industry while women think they are suitable.

The final objective is to give suggestions that would encourage women to stay in the construction industry. Employers can create more opportunities that would encourage greater interaction and communication between their male and female staff. This will enable them to better understand each other’s capabilities and issues faced at work, which will help to clarify any misconceptions and improve working relationships.

Future studies can be broadened by including more samples with a more even distribution of respondents from different areas of practice in the construction industry. This will lead to more representative results.

References


A bibliometric analysis of research on building energy performance gap

Zou, Patrick X.W.1*, Xu, Xiaoxiao2, Sanjayan, Jay3 and Wang, Jiayuan4

Abstract: During the past decade, the large building energy performance energy gap (BEPG) between predicted and reality has attracted increasing attention from researchers. These researches have resulted in a large number of publications over the last ten years. A thorough review of BEPG research will help researchers to having a comprehensive and systematic understanding of the current research focuses and future research trend. This paper aims to provide a summative reviews of the current state of art in BEPG research, by conducting a content and bibliometric analysis of 227 relevant articles and papers published during the last decade from 2007 to 2017. It was found that researches on BEPG has multiple perspectives and aspects, including building type, strategy, building life-cycle, energy related stakeholder and influencing factors. Through an in-depth analysis of the different perspectives, it was also found that (1) occupant behavior in operation stage attracts most attention from researchers; (2) technology and method are the main strategy for bridging BEPG; (3) building energy management is an organic system, and there are close connections between the factors in the system; (4) information and energy related stakeholders play an important role in BEPG.

Keywords: Building energy; Performance gap; Bibliometric analysis; Content analysis.

1* Zou, Patrick X.W.
Corresponding author, Department of Civil and Construction Engineering and center for sustainable infrastructure, Swinburne University of Technology, Australia
E-mail: pwzou@swin.edu.au

2 Xu, Xiaoxiao.
Department of Civil and Construction Engineering, Swinburne University of Technology, Australia

3 Wang, Jiayuan
School of Civil engineering, Shenzhen University, China

4 Sanjayan, Jay
Department of Civil and Construction Engineering and center for sustainable infrastructure, Swinburne University of Technology, Australia
1 Introduction

Building energy, as an important part of overall energy, has become the focus of attention in most countries over the past three decades. In 2010 buildings accounted for approximately 32% of total final energy use [1], or 117 Exajoules (EJ) [2], being one of the largest end-use sectors worldwide [3]. Considering an expected population of 9.7 billion by mid-century, along with the growing trend of urbanization and the improvement of living standards, people will work, study and live inside buildings for longer time, leading to a strong growth in energy consumption in buildings which would exceed that in transport and industry sectors [4]. Facing the grim energy situation, many countries have proposed energy conservation goals and strategies. Nevertheless, a large number of buildings did not meet the energy conservation goals, including those used advanced energy conservation [5, 6]. According to the statistics, the actual measured building energy can be as much 2.5 time the predicted building energy [7, 8], which will seriously hinder the realization of the goal of energy conservation. Therefore, it is important to have a comprehensive and systematic understanding of the energy performance gap in buildings.

Over the last 10 years, a multitude of researchers have explored the building energy performance gap. However, building energy management is an extremely complex system with long period (including design, construction, operation and retrofitting), complicated technology, complex information flow and multi-stakeholders [8]. Therefore, it is very important to undertake a systematic analysis of relevant publications. De Wilde [8] conducted a review of articles that were published up until 2013 on the building energy performance gap, both in terms of root causes and solutions. Numerous researchers have been conducted to close the performance gap. After De Wilde [8], more than one hundred papers related to BEPG have been published, along with the rise of new idea (e.g., pre-occupancy evaluation) and technology (e.g., augmented reality and virtual reality). It can be said that the field of building energy management has undergone enormous changes. With the deepening research on BEPG, researchers are increasingly aware that root causes may not be independent and the interaction between different stakeholders could have great impact on building energy. In addition, researchers also realized that a single strategy may be not enough bridge BEPG. To date, no comprehensive analysis has done to address the problem of (1) identifying the relationships among root causes of BEPG; (2) integrating strategies for better bridging BEPG. An in-depth review of researches on BEPG is needed to explore the BEPG formation mechanism and improvement strategy. As the first step, it is very important to have an overview of the existing researches on BEPG. Therefore, the aim of this research is to develop a framework for better understanding BEPG through analyzing the publications related to BEPG from 2007 to 2017. In specific, the research objectives are (1) identifying and collecting the publications related to BEPG; (2) reviewing existing researches from different perspectives; (3) identifying current state of art in BEPG research. In doing so, the research answers three questions: (1) what is the composition of the existing research related to BEPG; (2) what are the research topics; and (3) what are the current research focuses?

The remainder of this paper is structured into five sections. Pursuant to this introductory section is a detailed description of the research methods, including publication collection and content analysis. The third section presents a framework for understanding BEPG, followed a bibliometric analysis of BEPG research in section 4. Conclusion is given in section 5.
2 Research methods

2.1 Retrieving publications

Research in BEPG can be seen as a combination of multiple disciplines, including but not limited to computer science, management, behaviour, statistics, psychology and informatics [6, 8, 9]. Therefore, it is not enough to select target publications from only one database for providing a comprehensive search of BEPG. For example, Building Research & Information is published by Taylor & Francis, which cannot be found in ScienceDirect. To avoid missing important publications, the Google Scholar was used at the first stage. However, due to the issues related to updating frequency, some new publications may not be found in Google Scholar [10]. Therefore, a supplementary search in Web of Science, ScienceDirect, Ei CompenexWeb, Taylor & Francis, Emerald needs to be conducted.

Firstly, two key phrases “building energy” and “performance gap” were used to search in Google Scholar and 1060 records (from 2007 to 2017) were found on 18 May 2017. Each of these publications were examined to identify whether they are related to BEPG, and this effort resulted in 191 publications extracted from 1060 records. Afterward, 36 extra publications were identified from Web of Science, ScienceDirect, Ei CompenexWeb, Taylor & Francis, Emerald. Finally, a total of 227 publications were collected.

2.2 Analyzing contents using Nvivo

Nvivo® is a famous qualitative data analysis computer software, which has been used in numerous researches. All publications imported into Nvivo in this study are treated as “Sources”, which were analyzed by using “Node” function. A node is a collection of references (including sentence, paragraph, the entire paper and report) about a specific topic, theme or relationship. In this study, the references about the same theme will be gathered to a node by “coding”. Take a paper titled “A virtual reality integrated design approach to improving occupancy information integrity for closing the building energy performance gap” as an example, the sentence “In the operation stage, occupants may not usually perform in accordance with building designers’ design assumptions” is related to operation, occupant and design assumption, thus we could create three nodes named “operation”, “occupant” and “design”, and code the sentence under them. In most cases, nodes may have two or more than two level node structure. For example, when regarding the content reporting occupant, we could create a three-level node structure where the first level includes “Operation”, the second level includes “Occupant”, and the third level includes “Occupant comfort”, “Occupant characteristics”, “Occupant experience” and “Occupant behaviour”. Then we could analyze the content and code it under “Occupant characteristics”, “Occupant comfort”, “Occupant experience” or “Occupant behaviour”. According to the above approach, all sources can be coded. It should be noted that initial codes might be iteratively revised and refined throughout the coding process [11]. In order to ensure the reliability and validity of the analytical results, several round of coding would be conducted.

Having coded all sources, the relationship between nodes could be structured by using the “Model” function in Nvivo [12]. As shown in Fig. 1, a tentative framework is developed based on the analysis of the 227 publications (due to the limited space of the paper, only nodes in the first and second levels are shown). There are three different shapes that represent different meanings in
Fig. 1. The diamond represents the boundary of this research and contains all publications; the hexagon stands for the strategies for closing BEPG, including design concept, new technology and “soft” measures; the ellipses represent the nodes created in the coding process. Arrows in the framework means the relationship between different figures, which includes “results in”, “contributes to” and “impact”. For instance, the arrow between “design” and “construction” shows that inappropriate design may have a negative impact on construction. The number in each shows the total number of publications related to a specific theme. For example, there are 120 publications related to the causes of BEPG in design stage and 150 publications related to occupant. Furthermore, the number of each arrow shows the total number of publications connected with a specific relationship between two themes. It is worth noting that a publication may related to more than one themes and relationships.

### 3 A framework for understanding BEPG

The tentative framework of BEPG research shown in Fig. 1 is just an initial framework generated from the 227 publications, which may not be easily understood. Therefore, an illustration of framework (Fig. 2) based on the tentative framework was developed for better understanding BEPG research. As shown in Fig. 2, there are four major components in this framework: (a) the “Building type” including residential building and public building; (b) the “Strategy” for closing BEPG containing design concept, technology and “soft” measures; (c) the “Building life-cycle” indicating the stages that the causes of BEPG belongs to; (d) the “Energy related stakeholder” indicating the stakeholders that may have an impact on BEPG; and (e) the “Influencing factors” indicating the factors that may be related to BEPG. Component (a) was developed by synthesizing all nodes focusing on different types of buildings. Component (b) was formed by reviewing all
nodes proposing strategies for filling BEPG. Component (c) was developed according to the stage characteristics of nodes. Considering energy the important role of energy related stakeholder plays in BEPG, component (d) was formed by nodes connected with different stakeholders. Component (e) was developed according to the different categories of influencing factors of BEPG.

Based on the BEPG research framework, the existing research can be seen from more than one perspective. For instance, research on occupant behaviour simulation can be seen from “Occupant” in the Energy-related stakeholder, “Operation” in the Building life-cycle, “Technology” in the Strategy, and “Behaviour” in the Influencing factors. Therefore, the BEPG research framework not only helps readers but also future researchers to see a “panorama” of the BEPG research as published.

Based on the framework, the next section will conduct an in-depth analysis of BEPG research. The analytic result of eight pieces of interview material will serve as the supplement to the analytic result of publications.

4 A bibliometric analysis of the BEPG research

Through utilizing the BEPG research framework, all retrieved BEPG publications can be reviewed from different perspectives according to the components, and thus a comprehensive and systematic overview of BEPG research over the survey period from 2007 to 2017 can be understood. The framework shows that residential and non-domestic buildings are the focus of research on BEPG. According to the statistics, 153 publications (67.4%) are related to residential buildings and 175 publications (77.1%) are related to non-domestic buildings. It should be noted that the summation of the two numbers of exceeds 227 (the same situation can be seen in components (c), (d) and (e)) because there are 101 publications focus on both residential and non-domestic buildings. Due to the difference of building function, non-domestic building and residential building should be treated differently in research. For example, cooking and water heating are significant energy consumption in residential buildings, while HVAC and lighting are important end-uses in non-domestic buildings.

There are 184 publications proposing strategies for closing BEPG in detail, which can be understood by positioning them into a “Strategy spectrum”. The first of this spectrum is about design concept (33, 26.6%), such as, passive design and human-in-the-loop design. However, only
having the design concept is inadequate, technology is also needed to implement design concept, and thus the second component of this spectrum is related to technology. It is found that sustained research efforts have been devoted to “hard” technologies and methods (134, 59.0%), including Building Information Modelling (BIM), Radio Frequency Identification (RFID), Virtual reality (AR), Augmented Reality (AR), Data mining, machine learning, artificial intelligence and etc. The third component of this spectrum is about “soft” measures, which is more focused on the communication between energy related stakeholders, occupants’ comfort, occupants’ experience, rebound effect, “Soft Landings” process, information disclosure and etc. It is well acknowledged that BEPG cannot be filled only with advanced technologies, “soft” measures are equally important. Although the number of publications related to “soft” measures is relatively small, it has attracted an increasing attention from researchers.

By projecting the publications onto a building life-cycle, it is found that they fall into four major stages including design (120, 52.9%), construction (18, 7.9%), operation (150, 66.1%) and retrofitting (25, 11.0%). Since the causes of BEPG from different stages could interacted with each other, especially the interaction between operation and design [13], a publication may focus more than one stage. It can be seen that a large number of publications were concentrated on operation stage. The reason may be that operation is the stage that directly generates building energy consumption. A full understanding of operation stage could not only help to effectively reduce unnecessary energy consumption, but also help to optimize energy efficiency system design [6, 14]. Compared with the research on design and operation stages, only 18 publications were related to construction stage. It should be noted that, although the causes of BEPG in construction stage may not be as much as that in design or operation stage, they could have a great impact on building energy consumption. For instance, if the quality of a building as not in accordance with the specification, it is difficult for this building to achieve energy conservation goals [8, 15]. It is, therefore, proposed that future researchers should pay more attention to construction stage.

The research on BEPG representing in the 227 publications can be understood from another perspective by projecting them onto energy related stakeholder. Energy related stakeholder refers to the stakeholder from building life-cycle that may have impact on the building operation energy consumption. There are six major stakeholders in existing researchers, namely owner (39, 17.2%), designer (120, 52.9%), contractor (18, 7.9%), supplier (12, 5.3%), occupant (150, 66.1%), energy manager (32, 14.1%) and government (32, 14.1%), whose activities would directly or indirect affect building energy consumption, such as owner’s and designer’s decision, contractor’s construction, energy manager’s and occupant’s behaviour [8, 16-18]. There is a corresponding relationship with project life-cycle. It is found that a significant proportion of publications was concentrated on occupant, e.g., occupant characteristics, occupant behaviour, occupant experience and occupant’s comfort. As stated by Wang and Srinivasan [19], occupant plays an important role in building energy consumption. In addition, occupant factors is the focus of designers’ attention. It has been proved that if a designer could not evaluate occupant factors well, the predicted energy consumption is lack of reliability [6, 19].

By classifying the influencing factors, the 227 publications fall into information (186, 89.1%), knowledge & experience (106, 46.7%), behaviour (146, 64.3%), modelling & simulation (42, 18.5%) and environment (122, 53.7%). As an influencing factor that most publications are concentrated on, behaviour includes the behaviour of all energy related stakeholder, such as the
decision-making behaviour of designer, the management behaviour of energy manager and the energy consumption behaviour. Information, which attracts an increasing attention in both research and practice, refers to the data that is generated from different project stages, and is transferred among different project stages and energy related stakeholders. It should be noted that the lack of information integrity is one of the main causes of BEPG \[6\]. Knowledge & experience, had a great impact on building energy consumption though \[20, 21\], are largely out of the attention of existing research interests. Many researches had proved that a lack of knowledge & experience is a root cause of BEPG \[22, 23\] and hence, more researches need to be extended to knowledge & experience. As another influencing factors that should not be ignored, environment is full of uncertainties. As stated by Pollard \[24\], although the data about weather conditions is sufficient, it may now be less accurate due to the impact of global warming on climate.

5 Conclusions

This paper developed a framework for better understanding the BEPG researches through reviewing 227 related publications with the assistance of the Qualitative Social Research (QSR) software package NVivo. The framework consists of five dimensions, including building type, strategy, building life-cycle, energy related stakeholder and influencing factors, which provides researchers a “panorama” of BEPG research. Based on the framework, a bibliometric analysis of 227 related publications was conducted and the major findings can be summarized as follows: (1) occupant behavior in operation stage attracts most attention from researchers; (2) technology and method are the main strategy for bridging BEPG; (3) building energy management is an organic system, and there are close connections between factors in the system; (4) information and energy related stakeholders play an important role in BEPG

It should be noted that this research just developed a framework for BEPG research while future research directions and detailed relationships among different dimensions are not presented due to the limited space of the paper. Subsequent studies can improve the inadequacies of this study by undertaking further analysis.

References


Study on the Influence of Urban Rail Transit on Residential Rental Based on Hedonic Model -Taking Hangzhou Metro Line 1 as an Example

Jinmin Zhang¹, Renhan Xu²

Abstract: The urban rail transit, as an important factor influencing urban planning and development, which provides the material exchange channels and frame support for urban development, has an important influence on urban real estate value and urban spatial pattern. Based on Hedonic model, this paper analyzes the value-added components of the housing rental, then obtains the relationship between the urban rail transit and the residential rents of different distance.

Key Word: Urban rail transit; Residential rental; Hedonic model.

1 Introduction

With the process of urbanization in China accelerating, the housing supply of large and medium cities becomes tenser. Therefore, the housing market is further active, and the prices of commercial housing keeps rising, while low-income urban people can’t afford a house without enough economic strength and loan repayment ability, so part of the them will turned to residential leasing market, which is an alternative to residential sale market. Residential leasing can not only solve the housing needs of low-income people in the city, but also play an important role in meeting the short-term housing needs of other groups, such as graduates, migrants and foreigners.

Because of the expansion of rental housing demand, foreign scholars from the 20th century began to focus on the impact of residential rents. Since the real estate was viewed as a heterogeneous commodity, most scholars generally used the Hedonic model which was also called the characteristic price model to study the impact of real estate prices factors. For residential rent research, most scholars still followed the Hedonic model as the main research methods. Frew applied the Hedonic model to perform the research on the impact that characteristics of residential leasing brought to the rent [1]; Schultz applied Hedonic models in the analysis of housing rental factors, using monthly housing rental data of the four districts of Berlin [2]; Brunoer took Vienna as an example to use the Hedonic model to focus on the impact of spatial factors in residential rentals [3]. Domestic researches about residential rents started relatively late. But in recent years, some scholars used Hedonic Model to study the residential rent in China, using the real estate price research methods as reference. Wang Yichuan took Hangzhou as an example to study the characteristics of urban residential leasing, and summarized its influence on residential rent into architectural features, neighborhood characteristics, location characteristics and facilities, services and residence restrictions [4]; Su Yayi used spatial autocorrelation analysis method and Kriging interpolation method to study the spatial distribution of housing rent in Beijing, and to explore the influencing factors of its formation [5]. Cai Juhua collected the monthly rent and its characteristics of 130 houses in Guangzhou and applied the Hedonic model to discuss the micro-impact factors of residential rent [6].

During the process of urbanization, the demand for traffic in cities increases day by day. Traffic

¹ Jiamin Zhang.
School of public affairs, Zhejiang University, China
E-mail: zhangjer@zju.edu.cn

² Renhan Xu.
School of public affairs, Zhejiang University, China
E-mail:xurenhan@foxmail.com
congestion has become a common problem in large and medium cities. The contradiction between supply and demand of transportation has become more and more prominent. Therefore, traffic factors affect the final price of the residential housing market, whether it is residential sale market or residential leasing market. In recent years, in order to alleviate the problem of traffic congestion, rail transit has become an important alternative to traditional transportation. Rail transportation has many advantages such as higher speed, less accidents and smaller pollution over other traditional transportation. It can effectively improve the commuting efficiency and reduce commute costs. Therefore, rail transit will have an important impact on residential rent, especially for the rental housing market in the main part of low-income people.

From the current research, most scholars use the Hedonic model to study influencing factors of the housing rent, but few scholars focus on the impact of rail transit on the residential rents. In term of the information collected, only Benjamin use the example of residential housing near the Washington subway station to study the impact of rail transit on the residential rent along the subway. He concludes that the residential rents reduce when the distance from the station increases. In view of this, this paper mainly focuses on the analysis of the impact that the urban rail transit has on residential rents in its neighbor region.

2 Research areas and data acquisition

2.1 General situation of Hangzhou Metro Line 1

Hangzhou Metro Line 1 is the first subway line in Hangzhou and Zhejiang provinces. The construction project started in March 28, 2007. The line was built since March 28, 2007 and officially operated in November 24, 2012. Hangzhou Metro Line 1 is 53 kilometers long. According to the "three plan" period of Hangzhou subway construction, Hangzhou Metro Line 1 will be extended to the airport (under construction), then, the Xiaoshan airport will be connected to the downtown.

2.2 Data acquisition

This study uses Hedonic model which takes the online rental housing listing price as independent variables. According to the characteristics of rental housing prices, the study determines three main types of variables, the architectural features, location characteristics and neighborhood characteristics, selected 14 variables to study. The rental data needed by the research comes from the internet.

<table>
<thead>
<tr>
<th>Table 2-1 Introduction table of characteristic variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Dependent variable</td>
</tr>
<tr>
<td>Independent variable</td>
</tr>
<tr>
<td>Architectural features</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Decoration

Decoration

The decoration of the leasing house. Classification: The blank 1 points, the rough 2 points, the middle 3 points. The hardcover 4 points, the luxurious 5 points.

Distance to subway station

D_sub

The distance between the leasing house(neighborhood) and the subway station.

The number of the bus station

Bus

The number of the bus station within 1000 meters.

Distance to CBD

D_CBD

The distance between the leasing house(neighborhood) and the CBD.

Distance to the West Lake

D_lake

The distance between the leasing house(neighborhood) and the West Lake.

Near the river

Dm_riv

Dummy variable: the distance between the river within 500 meters value 1, or 0.

Near the university

Dm_uni

Dummy variable: the distance between the university within 500 meters value 1, or 0.

Living facilities

Equipment

In or near the area within 1000 meters is a supermarket, bank, hospital, post office, or park, each accounted for 1 points, a total of 5 points.

Education facilities

Education

In or near the area within 1000 meters is a kindergarten, primary school or middle school, each accounted for 1 points, a total of 3 points.

3 The application of the Hedonic model

Hedonic model is widely used in the pricing of durable goods. Many researches about real estate price use the Hedonic model as the core research method. The Hedonic analysis method is based on the Lancaster's preference theory and Rosen's product supply and demand equilibrium model based on the product characteristics of [7]. This paper changes the view from the real estate price to rental housing, mainly through the three aspects of architectural features, residential location characteristic and neighborhood features characteristic to analyze the characteristic price that influence the residential rent, mainly focusing on the impact of urban rail transit.

3.1 Determination of function forms

Hedonic model function mainly divides in three basic form: linear, semi logarithm and logarithm. This paper carries out the linear and semi logarithm multiple simulation, considering the explanatory ability of the model, in order to obtain more accurate results of model analysis.

With Rent (residential rental) and LnRent (logarithm residential rental) as the dependent variable for Hedonic analysis, the dependent variable residential rents have a better outcome, R2 and adjusted R2 are higher, compared to the logarithmic dependent variable residential rents, which can be seen in the test index. Therefore, this paper focuses on linear analysis.

Table 3-1 Population test index

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>D.W.test</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent</td>
<td>0.6326</td>
<td>0.6293</td>
<td>0.877</td>
<td>192.25</td>
<td>0.000</td>
</tr>
<tr>
<td>LnRent</td>
<td>0.5433</td>
<td>0.5392</td>
<td>0.856</td>
<td>132.83</td>
<td>0.000</td>
</tr>
</tbody>
</table>

3.2 Model testing and correcting
Through the analysis on Table 3-1, although a significant test of general model passed the test, but through the D.W. test, the model can be seen in the presence of serial correlation, so in order to correct the model, generalized least squares (GLS) estimation model will be used to eliminate the negative impact of serial correlation model. In the corrected model, R2 is 0.4170 and 0.5861, with the logarithm residential rental and residential rental as dependent variables, which is respectively of better goodness to fit in.

Table 1.2 GLS corrected population test index

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>D.W. test</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent</td>
<td>0.5861</td>
<td>0.5815</td>
<td>2.066</td>
<td>105.55</td>
<td>0.000</td>
</tr>
<tr>
<td>LnRent</td>
<td>0.4170</td>
<td>0.4118</td>
<td>2.077</td>
<td>79.80</td>
<td>0.000</td>
</tr>
</tbody>
</table>

3.3 Hedonic model analysis and results

With GLS method correcting the Hedonic linear model, the regression equation and the result are as follow:

\[
Rent = 369.7731 + 3.5087Tstorey + 35.6004Area - 6.7813Age + 7.8535Storey + 222.8150Dm_\text{ori} + 148.6414\text{Decoration} - 0.3403D_{sub} + 526.7692D_{riv} + 16.8813Bus + 301.2234D_{CBD} - 386.3248D_{lake} + 400.5557D_{uni} + 159.8273\text{Equipment} - 119.6901\text{Education}
\]

Table 3.3 The Hedonic model result of Residential rental

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>T-value</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant term</td>
<td>369.7731</td>
<td>0.72</td>
<td>0.470</td>
</tr>
<tr>
<td>Tstorey</td>
<td>3.5087</td>
<td>0.84</td>
<td>0.401</td>
</tr>
<tr>
<td>Area</td>
<td>35.6004***</td>
<td>32.10</td>
<td>0.000</td>
</tr>
<tr>
<td>Age</td>
<td>-6.7813</td>
<td>-1.36</td>
<td>0.175</td>
</tr>
<tr>
<td>Storey</td>
<td>7.8535</td>
<td>1.36</td>
<td>0.175</td>
</tr>
<tr>
<td>Dm_\text{ori}</td>
<td>222.8150***</td>
<td>2.57</td>
<td>0.010</td>
</tr>
<tr>
<td>Decoration</td>
<td>148.6414***</td>
<td>4.82</td>
<td>0.000</td>
</tr>
<tr>
<td>D_{sub}</td>
<td>-0.3403***</td>
<td>-3.31</td>
<td>0.001</td>
</tr>
<tr>
<td>D_{riv}</td>
<td>526.7692**</td>
<td>2.17</td>
<td>0.030</td>
</tr>
<tr>
<td>Bus</td>
<td>16.8813</td>
<td>1.36</td>
<td>0.175</td>
</tr>
<tr>
<td>D_{CBD}</td>
<td>301.2234***</td>
<td>8.22</td>
<td>0.000</td>
</tr>
<tr>
<td>D_{lake}</td>
<td>-386.3248***</td>
<td>-11.36</td>
<td>0.000</td>
</tr>
<tr>
<td>D_{uni}</td>
<td>400.5557**</td>
<td>2.81</td>
<td>0.005</td>
</tr>
<tr>
<td>Equipment</td>
<td>159.8273*</td>
<td>1.70</td>
<td>0.089</td>
</tr>
<tr>
<td>Education</td>
<td>-119.6901</td>
<td>-1.44</td>
<td>0.150</td>
</tr>
</tbody>
</table>

***、**、* mean 1%, 5% and 10% of significance level in statistical tests, respectively.

From the test of significance of individual variables, the 5 variables of building area, orientation, decoration, subway station distance, CBD distance and West Lake distance, are statistically significant at the 1% level, while the two variables, “near the river” and “near the university”, are statistically significant at the 5% level. “Living facilities” is significant at the 10% level. But the 5 variables of building types, building age, floor, the number of the bus station and education facilities, are not significant. These variables are not significantly related to residential rental, which may result from the limited sample size of model data.
In the presence of variables with significant influence on residential rental, impacts of “near the river” and “near the University” are the largest, their impact coefficients of residential rents are over 400. The “near the river” variable reflects the demand for landscape in the residential rental; And “near the University” reflects the demand for housing renting around the university, which contribute to the growth of residential rental.

Secondly, the four variables of the West Lake distance, CBD distance, orientation and decoration, also have large impacts on residential rents, with their influence coefficient of housing rent over 200. West Lake distance reflects the influence of the distance from West Lake to the surrounding residential rental, demonstrating that as one of Hangzhou's most famous cultural attractions, West Lake has a very important economic role in the residential rental; The impact of CBD distance is converse to expectations, probably associated with the selection of the central business district. Because of the rapid development of Qianjiang New City, which has gradually become a new central business district of Hangzhou in recent years, the original status of CBD Wulin is weakened. Therefore, the choice of Wulin Square as the CBD distance measure, influences the result of the model negatively; Orientation that reflects lighting conditions of the residential housing, has a great impact on residential rental; The decoration is the embodiment of comfort whose impact on residential rental differs according to decoration, the better the decoration conditions, the higher the rent.

The coefficient of the subway station distance is negative, showing that the residential rental is negatively related to the distance to the subway station. That is, the farther away from the subway station, the worse the accessibility, then the residential rental decreases. The impact factor of the subway station distance is -0.3403, which indicates that in the case of other factors unchanged, the residential rental will decrease by 340.3 yuan every 1 kilometers from the subway station. In addition, the influence of urban rail transit on residential rental is limited within a certain space, with the distance to the subway station increasing, the impact falls. The above model uses sample data for subway stations within 3 km of the general regression analysis results, so in order to study the impact of different space circle around subway stations on residential rental, the study will continue to apply the Hedonic model, based on 0-500 meters, 500-1000 meters, 1000-2000 meters and 2000-3000 meters, 4 scopes of data.

4 Analysis of the impact of urban rail transit on residential rental along the route

4.1 Analysis results of different scopes of data

According to the result, the negative impact coefficient varies at different scope. Under T-test and D.W.test, the result of coefficient can be accepted. Judging from the dataset, it is obviously that the coefficient at the circle of 0-500 meters is -0.0673, which means every one kilometer’s increase in the distance to subway station causes a decline of 67.3 yuan in the residential rental. The absolute value of coefficient increases to 0.4462 at the circle of 500-1000 meters and becomes largest in the whole result. Then the absolute value of coefficient shrinks as the distance keeps increasing to the circle of 2000-3000 meters.

<table>
<thead>
<tr>
<th>D_sub(m)</th>
<th>Impact coefficient</th>
<th>T-valve</th>
<th>Sig.</th>
<th>standard deviation</th>
<th>D.W.test</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-500</td>
<td>-0.0673</td>
<td>-2.28</td>
<td>0.028</td>
<td>0.831202</td>
<td>1.974461</td>
</tr>
<tr>
<td>500-1000</td>
<td>-0.4462</td>
<td>-2.76</td>
<td>0.006</td>
<td>0.6451014</td>
<td>2.024878</td>
</tr>
<tr>
<td>1000-2000</td>
<td>-0.1274</td>
<td>2.87</td>
<td>0.004</td>
<td>0.2187396</td>
<td>2.132049</td>
</tr>
<tr>
<td>2000-3000</td>
<td>-0.0631</td>
<td>-2.59</td>
<td>0.010</td>
<td>0.4712976</td>
<td>2.132480</td>
</tr>
</tbody>
</table>

4.2 The possible reason of the result

The possible reasons why the impacts of the urban rail transit on residential rental varies roughly in different scopes of circle could be discussed, referring the location theory of Johan Heinrich von Thunen. For the first class of the circle, 0-500 meters, the reason that the absolute value of coefficient is relatively
low may resulted from the replacement of the commercial real estate. Because this part of circle has the most preponderant accessibility of transportation, the open market here has the largest advantage over other circles, which causes the commercial agglomeration instead of the residential housing. And the high price of land push residential use which cannot afford it away. Since residential use don’t participate in the competition of price, this circle performs a relative homogeneity in the residential land.

Then for the second circle whose absolute value of coefficient is the biggest, the attractive force is lower for commercial real estate so the residential housing is of great advantage over industry land and farm land. In addition, the price is much lower as distance to the station increases, there are more profits in the commercial residential housing use such as house renting. As distance increases in this circle, the cut-throat competition with the circle between the inner part of residential leasing, which raises the price elasticity of housing rental and performs a obvious kind of heterogeneity.

Finally, for the last two circles, the impact coefficients of urban rail transit shrink because in this region, the accessibility is weaker that the residents prefer to take other transportation such as private cars. Those two circles may include or approach the edge of the impact range of the urban rail transit. As a result, the coefficient is not sensitive so the absolute value of it gradually approaches 0.

5. Conclusion

Urban rail transit can obviously change the accessibility of surrounding city services, and has significant value-added impact on residential real estate as well as other commercial real estate along the route. As TOD model develops in many cities successfully, rail transportation will attract many developers to the real estate investment and development, and therefore will have a significant impact on residential rental prices. On the one hand, urban rail transit will influence residential housing value; On the other hand, the size of urban rail transit and residential property will also influence the housing rental.

Taking Hangzhou Metro Line 1 as an example, the influence of urban rail transit on residential rents along the line is studied based on the Hedonic model. The results show that there are many factors that influence the rental price of housing, including location characteristics, architectural features, neighborhood characteristics and facilities, services, residential restrictions and so on. Among them, the location characteristic, that is, the distance between the house and the nearest subway station, has more obvious impact on residential rental, and has different impact in different distance spatial circles.

Although there are insufficient points in the study such the inadequate reasons of the coefficient result and vague edge of the effective impact of urban rail transit on residential rental. The paper’s main aim is that the results of this study can provide reference for the investor of real estate, especially of residential leasing market, and provide a basis for the government to formulate planning and housing related policies, and provide decision-making guidance for residential tenants.

References

The Impact of Financial Factors on Commercial Housing’s price—An Empirical Study based on VAR Model

Yang Donglang¹, Zhao Luyao²*, Cui Zhongfei³

Abstract: As the important means of production and material carrier for urban residents’ living, commercial housing is related to the development of China's macroeconomic and social stability. In 1998, China’s State Council proposed to reform the housing system, and prepared to implement the housing distribution monetization. Since then, China's real estate industry has developed rapidly. However, with the social funds influx into the real estate market, commercial housing prices of major cities in China rose rapidly in different level, which has caused negative effects on the national economy and residents’ living. In order to prevent bubble agglomeration in China’s real estate market and guide the healthy development of the market, studying the financial policy which is closely linked to the price of commercial housing and clarifying the mechanism are very important.

This study constructs the theoretical model of the impact of financial factors on the price of commercial housing. The study is based on the monthly data of 35 major cities in China, from 2004 to 2016, and uses vector autoregressive model to explore the impact of financial factors on the price of commercial housing.

Keywords: VAR Model; Housing Price; Financial Factors

1 Introduction

Since China State Council put forward deepening the reform of housing system in 1998, and stopped housing distribution in-kind which was instead by monetization of housing distribution, China’s real estate industry has made a rapid development. However, with influx of a large amount of social funds, the price of commercial housing appeared to rise rapidly, which made negative effects to Chinese residents’ living and macro economy’s regular running¹. In order to prevent the excessively rapid growth of housing price and guide the healthy development of the real estate market, Chinese government has introduced a series of policies, among which financial policy has become an indispensable means of real estate’s regulation and control². Therefore, it has much significance to analyze the economic behavior of participants in financial and real estate sector, and further clarify the mechanism between commercial housing price and financial factors.

Scholars around the world have done lots of research on the relationship between financial factors and the real estate price, and their work mainly includes interactive effects, causal relationship and the transmission mechanism between the two subjects. Taken together, there are some major factors involved, financial interest rates, credit, money supply, exchange rate and international capital flows,

1 Yang Donglang
School of public policy and management, Xi'an Jiao Tong University, China
E-mail: yangdl@mail.xjtu.edu.cn

2* Zhao Luyao
Corresponding author, School of public policy and management, Xi'an Jiao Tong University, China
E-mail: 124853307@qq.com

3 Cui Zhongfei
School of public policy and management, Xi'an Jiao Tong University, China
On the choice of research method, the academia circle mainly adopts econometrics as a means of analysis, and the specific application of the theory and model method mainly includes general equilibrium theory, Carey model, vector autoregression model, method of co-integration, impulse response function, variance decomposition analysis, panel data model analysis and structural equation model. Among these theory, the theory of general equilibrium model has been widely applied in the end of the 20th century, and vector autoregression model (VAR) can estimate the dynamic relationship between all the endogenous variables, and thus gradually become the main method to study financial factors and housing price. At the same time, most scholars choose to analyze the dynamic relationship between financial indicators and housing price from two aspects of long-term and short-term, and sequentially analyze of financial factors on the real estate market bubble and macro-economic impact.

2 Model constructing

2.1 Study frame constructing

Commercial housing has mainly two attribute—residential property and investing property, and both individuals and enterprises can obtain credit support from financial institutions through real estate mortgage, thus financial factor is one of the main elements that affect the price of commercial housing market. For a long time, as a pillar industry of national economy, the real estate industry plays an important role in the process of China's economic development, and because the real estate industry is one of the capital-intensive industries, both sides of commercial housing market—supply and demand need to devote a lot of money, therefore financial factors and the commercial housing market have an increasingly close relationship with the development of the real estate industry in China, and the change of capital amount that financial sector put into the housing market will inevitably affect the development of commercial housing market, which specifically appears as frequent fluctuation of commercial housing price.

At the same time, the supplying structure of commercial housing market and the price variation led by demand preference will cause relatively large effects on the social economic system through the wealth effect, mortgage effect and housing expenditure effect. Operation of commercial housing market is actually comprehensive action of the market main subjects—real estate developers and purchasing groups, whose microscopic behavior are under the influence of the macro economy, and the macro economy impact includes financial factors, therefore General Equilibrium Theory, which can co-analyze the microscopic behavior and macroeconomic fluctuations becomes the most ideal framework for research of the real estate market and financial factors interaction[10].

Based on the General Equilibrium Theory, this study suggests that, economic policy affects the market and buying behavior through affecting each developers and buyers, and ultimately affects the supply-demand relationship of real estate market, and causing housing price changes (figure 1).
On the basis of referring to the theory of general equilibrium, we put forward the theoretical analysis framework of this study. According to the economic subject concept, this framework proposed that real estate market includes five kinds of behavior subjects: real estate developers, retailers, the household sector (divided into deposit family and borrowing family), financial institutions (mainly banks) and the central bank (Figure 2).

2.2 Research hypothesis

Based on the research framework, this paper presents five research hypotheses and as shown in Table 1.

2.3 Model choosing

This research use vector autoregression model (VAR). Vector autoregression model is a kind of unstructured model, it takes each endogenous variable in the system as the lag value of all the endogenous variables to construct the model, and there is no strict distinction between endogenous variables and exogenous variables, so it is able to appear the dynamic correlation between different
variables in the model.

### Table 1 Research Hypothesis

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Hypothesis Content</th>
<th>Direction</th>
<th>Indicator</th>
<th>Variable Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>Financial institutions credit has positive influence on fluctuation of commercial housing price</td>
<td>+</td>
<td>RMB credit volume</td>
<td>lnLOAN</td>
</tr>
<tr>
<td>H2</td>
<td>Money Supply has positive influence on fluctuation of commercial housing price</td>
<td>+</td>
<td>M2 growth rate</td>
<td>M2</td>
</tr>
<tr>
<td>H3</td>
<td>International capital flow has positive influence on fluctuation of commercial housing price</td>
<td>+</td>
<td>Foreign direct investment</td>
<td>LnFDI</td>
</tr>
<tr>
<td>H4</td>
<td>Exchange Rate has negative influence on fluctuation of commercial housing price</td>
<td>-</td>
<td>Exchange Rate of Dollar</td>
<td>IR</td>
</tr>
<tr>
<td>H5</td>
<td>Interest Rate has negative influence on fluctuation of commercial housing price</td>
<td>-</td>
<td>Interest rate on interbank loan market</td>
<td>ER</td>
</tr>
</tbody>
</table>

### 3 Analysis of financial factors’ effect on commercial housing price

This research collected monthly data of financial and commercial housing market from 2004 to 2016 in China, and analyze the influence of financial factors on the commercial housing price from the macro level. All the data comes from <China's financial statistical yearbook> data To make the data more stationary and eliminate heteroskedasticity, in this paper, the dependent variable housing price($HP$), RMB credit HYPERLINK volume of financial institutions ($LOAN$) and the actual foreign direct investment ($FDI$) are transformed into the logarithmic form.

#### 3.1 Unit root test of original value

Because it has a defect to test stationarity through time series trend diagram, so we introduce unit root test to test stationarity. This paper used the ADF test and the results are as shown in table 2.

The test result indicates that each variable’s original value is non-stationary, and we need to run ADF test after the first order difference. The results are as listed in Table 3.

The test results indicates that after the first order difference, $lnHP$, $lnLOAN$, $lnFDI$, $M2$, $IR$, $ER$ all rejects the null hypothesis of ADF test: Variable has one unit root and its ADF test value is less than the critical value of significance level of 5%, thus the first order difference series is stationary.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Augmented Dickey-Fuller test statistic</th>
<th>Test critical values</th>
<th>Prob.</th>
<th>Test result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t-Statistic ADFTest value</td>
<td>1%level</td>
<td>5%level</td>
<td>10%level</td>
</tr>
<tr>
<td>lnHP</td>
<td>-1.951086</td>
<td>-4.023975</td>
<td>-3.441777</td>
<td>-3.145474</td>
</tr>
</tbody>
</table>
Table 3 The ADF Test Results after the first order difference

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>t-Statistic</th>
<th>Augmented Dickey-Fuller test statistic</th>
<th>Test result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Augmented Dickey-Fuller test statistic</td>
<td>Test critical values</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1% level</td>
</tr>
<tr>
<td>ΔlnHP</td>
<td>-3.565072</td>
<td>-3.473096</td>
<td>-2.880211</td>
</tr>
<tr>
<td></td>
<td>(C, T, 12)</td>
<td>(C, 0, 12)</td>
<td>-3.473096</td>
</tr>
<tr>
<td>ΔlnLOAN</td>
<td>-8.754028</td>
<td>-3.473096</td>
<td>-2.880211</td>
</tr>
<tr>
<td></td>
<td>(C, 0, 0)</td>
<td>(C, 0, 0)</td>
<td>-3.473096</td>
</tr>
<tr>
<td>ΔlnFDI</td>
<td>-4.452813</td>
<td>-3.473096</td>
<td>-2.880211</td>
</tr>
<tr>
<td></td>
<td>(C, 0, 11)</td>
<td>(C, 0, 11)</td>
<td>-3.476472</td>
</tr>
<tr>
<td>ΔM2</td>
<td>-10.23197</td>
<td>-3.476143</td>
<td>-2.881541</td>
</tr>
<tr>
<td></td>
<td>(C, 0, 10)</td>
<td>(C, 0, 10)</td>
<td>-3.476143</td>
</tr>
<tr>
<td>ΔIR</td>
<td>-17.33891</td>
<td>-3.473096</td>
<td>-2.880211</td>
</tr>
<tr>
<td></td>
<td>(C, 0, 0)</td>
<td>(C, 0, 0)</td>
<td>-3.473096</td>
</tr>
<tr>
<td>ΔER</td>
<td>-13.85430</td>
<td>-3.473096</td>
<td>-2.880211</td>
</tr>
<tr>
<td></td>
<td>(C, 0, 0)</td>
<td>(C, 0, 0)</td>
<td>-3.473096</td>
</tr>
</tbody>
</table>

### 3.2 Johansen Co-integration Relationship Test

This article adopts the method of Johansen test of co-integration relationship between the variables. Because the co-integration test is sensitive to the number of lagged periods and test form, so the determination of number of lagged periods is important. If the maximum is too small, then residual will possibly be auto-correlative, and can lead to inconsistency of parameter estimation; if maximum is too big and parameters to be estimated is too many, degree of freedom can severely reduce, which directly affect the effectiveness of the parameter estimation in the model. On the base that our data can support effective estimation, this article uses Eviews to determine the optimal lag length in the model, and according to the criteria of LR, FPE, AIC, SC, and HQ, adopts the option of minimum, and in the case of inconsistent results of different criteria, this article choose the minimum value of AIC criterion. By contrast, we find that when the lag length P = 3, minimum value under the FPE, AIC criteria is smallest, and the optimal lag length under the SC and HQ criteria is 1 order, so this study chooses 3 order as the optimal lag length.
Use Co-integration Test in Eviews, and test results are as shown in following table 4.

### Table 4 Johansen Test of co-integration (Trace Test)

<table>
<thead>
<tr>
<th>Hypothesized</th>
<th>Eigenvalue</th>
<th>Trace Statistic</th>
<th>0.05 Critical Value</th>
<th>Prob.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of CE(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None *</td>
<td>0.411487</td>
<td>176.9774</td>
<td>95.75366</td>
<td>0.0000***</td>
</tr>
<tr>
<td>At most 1</td>
<td>0.231739</td>
<td>96.92392</td>
<td>69.81889</td>
<td>0.0001***</td>
</tr>
<tr>
<td>At most 2</td>
<td>0.129108</td>
<td>57.11639</td>
<td>47.85613</td>
<td>0.0053***</td>
</tr>
<tr>
<td>At most 3</td>
<td>0.115774</td>
<td>36.24262</td>
<td>29.79707</td>
<td>0.0079***</td>
</tr>
<tr>
<td>At most 4</td>
<td>0.078724</td>
<td>17.66321</td>
<td>15.49471</td>
<td>0.0232**</td>
</tr>
<tr>
<td>At most 5</td>
<td>0.034374</td>
<td>5.281789</td>
<td>3.841466</td>
<td>0.0215**</td>
</tr>
</tbody>
</table>

It’s evident that there are no more than 5 null hypothesis are rejected, which indicates that there are no more than 5 co-integration relationship in the model we constructed.

### 3.3 Granger causal relationship test

Granger causal relationship test, in fact, is determining whether a set of coefficients that consists of lag items are significant the basis of the regression model. The causal relationship is determining whether lag items of \( \ln LOAN, \ln CDI, M2, IR, ER \) will have significant influence on \( \ln HP \). \(^{[13]}\) Test results are as shown in Table 5.

### Table 5 Granger causal relationship test

<table>
<thead>
<tr>
<th>Group</th>
<th>Null Hypothesis:</th>
<th>Lag</th>
<th>F-Statistic</th>
<th>Prob.</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( \ln LOAN ) does not Granger Cause ( \ln HP )</td>
<td>3</td>
<td>8.99559</td>
<td>0.0000***</td>
<td>accept</td>
</tr>
<tr>
<td></td>
<td>( \ln HP ) does not Granger Cause ( \ln LOAN )</td>
<td>3</td>
<td>1.17200</td>
<td>0.3226</td>
<td>accept</td>
</tr>
<tr>
<td>2</td>
<td>( \ln FDI ) does not Granger Cause ( \ln HP )</td>
<td>3</td>
<td>17.8304</td>
<td>0.0000***</td>
<td>reject</td>
</tr>
<tr>
<td></td>
<td>( \ln HP ) does not Granger Cause ( \ln FDI )</td>
<td>3</td>
<td>4.31609</td>
<td>0.0060***</td>
<td>reject</td>
</tr>
<tr>
<td>3</td>
<td>( M2 ) does not Granger Cause ( \ln HP )</td>
<td>3</td>
<td>14.2058</td>
<td>0.0000***</td>
<td>reject</td>
</tr>
<tr>
<td></td>
<td>( \ln HP ) does not Granger Cause ( M2 )</td>
<td>3</td>
<td>6.99491</td>
<td>0.0002***</td>
<td>reject</td>
</tr>
<tr>
<td>4</td>
<td>( IR ) does not Granger Cause ( \ln HP )</td>
<td>3</td>
<td>0.63324</td>
<td>0.5947</td>
<td>accept</td>
</tr>
<tr>
<td></td>
<td>( \ln HP ) does not Granger Cause ( IR )</td>
<td>3</td>
<td>1.60246</td>
<td>0.1914</td>
<td>accept</td>
</tr>
<tr>
<td>5</td>
<td>( ER ) does not Granger Cause ( \ln HP )</td>
<td>3</td>
<td>2.19543</td>
<td>0.0911*</td>
<td>reject</td>
</tr>
<tr>
<td></td>
<td>( \ln HP ) does not Granger Cause ( ER )</td>
<td>3</td>
<td>1.13683</td>
<td>0.3363</td>
<td>accept</td>
</tr>
</tbody>
</table>

The test results indicate that there exists one-way causation between Renminbi credit volume in financial institutions and commercial housing price, and under significant level of 5%, Granger test rejects the null hypothesis, which is, \( \ln LOAN \) is not the Granger reason of \( \ln HP \), but accept the null hypothesis that \( \ln HP \) is not the Granger reason of \( \ln LOAN \). This indicates that Renminbi credit volume in financial institutions is the Granger reason of commercial housing price, and the fluctuation of credit market can effectively explain the fluctuation of commercial housing price. Therefore, the regulation of commercial housing price should aim at restricting the financial scale of current market. There also exists bilateral causation between \( M2 \) growth rate and commercial housing price, and under significant level of 1%, \( M2 \) growth rate is the Granger reason of
commercial housing price, at the same time, commercial housing price is also the Granger reason of M2 growth rate. This is to say, the adjustment of money supply will have affection on the real estate market, and consequently have effects on commercial housing price, and this is consistent with China’s monetary policy. There exists bilateral causation between foreign direct investment and commercial housing price, and foreign direct investment is the Granger reason of commercial housing price, and vice versa. This indicates that under the intervention of international capital, commercial housing price will thus have wide change. Besides, there exists one-way causation between exchange rate and commercial housing price.

It is evident that the results of Granger test further verifies the conclusion drawn from the Var model, that is, RMB credit volume in financial institutions, money supply growth rate, foreign direct investment and exchange rate have significant influence on commercial housing price. And in Granger test, these four variables are all granger reason of commercial housing price, which means the variation of these four variables can sufficiently explain the variation of commercial housing price. However, the influence of interest rate is not significant in this model.

3.4 variance decomposition

Variance decomposition is based on the analysis of each structure impact contribution to the endogenous variable changes, and then to evaluate the importance of different variables. According to the cause, decompose the endogenous variables fluctuations within the system into different parts associated with various information, and therefore get the information of the endogenous variables’ importance to the model. Set the observation interval of variance decomposition as 20 months, and use Cholesky Decomposition method to decompose the commercial housing price lnHP. Decomposition results are as shown in following figure 3.

![Figure 3-1 Variance Decomposition figure](image)

We can see lnHP’s contribution rate drops rapidly in the first 3 months, and later on keeps at 60%. RMB credit volume’s contribution rate rises rapidly in the first two months, and slows down in the third month, and rises to 14.64% in the 20th month, on the whole, its contribution rate is at 15%. lnFDI’s contribution rate rises rapidly in the first 3 months, and then drops slightly, and its
contribution rate is 15.07% in the 20th month. The contribution rate of money supply to commercial housing price is basically steady, and its contribution rate is 7.11% in the 20th month.

The contribution rate of interest rate is rising up steadily, 2.03% in the 5th month, and 7.82% in the 20th month. The contribution rate of exchange rate is very weak and fluctuates between 0.10%~2.40%.

4 Conclusion

This article studies on China’s commercial housing, uses methods of variable autoregression model (VAR) and Panel data analysis to analyze the financial factors’ effects on commercial housing price, and draws following conclusions:

Financial institutions credit, money supply, international capital flow and exchange rate are factors that will significantly affect commercial housing price, and there exists one-way causation between financial institutions credit and commercial housing price, between exchange rate and commercial housing price, which indicates financial institutions credit and exchange rate are Granger reasons of commercial housing price, but not vice versa. The Fluctuation of financial institutions credit and exchange rate can validly explain the Fluctuation of commercial housing price.

There are bilateral causation between money supply and commercial housing price, between international capital flow and commercial housing price. Money supply and international capital flow are Granger reasons of commercial housing price, and commercial housing price is also Granger reason of money supply and international capital flow. Money supply and adjustment of international capital flow will have influence on real estate market, and consequently have influence on commercial housing price, and in reverse, the variation of commercial housing price will also stimulate money supply and international capital flow varies. The effect of interest rate is not significant in this model, a possible reason may be interest rate is not so sensitive to variation of commercial housing price and there is some delay.

The results of variance decomposition shows that, except housing price itself, RMB credit volume of financial institutions, foreign direct investment, M2 growth rate and interest rate all have contribution to fluctuation of commercial housing price, while exchange rate doesn’t have much contribution.

Reference


Bibliometric Analysis of Building Information Modelling (BIM) in the Construction Industry

Mustafa, A.H. ¹,a, Amir, A. ² and Tayyab, M.³

Abstract: Over the last decade, the emergence of BIM has reshaped the Architectural-Engineering-Construction and Facility Management (AEC/FM) industry. Despite the increasing importance of BIM in the construction industry, there is a scarcity of statistical analysis studies that shed the light on this sophisticated innovation. To fill this need, this paper is a bibliometric analysis research that aims to guide and orient researchers who are interesting in BIM publications. This study helps the researchers to know which authors and journals to consider when dealing with BIM topics. To achieve this aim, Web of Science (WOS) database was used to analyse BIM research domains in term of language of publications, areas of knowledge, countries, top journals impact factor and citations, and top authors who have published on BIM. The bibliometric analysis was carried out in 2017 using WOS and Scopus databases for the period between (2003-2016). The research findings analysed all articles found on this area according to certain criteria. The results comprised 450 journal articles in BIM in WOS and 904 in Scopus. The results have shown a comparison between WOS and Scopus in terms of research area, publication year, country and authors. Scopus have indexed double journal articles on BIM in this period.

Keywords: BIM, Bibliometric Analysis, Construction Industry, Web of Science, Scopus.

¹ Mustafa, A.H.
Corresponding author, Faculty of Engineering and Industrial Science, Swinburne University of Technology, Melbourne, Victoria, Australia

² Amir, A.
School of Engineering, Department of Mechanical Engineering and Product Design Engineering, Swinburne University of Technology, Melbourne, Victoria, Australia

³ Tayyab, M.
School of Property, Construction and Project Management, RMIT University, Melbourne, Victoria, Australia
1 Introduction

Recently, Building Information Modeling (BIM), which is also called Virtual Prototyping Technology, has rapidly changed the world of the construction industry. BIM is both a process and a technology. The process part enables high level of cooperation and promotes integration of the functions among stakeholders on the construction projects; while, the technology component helps project members to visualize the construction operation of the whole project in a simulated environment to recognize any potential design, construction and operational conflict [1].

A bibliometric analysis has been used in this study through the Web of Science and Scopus databases. The key units of the bibliometric analysis for this paper is to define the countries which are actively involved in BIM research, the best journals that in BIM publication, top Journal Impact factor and citations, and the top authors who published on BIM. This research aims to guide the new researchers who are interested in BIM to select the most relevant BIM research in this domain.

2 Building Information Modeling Concepts

There are many definitions to BIM, the National Building Information Modelling Standards (NBIMS) committee of USA defines BIM as, “a digital representation of physical and functional characteristics of a facility”. Further, Succar [2] defined BIM as “a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle”. From a very general industry point of view, Bazjanac [3] stated; “From a general industry point of view, a BIM is a shared digital representation of a building and its physical and functional characteristics, based on open standards for software interoperability”. Accordingly, the whole project life cycle, from the design, construction, and the operation and mountainous can get benefits from this promoting innovation [4].

A great deal of benefits can be gained when adopting BIM. A study showed the possible benefits of implementing BIM on real projects in Malaysia as following[5-7].:

• Avoid delays in construction
• Avoid construction cost overruns
• Contribute to better quality of the end product
• Minimization of waste
• Resolve fabricator issue
• 3D visualization of project design
• Using BIM will lead to more sustainable communities
• Conflict, interference and collision detection

The Building Information Modeling is now considered to be of having varying dimensions (nD). The idea was started from converting the 2D drawing to the 3D drawing. The element attributes can be added to the 3D model to be more real. The 4D model represents by adding one more dimension which is time to the 3D model. With this facility the project can be virtualized at any time and tested within different scenarios. While the 5D model can be formed by including the cost estimation to the 4D model. Thus, the model is open to include more and more dimensions to
be 6D, 7D and further in order to cover the facilities management and other functions leading to
nD BIM. This new philosophy of building representation brings significance efficiency to the
construction sector. For example, the wall in the BIM environment is not just few lines (as in
CAD), but it is an object that has many properties like; material types, required resources,
construction duration, etc. These properties will help to automate the project in terms of cost and
time and test it in a virtual environment to solve many issues before construction starts. They can
be useful to optimize project schedule and cost efficiently.

3 Research Method

In this research, bibliometric analysis has been adopted as a research method. A bibliometric
analysis is a statistical analysis method to the published publications in certain topic[8]. Moreover,
this kind of analysis leads to useful information for the researchers who are seeking to examine
scientific activities. A bibliometric analysis represents as a guide to the status of research into
certain domain. This study adopted the methodology from Rey-Martí, Ribeiro-Soriano [8]. Web
of Science (WOS) online database and Scopus database have been used in this study, which
consists of scientific research in all disciplines. The key words that been used in this study was
“Building Information Modeling” and limited to the journal article only. The analysis used the top
ranked results instead of all of them to avoid confusion resulted from huge unwanted output.

4 The Key Units of the Bibliometric Analysis

In this research, a bibliometric analysis took place in 2017 using WOS database and Scopus data
base on BIM research for the period between (2003-2016). The bibliometric key units of analysis
used in this research are as follows:

• Language of publication on BIM research
• Areas of knowledge
• Countries where authors have published research on BIM
• Journals in which authors have published research on BIM
• Top Journal Impact Factor and citations
• Authors who have published on BIM
• Comparison between WOS and Scopus output.

5 Bibliometric Analysis Using WOS

5.1 Language in BIM Publications

The bibliometric analysis revealed that some publications have been published in languages other
than English. From the total 450 journal articles, English language publications have a share of
438 journal articles.

5.2 Research Area

In general, BIM has been studied from the perspective of engineering, construction management,
architectural, business etc. The bibliometric analysis has revealed that the top three areas in WOS
contains 347 documents in engineering, 192 construction building technology, and 90 in computer
These figures reveal a clear difference between the number of documents in engineering and the number in other knowledge areas. This finding implies that BIM is a highly relevant topic in the field of engineering. Figure 1 shows the top five most relevant research areas to BIM. It can be seen clearly from Figure 1 that the total number of publication exceeds 450 documents. The reason is that some of the documents can be classified in more than one research area at the same time.

![Figure 1. Number of BIM publications in each area of knowledge](image)

5.3 Countries

In Figure 2 below show the countries involved in publishing BIM research between 2003-2016. The top country to publish BIM research is USA at 172. South Korea ranks second with 84 publications. Moreover, China got the third rank with 61 publications. The figure also shows the other rest 31 countries account 60 articles all together.

![Figure 2. Countries where BIM research has been published](image)

5.4 Top Journals in BIM

It is important for the researchers to know about the top journals that publish on BIM research. Figure 3 shows the journals that have published most research papers on BIM. Automation in Construction has taken the lead by published 108 documents on BIM. Journal of Computing in Civil Engineering got second rank with 32 publications, while Advanced Engineering Information ranked third with 30 publications.
### 5.5 Top Journal Impact Factor and citations

As mentioned previously, the Automation in Construction was the most published journal in BIM. Consequently, this journal was selected to conduct more significant analysis. The impact factor and the total citation of this journal were analysed through WOS between 2002-2015 as shown in Figure 4 and Figure 5, taking into account that the data is not available yet for year 2016. In general, the analysis showed that the impact factor increased consistently with the time except three jumps in 2006, 2008 and 2009 respectively. On the other hand, the total citations were increased rapidly during the same period.
5.6 Authors

In terms of authors who have published on BIM between 2003-2016, the bibliometric analysis as illustrated in Figure 6, shows that Sacks, R has published 21 research papers, the highest number of publication on BIM in that period. We can see that Eastman got the second rank in this regard with 15 publications. Lee, G and Teizer, J. got the third rank with 13 publications for each. The rest of the top 15 authors are listed in the Figure 6 below.

![Figure 6. Top 15 authors who published in BIM](image)

5.7 Publication Years

The search criteria has been set to include any year between 2003-2016. Figure 7 Shows the number of publications in each year. In year 2016, the number of publication is the highest with 129 publications. In general, the figures show the increase in number of publication in BIM with the time, especially between 2013-2016.

![Figure 7. Publication year](image)

6 Bibliometric Analysis Using Scopus

The Scopus indexed 904 journal articles for the period 2003-2106. The following Figures show the analysis results for Scopus;
6.1 Research area

BIM has been studied from the perspective of engineering, computer science, business, etc. The bibliometric analysis has revealed that the top three areas in Scopus contain 693 documents in engineering, 237 computer science, and 156 in business and management. This finding implies that BIM is a highly relevant topic in the field of engineering. Figure 8 shows the top five most relevant research areas to BIM.

![Figure 8. Number of BIM publications in each area of knowledge](image)

6.2 Top Journals in BIM

As mentioned previously, it is important for the researchers to know about the top journals that publish on BIM research. Figure 9 shows the journals that have published most research papers on BIM. Automation in Construction has the highest publication of 133 journal articles on BIM. Journal of Information Technology in Construction got second rank with 38 publications, while Journal of Construction Engineering and Management ranked third with 33 publications.

![Figure 9. Journals that have published research on BIM](image)

6.3 Authors

Scopus has shown the top authors who have published on BIM between 2003-2016, the bibliometric analysis as illustrated in Figure 10, shows that Wang, X has published 22 journal articles, the highest number of publication on BIM in that period. We can see that Sacks, R got the second rank in this regard with 19 publications. Issa, R.R.A got the third rank with 13 publications for each. The rest of the top 15 authors are listed in the Figure 9 below.
6.4 Countries

Figure 11 below shows the countries involved in publishing BIM research between 2003-2016. The top country to publish BIM research is USA at 248. China ranks second with 115 publications. Moreover, England got the third rank with 100 publications. The figure also shows the other rest countries.

6.5 Publication Years

Figure 12 Shows the number of publications in each year. In year 2016, the number of publication is the highest with 229 publications. In general, the figures show the increase in number of publication in BIM with the time, especially between 2011-2016.
A comparison between WOS and Scopus in terms of research area, publication year, country and authors shows that Scopus have indexed double journal articles on BIM in this period. However, the popularity of the WOS is because the searching features that embedded in it, which make the researcher more comfortable to use it.

7 Conclusion

The bibliometric study on BIM found out that BIM as a research area is consistently growing. There were 450 BIM journal article gathered from the WOS database between years 2003-2016 and 904 in Scopus. The bibliometric analysis showed that the leading country of BIM research is the United States of America in both databases. Moreover, the journal that has published most of the BIM research is Automation in construction. The analysis presented in this study is helpful as a general guide to researchers and doctoral students who are carrying out research in BIM. The recommendations for future work are performing periodic update of this research after the end of new year, and performing content analysis of publications taken into account a suitable classification method.

References

5. Azhar, S., et al. Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction projects. in Proc., First International Conference on
Construction in Developing Countries. 2008.


Factors Affecting Informal Housing Price Discounts At City Level In China

Shen, Lu* and Chau, K.W.

Abstract: Informal housing are housing units without legal title. Despite the lack of legal title, there is a huge black market for informal housing in China. While legal title is usually the most effective means of protecting owner's rights over their properties, there are other means of ensuring some degrees of owner's confidence in tenure security, which is essential for the allocation of informal housing units using the price mechanism. We propose that private property rights is not a discrete concept but a continuum that depends on people's confidence in the intuitions that enforce that these rights. In the absence of legal titles, other institutions such as culture, social norms, illegal violence etc, will emerge to boost people's confidence. If the emerged institutions allow the use of the price mechanism, we can observe how the assets without legal titles are transacted and priced. If the same assets with and without titles are transacted in the market, assets without legal titles should be transacted at a discount1 ("Discount") to those with legal titles. The Discount can be viewed as the value of a legal title and is believed to be analogous to the institutional costs of informal housing. This study proposes a theoretical framework to explain the why the value of legal titles in different places vary despite the same legal institution. In addition, it also describes the situation where formal and informal institutions are in conflict and how their roles affect the price discounts observed.

Keywords: Informal housing; Property rights; China.

1* Shen, Lu.
Corresponding author, Ronald Coase Centre for Property Rights Research, HKUrbanLab., The University of Hong Kong, Hong Kong SAR
E-mail: shenlu@hku.hk

2 Chau, K.W.
Ronald Coase Centre for Property Rights Research, HKUrbanLab., The University of Hong Kong, Hong Kong SAR.

3 Assuming that the legal title gives asset owners the highest level of confidence.
1 Introduction


1.1 Dual land tenure system

State owned land and collectively owned land coexist in China (Tian, 2008). However, compared with the property rights the state has over state-owned land, the collective doesn’t have the complete property rights of collectively owned land (Tian, 2008). Article 63 of *The Law of Land Administration of the People’s Republic of China* regulates that the land use rights cannot be leased, transferred or rented for non-agricultural construction except in the case of legal transfer of the land that conforms to the general plan for the utilization of land and legally obtained by enterprises due to bankruptcy or acquisition. In addition, article 2 of *the Circular of the General Office of the State Council on Strictly Implementing Laws and Policies on Rural Collective Construction Land* states clearly that collectively owned land can only be allocated to members of the particular village collective. Article 2 of the *Circular of the General Office of the State Council on Strengthening Management of Transfer of Land and Strictly Banning Speculative Land Dealing* states that farmers’ residences cannot be sold to urban residents, and urban residents should not be approved to occupy land collectively owned by farmers to build residences. Therefore, the property rights enjoyed by the village collectives are incomplete because (1) the rights to transfer can only be used among village collective members, or village committees and enterprises; (2) the rights to generate income can only be exercised for rural use or for the use of collective enterprises; (3) collectively owned land cannot be mortgaged; (4) the lease term of collectively owned land is much shorter than state owned land (Tian, 2008).

1.2 Informal housing

Informal housing in China refers to housing units constructed on collectively owned land but sold to purchasers outside of the specific village collective (CRECC, 2012). Formal housing units, on the other hand, usually refer to housing units that are constructed on state owned land. Different from most informal housing in foreign countries, informal housing in China can be of very different nature from worsened urban villages to well-organized high-quality gated communities (Zhao, 2017).

The incomplete property rights of collectively owned land lead to the void of legal rights in informal housing. Although these legal rights are absent in informal housing, in practice, constructions and transactions of informal housing still occur continuously in various cities. Though there is no official statistics published on the exact constructed area or on the transaction volume of informal housing, some unofficial reports have revealed the huge size of informal housing and claimed that the constructed area of informal housing has reached 6 billion square meters (First Financial Daily, 2012), which has accounted for around 20% of the total housing market in China (Beijing Youth Daily). Sun and Wang (2010) reported that till 2007, informal housing has reached 6.4 billion square meters, which accounted for around 17% of total constructed area of all the housing based on the statistics given in Guo and Cai (2009) that over 20% of all the housing in rural areas are informal housing. Zhao (2017)
reported that from 2006 to 2010, 4 million square meter informal housing was established in Beijing, despite the strict controls from the government. According to the survey done by *Urban Planning, Land & Resources Commission of Shenzhen Municipality* and the report from Guo and Cai (2009), the informal housing has accounted for around 49% of all the housing in Shenzhen till 2009. In Harbin, the government has identified 144 informal housing buildings, the constructed area of which accounted for around 10% of the constructed area of all the residential units in the city (CRECC, 2012). The percentage of informal housing in Taiyuan and Chengdu are respectively over 20% and over 30% (CRECC, 2012). The figure reached around 18% to 20% of the whole market in Beijing and between 25% to 30% in Xi’an. (Guo and Cai, 2009; F et al, 2007; CRECC, 2012).

### 1.3 Property rights of informal housing

Previous studies done in other countries have also found that lack of legal titles does not stop the construction or transaction of informal housing units (Gilbert, 2002, Varley, 2002, Musembi, 2007). The illegality merely affects the prices rather than market functioning (Gilbert, 2002). However it is found that informal sources of property rights may be able to confer many of the same advantages just as formal ones (Lanjouw and Levy, 1998). The enforcements of informal rights to land can be based on informal approaches such as conventions or self-help (Razzaz, 1993), community information, sanction capabilities or even private protection agents (Lanjouw and Levy, 2002).

Although in China, the law prohibits informal housing buyers from exercising the legal rights. However, the void of private property rights are filled by the emergence of other rights (Cheung, 1998). To facilitate the transactions of informal housing in the market, informal institutions such as village committees, trust, witness, reputation, etc. emerge to recognize and enforce the informal rights to transfer, to generate income and to exclude others. With informal rights and institutions, informal housing can be traded in reality and therefore parts of its intrinsic value are recaptured and reflected in the market price.

### 1.4 Price discounts of informal housing

Although informal rights and institutions emerge to partially replace the role of formal ones, there still exist significant discounts. Informal housing is usually priced at only 20% to 60% of the formal housing with similar physical attributes (CRECC, 2012). With the remaining 40% to 80% of rents recaptured by informal institutions, the discounted price deserves more study on why and by what way the value disappears. Furthermore, according to the rough statistics from China Real Estate Chamber of Commerce, the price discounts of informal housing compared with formal housing of similar attributes in different cities are various from 40% to 80% (CRECC, 2012). (see Table 1) Wu et al. (2013) also reported that the scales of informal housing and the sources of informality across cities in China are different. Therefore this study aims to study what factors contribute to the price discounts of informal housing and why price discounts across cities are different.

## 2 What account for the price discounts?

Jimenez (1984) did an economic analysis on illegal land squatting and argued that holding all other housing attributes the same, the price difference represents the premium related to the tenure status. Later on, Friedman et al. (1988) interpreted the price differences as the reflection of market determined risk premium. Though using different concepts, Friedman et al. (1988) and Jimenez (1985)
both believed that the perceptions of tenure security affect this premium. Adding to this argument, Lanjouw and Levy (2002) found that the transferability of informal housing also has great impacts on discounts because great transaction uncertainty can increase the risk faced by the households and transaction costs (Lanjouw and Levy, 2002).

The concept of tenure security itself has been in debates (Arnot et al., 2011). A key distinction in all these definitions is whether tenure security is an objective standard (using ‘legal titles’ and ‘probability’) or subjective feeling (using ‘uncertainty’, ‘confidence’ and ‘perceived probability’). Instead of giving ‘tenure security’ a conclusive and uniformly applied definition, Varley (2002) proposed to distinguished ‘de facto tenure security’ from ‘legal tenure security’ and found that actual tenure security can be achieved even without legal titles. Informal property rights emerge to effectively replace the roles of formal ones and lead to ‘de facto tenure security’ (Lanjouw and Levy, 2002).

One example is that eviction can be prevented through administrative or political strategies instead of legal titles and therefore result in a de facto recognition of rights (Durand-Lasserve and Selod, 2009). Different from ‘de facto tenure security’ and ‘legal tenure security’, ‘perceived tenure security’ is a subjective expectation of enforcements of rights, community organization and cohesion, the length of residence and so on (Van Gelder, 2010). The concept was adopted in discussing informality (Jimenez, 1984, Friedman et al., 1988, Lanjouw and Levy, 1998, Razzaz, 1993, Strassmann, 1984, Lanjouw and Levy, 2002, Payne, 2004, Deininger et al., 2011, Burnod et al., 2012, Wu et al., 2013), because it is found that the impact of a legal title is much less than the impact of the perceptions of past and present government policies, especially those related with forced evictions (Payne, 2004, Razzaz, 1993, Strassmann, 1984). Many studies showed that the legality does increase people’s perceptions of the tenure security in most cases (Wu et al., 2013, Payne, 2004, Burnod et al., 2012, Deininger et al., 2011). However, compared with the legal titles, most residents rely more on indicators such as infrastructural improvement and tax and fees collections to assess the government’s attitudes and perceive the security of tenure (Varley, 2002). Since it is the perceptions of the buyers that can directly affect households’ economic choices (Ma et al., 2015), the price discounts can be better explained by perceived tenure security.

Many factors are proposed by previous studies that are considered able to affect tenure security perceptions, including the size of informal housing, varying degrees of community organization (Jimenez, 1985), community age (Lanjouw and Levy, 2002, Gilbert, 2002), community protection from eviction (Lanjouw and Levy, 2002), the number of squatters in the community (Lanjouw and Levy, 2002), availability of services (Gilbert, 2002), sanitation and water facilities, building heights, building materials, dwelling age, neighborhood types (Friedman et al., 1988), the location of the land, the alternative uses of the land, the nature of the government (Gilbert, 2002), the presence of male in the household, the length of residency in the estate (Burnod et al., 2012), whether major investments were made (Fass, 1990, Razzaz, 1993, Hirschman, 2013) and even whether the community organizer is paid (Lanjouw and Levy, 2002).

Lanjouw and Levy (2002) and Durand-Lasserve and Selod (2009) proposed that other than the increase in tenure security premium, the price differentials of informal housing can be also contributed to by the decrease in transferability (Lanjouw and Levy, 2002, Durand-Lasserve and Selod, 2009). In the study of Lanjouw and Levy (2002), factors including reputation and signed ownership documents are believed to be able to increase the transferability by refraining households from violating the contracts. Factors such as community age and dispute settlement means can also indicate the expected transferability (Lanjouw and Levy, 2002).
In this study, it is argued that all these factors can be classified into two categories, respectively institutions and confidence in institutions.

One important implication given by Coase (1960) is that when transaction costs exist, institutions matter. Institutions are ‘rules of game in a society’ or constraints devised by human beings to ‘shape human interaction’ and reduce uncertainty by defining the set of choices people have. Institutions include not only the formal and informal rules but also the type and effectiveness of enforcement (North, 1990).

Among all the factors mentioned in the previous literature proved to affect the price differentials of informal housing, legal rules are apparently formal institutions that lay down significant parts of the ‘rules of game’. Factors including culture, customs, religions (Durand-Lasserve and Selod, 2009), informal certification and witnesses (Lanjouw and Levy, 2002), family networks, personal relations and locally based informal dispute resolution processes (Musembi, 2007) are informal institutions that also affect the rules of game. Changes in these institutions can lead to the variations in the rules and thus affect people’s perceived tenure security and transferability.

Besides, some factors that seem to be irrelevant to the rules can also affect price discounts. These factors mentioned in previous studies include infrastructural improvements, sanitation and water facilities, building heights, building materials, dwelling age, neighborhood types, neighborhood size, tax or fee collections, the presence of a ‘paid boss’, the nature of government, the location and alternative use of the land, the presence of male in the household, the length of residency, the major investment (Varley, 2002, Friedman et al., 1988, Lanjouw and Levy, 2002, Jimenez, 1985, Gilbert, 2002, Burnod et al., 2012, Fass, 1990, Razzaz, 1993, Hirschman, 2013). In this study, these factors are considered factors affecting people’s confidence in institutions. Confidence in institutions represents people’s subjective judgements on the functioning of institutions. As mentioned by North (1990), the costliness of ascertaining violations and the severity of punishments are essential to the functioning of institutions. Therefore, confidence in institutions can be viewed as friction affecting the functionality of institutions. With exactly the same institutions, when the confidence in institutions favoring informal housing buyers is lower, the perceived tenure security and transferability will be lower.

It is therefore argued that the perceptions of tenure security and transferability are affected by both institutions and confidence in institutions. However, price discounts of informal housing cannot be completely accounted for only by the perceived tenure security and transferability.

There exist discrepancies towards the premium value among households when facing similar risks due to various attitudes towards risks (Jimenez, 1984). On the other hand, Lanjouw and Levy (2002) also found that the household characteristics can change the risk of eviction due to different levels of access to other mechanisms of property right enforcements, e.g. through bribes, more information, greater media attention, etc. As a result, provided with the same perceived tenure security and transferability, the value of a legal title can still be different due to various valuation for tenure security and transferability.

3 Analysis

In this study, it is argued that both the perceptions of tenure security and transferability and the valuation of tenure security and transferability affect the price discounts of informal housing in different estates or even different cities. Many factors are identified to be able to affect either the perceptions or the valuation and hence have impacts on the price differentials observed. Given that
both the legal rules and informal institutions including witnesses, informal registration, etc. to informal housing uniform to all the cities, factors causing the differences in price discounts either affect people’s confidence in institutions or affect people’s valuation on tenure security and transferability.

This paper will discuss four factors among all these mentioned factors as follows.

3.1 Perceived tenure security & transferability

**Hypothesis 1**

Holding all other factors constant, informal housing price discount decreases when more court judgements are in favour of informal housing buyers.

Due to the ambiguity in property rights issue, many disputes over the validity of sales contract between villagers and subsequent buyers in many cases end up in the courts. Since civil law system is adopted in China, court decisions do not have impacts on the legal institution itself. The Chinese courts’ decisions on the disputes between first hand sellers of informal housing and the buyers will affect potential informal housing buyers’ perceptions on how well their property rights are protected (the perceived tenure security) despite the Chinese legal system does not need to refer to precedence cases. When courts’ decision are more in favour of the first hand sellers, buyers would perceive a higher risk and therefore a larger discount can be led to. The court decisions will be classified into support, refuse and no decision. Weightings will be assigned to the court decisions as well to take into consideration that courts of different hierarchies may have various impacts on consumers’ behaviour.

**Hypothesis 2**

Holding all other factors constant, informal housing price discount increase with stricter enforcement of existing rules against existing informal housing.

Now in China, substantial administrative and economic power have been decentralized to local governments from the central government, which promotes the local incentives to and responsibilities for economic developments (Ren, 2017, Lin et al., 2006). Therefore it is within the local city government’s autonomy to decide whether any enforcements will be taken against the developed estates. Stricter enforcement of existing rules against developed informal housing will weaken the informal housing buyer’s confidence of their rights being protected by informal institutions and affect negatively the perceived tenure security the purchasers have on informal housing and therefore increase the informal housing price discount. In this study, enforcements against developed estates only refer to the eviction of developed informal housing estates. Both whether there is any eviction and the number of evictions are used to describe the impacts of enforcements of formal institutions.

Wu et al. (2013) described three cases of informal housing (all high-density, low-quality and self-built housing) respectively in Beijing, Shanghai and Guangzhou and found that the informality sources and the redevelopment approaches the government adopted are completely different in these cities. In Shanghai, the government capacity is stronger and therefore the bargaining power of villagers is weaker in redevelopment process, as opposed to the situation in Guangzhou (Wu et al., 2013). Wu et al. (2013) recognized the significant diversity and flexibility in the applications of the law in different local circumstances.
3.2 Valuation of tenure security & transferability

**Hypothesis 3**

Holding all other factors constant, the informal housing price discount decreases as income polarization increases.

People’s valuation of properties with incomplete private property rights (informal housing) increases with the cost they need for pay for the alternative (formal housing). Similarly, people’s own premium assigned to risk and tenure insecurity can change with the costs for the alternative. When the cost of the latter increases, the valuation of informal housing will increase and the premium to risk and discounts for tenure insecurity may drop. Increase in income polarization implies larger proportion of lower income households. This will increase the demand for low-end formal housing and informal housing and it is assumed that lower income people have higher tolerance to risks and tenure insecurity and lower premium to risks.

A major function of informal housing is to provide settlements to low-income group (UN-Habitat, 2004, AlSayyad, 2004). Sun and Wang (2010) found that as prices of formal housing go up, the probability of purchasing informal housing increases as informal housing is becoming an important approach to solve the housing demands. It is also found that higher income groups are more likely to purchase formal housing (Sun and Wang, 2010). Therefore in this study, it is proposed that the price discounts will be negatively correlated with income polarization.

**Hypothesis 4**

Holding all other factors constant, the informal housing price discount decreases when there is restriction on formal housing purchases.

With the decentralization proceeding, local governments start to have great autonomy in making its own housing and urban policies (Ren, 2017). In certain cities, migrants are not allowed to purchase formal housing unless certain strict requirements are met such as paying taxes for consecutively 60 months. Zhao (2017) classified such policy as institutional discrimination against rural people which also contributed to the emergence of informal housing communities. In this study, it is proposed that the prohibitions on the formal housing purchase will reduce people’s valuation on tenure security and therefore price discounts may shrink.

4 Conclusion

Informal housing has widely existed in developing countries and the measures to take towards informal housing have also been long under debate. On the one hand, the economic and social benefits to marginalised groups shouldn’t be neglected (Pruijt, 2013). After all, informal economy is considered spontaneous responses to the incapacity of the government to meet the basic needs of certain groups of people (De Soto, 1989). Where the state is unable to deal with the hukou restriction and provide sufficient formal affordable housing, informal housing in fact takes up important roles in both satisfying the housing demands from migrant workers and providing reasonable income to villagers (Tao and Wang, 2011). On the other hand, the existence of informal housing destroyed the credibility of formal property rights. The economic performance and investment potentials of formal housing
market will be negatively affected. Such complexity led to the tolerance of ambiguity in property rights and different market performances of informal housing can be observed and studied.

This study is an ongoing research which aims to discuss why price discounts of informal housing in different cities are different given that the law against informal housing is nationwide. In other words, this study intends to discuss why the value of legal titles varies. It proposed a theoretical framework to explain the value of formal title that argues not only institutions but also people’s confidence in institutions matter. Different contexts of cities will alter people confidence in institutions as well as how much people value formal title.
References


Exploring The Planning Orientation of Different Types of Characteristic Towns: Based on The Perspective of Population, Industry and Land Integration

Yun Hang1  Yuzhe Wu2  and Sheng Zheng3

Abstract: Since the Ministry of Housing announced China's first batch of 127 characteristic towns, the characteristic town has become a research hotspot. In this paper, 127 characteristic towns are used as the research object, the clustering analysis of 127 characteristic towns is carried out from the perspective of population size and distance, and five different types of characteristic towns are produced. The first type is the towns with population size greater than 100000, the second type is the towns with population size greater than 50000 and less than 100000 and distance less than 25km, then comes the third one, with population size greater than 50000 and less than 100000 and distance greater than 25km, and the last two types, one with population size less than 50000 and distance less than 25km, and another with population size less than 50000 and distance greater than 25km. For towns with the population of more than 100,000, the most important thing is to do a good job of population settled, to promote industrial stability so that the planning is efficiency, for the towns with population size of more than 50,000 and less than 100,000, the focus is to promote the town's own development, mainly giving land policy support, and making population and industrial gathering, and for towns with population size of 50,000, the most important is the accumulation of industrial development and the problem of population absorption Characteristic towns should choose the development focus combined with their own characteristics and local conditions, and then other factors of planning and construction as supports.

Keywords: characteristic towns; clustering analysis; agglomeration index; planning and positioning recommendations; population - industry - land integration policy

1 Yun Hang
Corresponding author, School of Public Affairs, Zhejiang University, China
Email: monkey1896@126.com
2 Yuzhe Wu
Department of Land Management, Zhejiang University, China
Email: wuyuzhe@zju.edu.cn
3 Sheng Zheng
Department of Land Management, Zhejiang University, China
Email: shengzheng@zju.edu.cn
1 Introduction

As we all know, China is now taking the road of new urbanization, urbanization is rapidly advancing, and this is a big and even the biggest source of power for China's economic growth at the present stage. In July 2016, the Ministry of housing, the national development and Reform Commission and the Ministry of Finance jointly issued the "notice" on the characteristic towns development work, put forward that before 2020, they will cultivate about 1000 characteristic towns, which will lead the construction of small towns nationwide. October, the Ministry of housing officially announced the first batch of 127 Chinese characteristic towns.

Since the Ministry of housing announced the first batch of 127 characteristic towns, the characteristic town has undoubtedly become a hot spot of research. Many people think that the characteristic towns can give full play to the role of the market, promote the development of small towns, ease the function of big city, and can promote the development of rural areas. However, there are still many contradictions in the construction of the characteristic towns, such as industry, land, population and so on. Therefore, it is very important to promote the construction of characteristic towns from the point of view of population, land and industry, and to promote the healthy development of characteristic towns. Under this background, this paper aims to divide the 127 characteristic towns into several types, and study on the characteristics of different types of towns to explore the reasonable construction of the characteristic towns, the rational planning methods and the future development path, finally in view of different type of characteristic towns, provide the corresponding land, population and industrial supporting policies.

2 Literature review

The characteristic town is development space platform with definite industrial orientation, cultural connotation, tourism or other community functions, and is an important content of "multi rules and one" in each city and county. The planning and construction of the characteristic towns cannot do without the town population and industrial agglomeration, land supporting and other aspects of the content. I read the relevant literature about population, industry and land planning and development of small towns, as the theoretical basis for the following writing.

The scale of small towns involves the population scale, industry scale and land use scale, and the planning and construction of these areas are very important for small towns. As for population, the population scale of small towns is one of the important factors in the development of small towns, scholars in China have already proposed that the essential goal of building small towns is to promote the agglomeration of the largest population to promote the development of the national economy [1]. On the contrary, small size of population will lead to difficult to improve the urban functions. Foreign related studies have found that the urban population size should reach at least 30 thousand, then the allocation of infrastructure and public service system can reach a relatively economic and reasonable level [2]. Many experts has calculated the rational population scale of small town. According to the specific situation of the construction of small towns in China, combined with the results of a large number of expert research, the Ministry of housing had made the small town township appropriate population size of 3-5 million people [3]. As for industry, the industry is the foundation of the survival and development of small towns. A small town constructed under the direction of industrial economy, will lead to development of transportation, education, tourism and other infrastructure, public services and other industries in the whole town [4][5]. In order to
coordinate the development of cities and regions, China should pay full attention to the significant influence of industrial agglomeration and industrial clusters to productivity, actively cultivate the industrial clusters with local characteristics [6]. In terms of land, land is an important carrier for the development of small towns. The land use of the characteristic town has some problems, such as unreasonable land use structure and difficult to guarantee the new land use, so on [7]. Small towns in China should speed up the circulation of rural land, strengthen the construction of infrastructure, and should pay attention to the coordination of the relationship between economic development and ecological environment, to promote the sustainable development of small towns. In addition, we must constantly optimize the allocation of land resources [8].

In short, planning of characteristic towns is not a simple unilateral planning positioning. With obvious characteristics of diversity and combination, it is the key content of this article to combine the planning positioning scheme of small towns with the actual situation of characteristic towns, adjust the planning position according to local conditions.

3 Characteristics of different types of Characteristic Towns

3.1 Cluster analysis of Characteristic Towns

3.1.1 Select clustering index

This paper aims to classify the China's first 127 characteristic towns according to certain indexes, and draw several different types. Choosing appropriate classification index is a very important step in this study, and is also the basis for further research. In the article "World Development Report 2009: Reshaping world economic geography", the author puts forward three characteristics of new economic geography: density, distance and division [9]. This paper selects the agglomeration effect of the characteristic towns and the distance as the classification index. The agglomeration effect is reflected by the population size, while Distance is the distance from the upper administrative area.

3.1.2 Threshold determination

In this paper, according to China's national conditions, 50 thousand people are chosen as the threshold of population size, and 100 thousand people are used as the population threshold of small towns that can better radiate to rural areas. Choose half an hour's drive, that is, 25 kilometers as distance threshold, distance data comes from Google map online ranging.

3.1.3 Cluster analysis results

Based on the population threshold and distance threshold selected above, the article collects data of 127 characteristic towns and sorts them. The classification results are shown below (see Table 1).
Table 1. Cluster analysis results

<table>
<thead>
<tr>
<th>Population Distance</th>
<th>≤50 thousand</th>
<th>50 thousand–100 thousand</th>
<th>≥100 thousand</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤25 kilometers</td>
<td>Xiao Tangshan town and the other 56 towns</td>
<td>An Feng town and the other 16 towns</td>
<td>Ding Shu town and the other 13 towns</td>
</tr>
<tr>
<td>&gt;25 kilometers</td>
<td>Jin Chuan town and the other 25 towns</td>
<td>Zhong Tang town and the other 10 towns</td>
<td>Yang Kou town and Nan Ba town</td>
</tr>
</tbody>
</table>

As characteristic towns with a population of more than 100 thousand already have the gathering function, the distance is no longer a constraint condition. So we can combine the fifth categories with the sixth categories, and finally get five types of characteristic towns.

The first type is the towns with population size greater than 100000, the second type is the towns with population size greater than 50000 and less than 100000 and distance less than 25km, then comes the third one, with population size greater than 50000 and less than 100000 and distance greater than 25km, and the last two types, one with population size less than 50000 and distance less than 25km, and another with population size less than 50000 and distance greater than 25km.

3.2 Characteristic analysis of different types of Characteristic Towns

In this paper, a typical example is selected from each type of characteristic town, and the detailed analysis is shown in the following table (see Table 2)

Table 2. Characteristics and existing problems of different types of typical characteristic towns

<table>
<thead>
<tr>
<th>Town Comparison project</th>
<th>Wu Quan town</th>
<th>Gu Tian town</th>
<th>Zhu Jiajiao town</th>
<th>Fen Shui town</th>
<th>Lu Zhi town</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>22 thousand and 200 people</td>
<td>18 thousand and 800 people</td>
<td>59 thousand and 800 people</td>
<td>78 thousand people</td>
<td>200 thousand people</td>
</tr>
<tr>
<td>Distance</td>
<td>7.82 kilometers</td>
<td>45.06 kilometers</td>
<td>9.04 kilometers</td>
<td>27.94 kilometers</td>
<td>22 kilometers</td>
</tr>
<tr>
<td>Industrial characteristics</td>
<td>Modern agriculture, ecological tourism</td>
<td>&quot;Red +N&quot;</td>
<td>&quot;Cultural Creation +fund&quot;; tourism</td>
<td>Pens, characteristic agriculture</td>
<td>Mold, tourism, ecological leisure</td>
</tr>
<tr>
<td>Main problems</td>
<td>Small population size</td>
<td>The population size is small, and far from the agglomeration area</td>
<td>Insufficient land supply</td>
<td>Land supply, and far from the agglomeration area</td>
<td>Sources of funds, population and industrial stability</td>
</tr>
</tbody>
</table>

From the above table, we can summarize the characteristics of each type of characteristic town.

As for towns with population size less than 50000 and distance less than 25km, the population is small, but infrastructure, including education, medical and other resources, can be helped by a higher level of agglomeration. Therefore, we should focus on the attraction of the population and the introduction of talents, and strive to improve the population size of the small towns to meet the small town population scale requirements. For this kind of characteristic towns, population should
be introduced as a key problem to be solved, the industry and land policy support.

As for towns with population size less than 50000 and distance greater than 25km, such small towns are the most difficult to plan, planning is likely to be inefficient. For such characteristic towns, the infrastructure also needs to rely on their own development, therefore, they not only need to attract people, at the same time should try to reduce the distance from the upper level agglomeration area, and the industrial policy and land policy should also be matched at the same time.

As for towns with population size greater than 50000 and less than 100000 and distance less than 25km, the population is large in scale and has been able to reach the size of a small town population. This type of towns should pay attention to land supporting problems, give appropriate land policy to meet the needs of the development of industrial upgrading. At the same time pay attention to the town ecological and livable construction, so that the industry can continue to develop and upgrade, to continue to attract the inflow of population.

As for towns with population size greater than 50000 and less than 100000 and distance greater than 25km. In addition to the stability of population and industry, the characteristic towns need to build infrastructure and public services, land demand in this area should be included in the land supporting policies. In addition, the distance between the upper and lower concentration areas should be shortened.

As for towns with population size greater than 100000, These characteristic towns can radiate to rural areas, drive the economic development of rural areas and the urbanization of rural population, and promote the process of urbanization in china. Such towns should promote the population settled, improve the efficiency of land use and the construction efficiency.

Each kind of characteristic towns has its own characteristics and development problems, can not only rely on experience to plan, but should also make local planning and construction proposals for different types of characteristic towns.

4 Planning positioning of different types of Characteristic Towns

4.1 Planning orientation of characteristic towns with population greater than 100 thousand

For this type of characteristic towns, its positioning should be capable of stable development, have radiating effect on the countryside and can continue to strengthen this role. For such towns, we should speed up the reform of the household registration system and promote the settlement of the population in the small towns. At the same time, the rural population can be appropriately relaxed and settled, and the housing security for the population will be improved. For young talents, we can create some excellent innovative atmosphere and innovation platform for them, and have some talent introduction measures to attract the influx of talent. At the same time, the rural population can be appropriately relaxed and settled, and the housing security for the population will be improved. For young talents, we can create some excellent innovative atmosphere and innovation platform for them, and have some talent introduction measures to attract the influx of talent.

The following measures can promote population settled: 1) First of all, to speed up the reform of the household registration system, we can relax the town's population settled conditions; 2) Ensure employment and solve the worries of rural population settling in the small town. On the one hand, we should train the rural population; on the other hand, the government should provide sufficient jobs; 3) To speed up the construction of infrastructure and public services, establish and improve the social security system, and build livable town; 4) To create a friendly atmosphere of life, enhance
people's sense of identity and belonging, increase their happiness in the town. Strengthen the cultural construction of the town, organize various cultural and recreational activities, so that settled population can participate in the activities, which can promote its integration with the town.

4.2 Planning orientation of characteristic towns with population size greater than 50000 and less than 100000

For this type of characteristic towns, its positioning should be able to get its own development, improve population and industry agglomeration, better land policies are needed. For those towns within 25 kilometers from the upper one, mainly to provide land policy supporting, in order to attract industrial agglomeration in small towns, improve the town's livable environment, thereby attracting the inflow of population. The following land measures can improve the intensive and economical use of land: 1) The land should be scientifically and rationally planned to optimize the land and space layout of the town; 2) To promote the circulation of rural land; 3) To actively revitalize the stock of inefficient land use, fully excavate the potential of land exploitation and utilization; 4) The land layout of the town can be divided into areas, such as industrial agglomeration area, commercial residential area, agricultural development area and leisure tourism area, and so on.

If the land policy can meet the development needs of the industry, through the establishment of industrial parks, we can on the one hand, promote the development of the industry agglomeration, on the other hand, the scattered industries can be clustered together to maximize the efficiency of land use. And the practice of industrial parks can make the town's industrial chain more perfect, to meet the complementary advantages of enterprises, And also easier to attract outstanding enterprises to landing here, expanding the size of small town industrial agglomeration.

And for those towns more than 25 kilometers from the upper one, the planning orientation is similar to the former, the difference is that the planning of such characteristic towns needs to take full account of the improvement of traffic conditions. Attention should be paid to the integration of land use and transportation construction.

4.3 Planning orientation of characteristic towns with population size less than 50000

The most serious problem of this kind of characteristic towns is population scale and industry problem. It is necessary to emphasize the introduction of industry and the development of industry agglomeration. At the same time, it can provide enough attraction for the introduction of population in other aspects. In the aspect of industry, the following points can expand the industrial agglomeration influence: 1) should take the leading features of the industrial development on the theme, from the long-term vision to choose the leading industry; 2) introduce some emerging industrial service industry to promote the diversification of industrial structure; 3) To speed up the construction of industrial parks, to form a good platform for industrial agglomeration; 4) The government should provide support for the development of the industry, can provide financial and tax concessions, in addition, the government should broaden the financing channels; 5) strengthen the construction of small town industrial talent team, enhance the technological level of the industry.

But for those towns more than 25 kilometers from the upper one, infrastructure and public services should also be considered, planning is very difficult. This type of towns is small towns for survival and development, planning is likely to be inefficient, multiple considerations are needed.

5 Conclusion and discussion
In this paper, cluster analysis is conducted on 127 Characteristic Towns. All the characteristic towns are divided into 5 types, and the planning and location analysis of these 5 types of characteristic towns are carried out, and suggestions for population, industry and land in the planning and construction of characteristic towns are obtained. Some characteristic towns need to optimize the allocation of land, some need to attract population agglomeration, some need to promote industrial upgrading and transformation. Different types of characteristic towns have different planning positions, and the land, population and industry allocation should be carried out according to the focus of the planning orientation, and the construction of characteristic towns should be carried out according to local conditions.

In the classification we found that several small towns are special, and they mostly belong to the western region. Taking into account the differences in the economic base of the eastern and Western regions, selecting the same clustering criteria cannot articulate different types of characteristic Towns, we believe that each type of characteristic towns should be refined and classified, and the differential planning positioning of the characteristic towns in the western regions may be more accurate to describe the different characteristics of the characteristic towns.

Hope to be able to more accurately classify the characteristic towns, take into account the differences between the eastern and western regions, and make a deeper and more detailed analysis of the characteristic towns that are most difficult to plan.

6 Acknowledgements

The research is supported by the National Natural Science Foundation of China (No. 71373231).

References

GREENHOUSE GAS EMISSION MONITORING OF PREFABRICATED COMPONENT MANUFACTURING: A CYBER-PHYSICAL SYSTEM APPROACH

Tao, Xingyu¹, Mao Chao²*, Xie Fangyun³, Liu Guiwen⁴

Abstract: The construction sector is one of the main contributors of greenhouse gas (GHG) emissions. Previous studies have focused on the calculation and analysis of the carbon footprint of construction activities. However, few studies have reported on real-time monitoring systems for GHG emissions. Cyber-physical system (CPS), an information technology-based method, has been identified as a potential solution to address problems in the construction industry. This paper proposes a CPS-based system framework that enables supervisors to monitor and control GHG emissions in real-time by considering the manufacturing process of prefabricated components as a case study. To develop a CPS-based GHG emission monitoring system, the emission sources are first identified. Second, the technologies essential for the system are introduced. Finally, the framework of the GHG emission monitoring system is designed comprising four parts: (1) acquiring carbon-related data, (2) analyzing data in a virtual model based on Building Information Modeling, (3) setting the warning threshold, and (4) controlling the GHG emissions through mobile devices.

Keywords: Cyber-physical system, greenhouse gas emission, prefabricated components

¹ Tao Xingyu
School of Construction Management and Real Estate, Chongqing University, China

²* Mao Chao
Corresponding author, School of Construction Management and Real Estate, Chongqing University, China
E-mail: maochao1201@126.com

³ Xie Fangyun
School of Construction Management and Real Estate, Chongqing University, China

⁴ Liu Guiwen
School of Construction Management and Real Estate, Chongqing University, China
1 Introduction

The construction industry is one of the major greenhouse gas (GHG) emitters and an unregulated sector in the management of carbon emissions\(^1\). According to the Intergovernmental Panel on Climate Change (IPCC) report, the entire life cycle of buildings, ranging from manufacture of components, construction, operation up to demolition, accounts for approximately 40% of the global energy consumption and contributes up to 30% of the total GHG emissions annually. In recent years, studies have increasingly focused on the carbon footprint of the construction industry, especially its GHG emissions in the construction phase. From the life cycle perspective, emissions from the construction stage account for a small proportion. However, Guggemos and Horvath identified that the environmental effects and GHG emissions from this phase cannot be disregarded\(^2\). The manufacture and transportation of building materials, on-site installation, and construction of buildings consume massive amounts of energy and emit large quantities of GHGs\(^3\). Emissions from the construction stage became an apparent and emerging challenge.

With the development of information technology (IT), considerable researches have been conducted to analyze the emissions released from construction activities using IT-based methods. A geographic information system and a computer-aided design-based approach are adopted to visually communicate and analyze the GHG emissions caused by construction activities\(^4\). Wong et al. described the use of virtual prototyping technology and mixed reality for the carbon emission visualization and prediction of a construction project\(^1\). Mani proposed a D\(^n\)AR-N-dimensional augmented reality model in which the expected and actual embodied carbon footprints released from a construction project are equally represented in a common 3D environment\(^5\). However, IT-based carbon emission monitoring remains at the initial stage, and few studies have proposed systems that can monitor and provide tools to control the carbon emissions from construction activities.

Cyber-physical systems (CPSs) demonstrated the potential to improve GHG emission monitoring. By definition, CPSs are physical and engineered systems with monitored, coordinated, controlled, and integrated operations using a computing and communication core\(^6\). A CPS involves a high degree of integration between computing (virtual) and physical systems; this integration is supported by the networked implementation of CPS\(^7\). A CPS consists of two key elements: “physical to cyber” and “cyber to physical” bridges\(^8\).

- The physical to cyber bridge is a sensing process that involves the use of sensors to acquire data from the physical system. Information is transformed to the virtual model through a communication network.
- The cyber to physical bridge is a process showing how sensed information affects the system. In the construction context, the virtual model can utilize sensed information to physically control construction activities.

CPSs have been implemented in several industrial sectors, including the healthcare\(^9\), transportation\(^10\), and manufacturing industries\(^11\). In addition, the applicability and potential benefits of CPSs have been examined in various areas of the construction industry. Akamnu investigated the application of the CPS approach in enhancing bi-directional communication between the virtual models and physical construction\(^12\). Hackmann proposed a cyber-physical co-design approach on structural health monitoring\(^13\). Furthermore, the CPS approach is used to actively monitor and control light fixtures during building construction and operation\(^14\). Yuan
developed a CPS-based temporary structures monitoring system to facilitate real-time monitoring of temporary structures\textsuperscript{[15]}. What’s more, some research has implemented CPS in monitoring energy consumption recently\textsuperscript{[16]}. Based on these investigations, CPS is considered suitable in monitoring GHG emissions.

This paper aims to design a GHG emission monitoring system framework based on CPS, called GHG Emission Monitoring (GEM) system. This system enables supervisors to monitor and control GHG emissions in real-time. The system framework design can be implemented by the following three steps.

1. Production flow is investigated, and four types of emission sources are then identified.
2. Essential technology for system development is identified. This process is followed by the creation of the GEM system framework.
3. The operation of the GEM system, along with its advantages and limitations, are illustrated in detail.

2 GHG Emission Sources

The manufacturing process of prefabricated components in an off-site prefabrication is selected as the research object in this study. Off-site fabrication is a process that incorporates prefabrication and pre-assembly. Building components or units are produced in the factories, which are usually remote from the work site, and these components are then delivered to the site and assembled in their final positions\textsuperscript{[17]}. Figure 1 shows the off-site construction implementation process and the manufacturing of prefabricated components as parts of the construction phase.

![Figure 1. Off-site construction implementation process](image)

Prefabrication is a manufacturing process in construction that contributes to less GHG emissions and cleaner production\textsuperscript{[18]}. Compared with conventional cast in situ construction methods, adopting prefabricated construction methods contributes significant environmental benefits on GHG emissions\textsuperscript{[19]}. Dong indicated that precasting can lead to 10\% carbon reduction for every 1 m\textsuperscript{3} concrete\textsuperscript{[20]}. Sandanayake investigated tow cases in Australia, and the results indicated that adopting a pre-fabrication method provides 1.7\% GHG emission reduction\textsuperscript{[21]}. 
Therefore, a real-time GHG emission monitoring system will improve the environmental performance of prefabricated construction.

Manufacturing of components is a typical procedure in prefabrication. A large number of construction materials and equipment are distributed in a factory to produce components. This procedure is called “the transferring stage of construction activities from field to an off-site production facility”[22]. Raw materials, equipment, and carbon emissions are transferred to the production line. In other words, many on-site carbon footprints are moved toward the factory. Thus, this study focuses on the real-time monitoring of GHG emissions in the component manufacturing process. Fixed positions and regular operations of the equipment in the production line provide a stable environment for carbon emission monitoring, which is highly necessary to develop the GEM system. The process of manufacturing building components is investigated in a precast plant in Chongqing, China. As a result, the production flow of a precast wall is presented in Figure 2. The following four emission sources are calculated and monitored.

![Figure 2. Production flow and emission resources](image)

- E1: Embodied GHG emissions of materials
- E2: GHG emissions from the electricity consumption in equipment operations
- E3: GHG emissions from water consumption in equipment operations
- E4: GHG emissions from diesel consumption in equipment operations

Based on a quantitative model[19], the following four types of data are measured to calculate GHG emission: the amount of building materials (Mj, in tons), as well as the electricity (Re, in kWh), water (Rw, in m³), and diesel usages (Rd, in L).

### 3 DEVELOPMENT OF CPS-BASED GEM SYSTEM

#### 3.1 Enabling technologies

##### 3.1.1 Sensors

The target of sensors is to obtain relevant information on products that are constructed, processes and equipment utilized in constructing these products, and monitoring existing conditions of an infrastructure throughout its service life[23]. Sensors can capture information from the physical world and provide data to virtual models. Therefore, sensors serve as bridges between the cyber and physical world.
3.1.2 Virtual model

A virtual model can visualize buildings and also visually monitor construction activities. In CPS integration, the information obtained from wireless sensors are visualized and sometimes stored in virtual models. These models can be created and navigated using software, such as Autodesk Revit, Navisworks, and Bentley Architecture.

3.1.3 Communication networks

Communication networks used in the construction industry include the Internet, the wireless local area network, and the wireless personal area network. These networks are considered the significant technologies for enhancing the bi-directional communication between the virtual model and physical system. With these networks, data can be exchanged wirelessly between the sensors and the mobile and fixed devices on the construction site[14].

3.1.4 Mobile devices

Mobile devices have been introduced in the construction industry, particularly in logistics management, building maintenance[24], and safety management[25]. In this study, smartphones are selected as the mobile device for the GEM system. With this mobile device, production line supervisors can receive control instructions from the virtual model or send requests to the main office.

3.2 System operation

To fully realize the operation of a CPS-based GEM system, the system framework is presented in Figure 3. This presentation is followed by an explanation of some key procedures that include (1) acquiring data from the production line, (2) developing a virtual model, (3) setting the warning threshold, and (4) controlling GHG emissions through mobile devices.
3.2.1 Data collection

The data types required for GHG emission calculation is outlined in Figure 4. Wireless sensors, such as smart meter, remote water meter, and smart diesel meters, are selected to measure electricity, water, and diesel consumptions, respectively. A laser scanner is selected to measure the volume of precast wall, and the results are used to calculate the embodied emissions. In addition, a radio-frequency identification tag, which stores unique ID information, is embedded in the wall. In this manner, the position of the components on the production line can be tracked real-time. Data acquired by sensors can be transferred to the virtual model through the communication network. The virtual model queries the database every few seconds for an updated production line information.

![Image of wireless sensors](image.png)

**Figure 4. Wireless sensors**

3.2.2 Identify warning thresholds for GHG emissions

The warning threshold is a value predefined in GEM. If the actual emission value is greater than the warning threshold, then a risk of excessive emission occurs. When the equipment operates at an underrated output, the GHG emissions within a certain period are set as warning thresholds. If the power of the operating equipment exceeds the rating, then large amounts of GHGs are released and equipment are easily damaged. Considering the vibrating station as an example, the emission source in this station is the electricity consumed by the motor, thus, the electricity threshold \( R_e = P \times T \). \( P \) is the rated output power of the motor, and \( T \) is the duration of this procedure based on industry best practices. The emission warning threshold in the vibrating station can be calculated. No standards or specific requirements exist in setting GHG emission warning thresholds in component manufacturing. Thus, environmental experts or relevant government departments can set emission warning thresholds.

3.2.3 Virtual model based on Building Information Modeling (BIM)

Several emerging BIM software provides various choices to visualize construction activities. For example, Autodesk Navisworks is frequently used in developing a virtual model for CPS\[^{[7, 14]}\]. This software provides an open-source .NET application programming interface and privileges to developers in managing the properties of virtual models. These features contribute to the development of the GEM system. Thus, Autodesk Navisworks Manage is selected as the development platform for the virtual model. This study presents a virtual model of the GEM system, which includes (1) a virtual model of the precast wall production line, (2) the location of every component, (3) the visualization of the GHG emission value for each station, and (4) the generation of control instructions.
3.2.4 Mobile device for human–production line interaction

To ensure that GHG emissions are within an acceptable range, the GEM system is required to simultaneously monitor and control the carbon emissions during the component manufacturing process. The system control of the production line is realized through the following two steps: (1) the GEM system sends control instructions to on-site supervisors, and (2) supervisors implement directional intervention in the production line. To perform this step, a mobile APP, called GEM, can be used and installed in the smartphones of on-site supervisors. As the virtual model sends a notification, the App will alert relevant supervisors through a warning alarm. In addition, an overview of the environmental performance of the production line is displayed to instruct supervisors. Thus, appropriate corrective actions can be implemented to control GHG emissions.

4 Conclusion

In this study, a CPS-based GEM system framework is designed to monitor GHG emissions in real-time. This system realized the bi-directional communication between the production line and virtual model through a “CPS bridge”, which can transmit GHG emission data from the production line to the computing system. In contrast, the feedback from the virtual model can affect GHG emissions through the bridge. This framework provided the possible solution for monitoring and controlling GHG emissions in real-time. The CPS-based GEM system is still at its initial stage and should be applied to real scenario. In addition, future work can extend the study scope to the entire construction phase (from component manufacturing to on-site installation).

References


Towards an Ex-post Evaluation of PPP Projects

Oliveros R., J.1*, Aibinu, A.A2

Abstract: Public Private Partnerships (PPP) are employed worldwide to deliver public infrastructure using private funding and managing risk for public purposes. Currently, their effectiveness for achieving real public welfare has been questioned from a technical perspective (Value for Money), and from an ideological and political perspective. The ex-post evaluation is an instrument that can address the questioning and protect taxpayers’ interest. An exploratory research to investigate the relevance, current practice, and challenges of PPP ex-post evaluation was conducted by interviewing PPP experts and practitioners in Chile and Australia. A thematic analysis was performed and 7 themes are identified namely: (1) contribution and purpose of the ex-post evaluation; (2) Urgency and importance of PPPs versus value for money considerations; (3) ex-ante evaluation; (4) separation between PPP and project impacts; (5) relationship with public policy; (6) ideological component of PPPs; and (7) stakeholders’ expectations. Among other findings, the research suggests the importance of this kind of evaluation and the lack of existing methods to perform it, specifically for PPP projects. The research contributes to the theoretical development of PPP ex-post evaluation methods. It points out several issues that need to be addressed when attempting to evaluate PPPs beyond the financial and contractual parameters; considering the multiple stakeholder perspectives towards a project.

Keywords: ex-post evaluation, qualitative research, project management, public private partnerships, stakeholders.

* Oliveros R., J.
Corresponding author, Faculty of Architecture, Building and Planning, The University of Melbourne, Australia
E-mail: joseo@student.unimelb.edu.au

2 Aibinu, A.A
Faculty of Architecture, Building and Planning, The University of Melbourne, Australia
1 Introduction

Public Private Partnership (PPP) model of procurement is a way to deliver public infrastructure using private funding and managing risk for public purposes. PPP projects have been developed in many sectors, such as health, education, water supply, transport, electric power, etc. Many countries such as Australia and the UK have been using this model since the 1980s with some satisfactory results especially in terms of efficiency; delivering on average more projects on time and on budget [1, 2]. This type of partnership between public and private sectors has been promoted world-wide especially in developing countries to improve economic performance.

Currently, PPPs have been criticised in the media, social media, and also the academia. Much of the criticism can be divided in two levels: (1) problems in the performance of PPP and (2) a complete opposition to the development of PPPs, based on the argument that they do not achieve public welfare better than traditional procurement [3].

From a taxpayer point of view, the impact of PPP projects, like any kind of public investment, should be assessed and analysed, especially if a private company is making profit with it. One relevant instrument to protect the taxpayers’ interest is an ex-post evaluation. However, the problem is that a PPP ex-post evaluation is difficult to perform because usually (1) projects are large and complex, (2) there are different perceptions of the impacts because of the multiple stakeholders, and (3) the time horizon for the evaluation in some cases is more than 20 years. An assessment to identify what are the impacts of a PPP project on every stakeholder is complex but extremely relevant from the taxpayer’s view. Evaluating the impact of a public investments rest partly on the assumption that citizens at large should know if public projects are making the difference, and is related to the accountability of public decisions [4]. Lessons learned from the assessment can inform future PPPs.

In the literature, there is not yet a well-developed ex-post evaluation approach for PPPs. Thus, an exploratory research to investigate the relevance, current practice, and challenges of PPP ex-post evaluation was conducted by interviewing PPP experts and practitioners in Chile and Australia. The study is based on the assumption that the complexity for evaluating PPP is related to the multiple stakeholders involved. Thus, the perspective of multiple stakeholders would allow a broad view of the project beyond the financial and contractual parameters, and it is supported by the theory of project success. A project will be successful if it can meet the stakeholder’s expectations. [5, 6].

The article is structured as follows: the introduction, literature review, methodology, results and discussion, and conclusion.

2 Literature Review

In the literature, there is no ex-post evaluation framework to assess the impact of PPP projects on the stakeholders. However, there are several approaches that can inform PPP evaluation.

Within the public-private partnership evaluation, the main criteria to evaluate a PPP is Value for Money (VfM), which is done by simulating a comparison between the real private best bid and an artificial traditional procurement option. This method is used ex ante for approving the development of a PPP and not ex-post. Moreover, studies have concluded that this tool presents biases toward the PPPs in cases that there is not funding for developing the project with public resources [7].
The European PPP expertise centre [8] from the European Investment Bank (EIB) is an organization that strengthens the ability of the public sector to engage in PPP transactions by helping the members to share their experience and expertise. In their PPP guidelines, they include the application of a PPP ex-post assessment as part of the process of procuring and delivering a PPP. However, the approach is presented as a general guideline with no clear instruction on how to really assess a PPP, and the examples provided are not coherent with the suggested guide. Nevertheless, the existence of a guideline that refers to an ex-post assessment further validates the relevance of the research topic and the need for a tool.

PPP performance has been studied by many researchers in construction management [1, 9-14]. However, studies relating to PPP evaluations are conceptual, lacking clear guidance about how the evaluation can be implemented in practice. In fact, the conceptual models do not go beyond the theoretical development. Also, the whole life assessment presented by Liu and Love has the aim of improving the performance of the PPPs (formative evaluation) but did not address the summative evaluation of PPP impact on stakeholders.

To assess the impact of a PPP on stakeholders, the project success concept from the Project Management discipline could be employed. Existing literature has focused on (1) developing frameworks to analyse project success; (2) success factors, which are key areas that can improve the possibility of having a successful project; and (3) success criteria, which are the measurements that can be assessed to determine if a project is successful or not. However, existing literature [15] in this area lack details. For example, there is not yet an accepted method to assess the success of a project, and development in this area is still limited; the theory has limited application in practice. Moreover, the definition of project success is ambiguous and difficult to apply because it disregards the differences that could arise in the judgement of project success by different stakeholders. Nevertheless, the theory of project success is the only approach that supports a broad view of the project, involving all the stakeholders.

Performance Measurement Systems (PMS) such as the Balance Scorecard [16] and the Performance Prism [17] could also be an approach to perform an ex-post evaluation. The problem is that a PMS is good only for measuring performance; and an evaluation has the aim of not only measuring, but also making a judgement out of that measurement, for decision-making purposes.

Program Evaluation theory could also be used as an approach for evaluating a PPPs using, what is called, an impact evaluation [4, 18, 19]. However, the problem with this approach is that all the different types of impact evaluation are mostly performed by a team of experts using their unique perspective without considering each stakeholder as an object of study. Thus, the impact of the project on each stakeholder are disregarded and are not clearly assessed and explained so that lessons learned can be used for improving future PPPs.

In practice, there is a lack of evaluation examples in the public domain, perhaps because of the controversial nature of PPPs; whereas PPPs are supposed to be as transparent as any public project that provides a public service. However, the existing methods to monitor PPPs are not fully developed and applied. Therefore, this study will explore the relevance and the challenges in practice of PPP ex-post evaluations.
3 Method

A qualitative approach has been undertaken for exploring the actual meaning, context, and application of PPP ex-post evaluations. This is part of a larger research project that employs Design Science [20] to design a PPP ex-post evaluation tool. At this stage of the research, interviews with experts and practitioners related to the development of PPP projects were held. The experts are from Australia and Chile, two countries in which the PPP environment is considered mature, leading in their region (South Pacific and Latin America respectively) [21, 22].

The interviews were structured using a presentation-discussion sequence in which the researcher described concisely the architecture of a possible evaluation tool (based on a multiple stakeholder approach) to introduce the discussion around the topic. From that point, the discussion with each of the interviewees focus on (1) general insight about evaluation of PPPs, and (2) specific insight for the development of an evaluation tool. Each interview took one hour to complete. This article presents the results related to the general PPP evaluation topic.

The interviews were transcribed verbatim and a thematic analysis was performed employing MS excel for coding and then grouping the information. The results are presented as a combination between the interviews and a phronetic approach [23]. Phronetic research differs from a descriptive approach and consists of a reflexive process that includes the researcher knowledge as an input for the outcome, looking for the motives and interest that are present on a specific social phenomenon.

In total, 13 interviews were held with experts and practitioners from the public and private sector in Chile and Australia: They include three former senior public sector authorities in infrastructure and public evaluation; one senior public sector authority in infrastructure; two junior public sector executives, two senior PPP consultants, one mega contractor project manager, four junior private developers in PPP social housing projects. The respondents have been involved in many PPP projects from conception to completion. Some have also been involved in policy formulation around PPPs. They have been purposefully selected because of their firsthand experience and in-depth understanding of PPP across the lifecycle. Prior to the interview they were asked to give consent. For confidentiality reasons, is not possible to reveal the identity of the experts or whether they are from Chile or Australia.

4 Results and Discussion

The thematic analysis of the interviews generated 170 pieces of information coded with more than 40 key concepts. These concepts were grouped in 11 themes, and seven were selected for these articles due the relevance and connection with the main topic. Each theme discusses an issue that affects the development of PPP evaluations; including, the difficulties associated with PPP evaluation, the incentives and limitations, and the considerations that need to be addressed when planning a PPP evaluation. The geographic variability (Chile and Australia) was not relevant for the analysis and significant differences were not found.

4.1 Theme 1: Contribution and Purpose of the Evaluation

There is a general agreement that an ex-post evaluation can contribute to the development of better future projects and that the effort is worthwhile from both the public and private sector perspective. Even though there are limitations for the systematic implementation of this kind of
In general terms, knowledge about PPP ex-post evaluations is rare. The existing approaches are related to satisfaction surveys, financial audits, and some pure lessons learned reports. Specific evaluation methods for assessing PPPs after completion are recognised as something that is not known or at least not sufficiently publicised.

Prior to performing an evaluation, defining its purpose is essential, because it guides the evaluation process. The result of the evaluation could be driven by one or more general aims: transparency and accountability, PPP legitimization, industry learning, and/or government agency learning.

For transparency and accountability purposes, the ex-post evaluation needs to be presented in plain language allowing the general audience to understand and validate the evaluation, without excessive technical financial information as the core outcome. Additionally, it should declare who is accountable for specific impacts that occurred during the project lifecycle, and make clear distinction between the impact created by the PPP strategy and the impacts of the project (further explanation of this distinction in theme 4).

PPP legitimization can also be the purpose of an evaluation; however, this purpose is difficult to achieve due to the ideological component that supports PPPs. It is not easy to find results of PPP performance that goes beyond the time/cost comparison with traditional procurement. A more detailed approach of the real short and long-term effects can contribute to public discourse about the general use of PPPs.

Industry learning is also an important purpose of the ex-post evaluation. The recognition of the impacts that affect every stakeholder helps private companies assessing the results of previous projects; thus, improving the precision of their proposals for new PPPs in terms of output quality and procedural strategy. Depending on the type of evaluation, it can also be used to assess government performance, and help private companies to make better risk assessment in terms of macro-economic issues, long term financial options, etc.

Government agencies can also learn from a PPP ex-post evaluation. They can replicate successful component of PPPs and modify unsuccessful ones. Issues such as negotiation process, monitoring strategies, revenue systems, quality assurance, etc. can be declared as positive or negative outcome with a clear course of action.

4.2. Theme 2: Urgency and Importance of PPPs versus the Value for money consideration
For the evaluation of PPPs, three concepts are discussed as part of the PPP decision-making process: value for money, urgency, and importance.

The value for money concept is essentially an efficiency measurement to establish the amount of value that is possible to get with a certain amount of money. It has been stated that VfM lacks precision due to the inclusion of concepts that are difficult to quantify (intangible benefits). However, it is a concept that is associated with the evaluation of PPPs and the evaluation of international agencies projects (World Bank, regional development banks, etc.). The interviewees confirmed that the VfM measurement is biased to the acceptance of PPPs when comparing it with the public sector comparator (PSC). It is rare (or impossible) to find projects that have been rejected because the VfM of the PSC was better than for the PPP.

According to the interviewees, urgency is stated as the principle that guides PPP development
on the basis that the need for service facilities cannot be postponed. This urgency in practice is not driven by a technical perspective, but by a political perspective. This means that VfM does not reflect objectively the real decision-making for developing PPPs.

Importance, contrary to urgency is also part of the trade-off. Political decisions are the ones that drive the development and the conceptualization of PPPs depending on how relevant is the facility. It supports long term benefits when comparing different investment options.

The analysis of Value for Money is never perfectly adopted, as the theoretical comparison between PPPs and traditional procurement using public funding is almost never feasible. Public funding can always be spent in other projects that are not possible to do using a PPP strategy. Therefore, efficiency seems to be irrelevant in the final decision; and consequently, in an ex-post evaluation.

4.3 Theme 3: Ex-ante evaluation
For performing an ex-post evaluation, is important and helpful to clearly define an ex-ante evaluation. With a precise ex-ante evaluation scope, the ex-post evaluation can contain the comparison of what was expected and what was really achieved by the project. This before-after comparison legitimises the evaluation process. If there is no clear ex-ante evaluation, the ex-post evaluation can be biased by the drivers that are present at the moment of the evaluation such us current affairs, political scenario, media scandals, etc. For PPP projects, Key Performance Indicators (KPI) are employed to control and monitor the facility operation, tracking the service quality; this, from the perspective of the public authority to assess the private consortium performance.

Even though the ex-ante evaluation is an important input for the ex-post evaluation, it cannot be the only source of information. Additionally, all the unforeseen events that are considered impacts to specific stakeholders need to be addressed. PPPs can last for more than 20 years, making the lifecycle of the project as relevant as the initial conceptualization of it.

4.4. Theme 4: Separation between PPP and Project Impacts
The PPP is only the procurement method of a public project; then, the evaluation must consider a separation between the impact that are a direct effect of the procurement strategy, and the impacts that are common to any kind of procurement method. For example, an inner-city toll road that produces social segregation can be assessed as an impact of the project, with no relation to the procurement method. With a traditional procurement or with PPP, the urban impact to the surrounding community will be the same.

In practice, the process of classifying the impacts is not easy to do and involves expert judgement, because there is a lot of “noise” that affect the analysis. For the same case of the toll road, the impact could be analysed as a result of the proposed and accepted design of a Design Built Operate Transfer (DBOT) strategy, which could differ from the design in a traditional procurement strategy.

For evaluating this separation of impacts, the first layer of analysis should be done by contrasting the specific outputs with the official partnership documents that specify the scope of work that the private consortium was entitled to follow. The second layer of analysis is the search of motives and interests that the PPP structure generates, such as the political bias, cost cutting strategies, response to unforeseen issues, etc.
4.5 Theme 5: Relationship with Public Policy
The PPP as a project procurement method needs to be differentiated from the public policy that supports the project. There is a misconception that a PPP is a goal by itself, whereas it needs to be considered only as a tool to pursue a public policy goal. This differentiation is relevant when evaluating a PPP, because it narrows the purpose of the PPP to a specific objective within a public policy. If the separation is not made, the PPP could be negatively assessed, because it is not possible for the procurement method to stand over a public issue that needs to be solved with a public policy.

4.6 Theme 6: Ideological Component of PPPs
The ideological perspective towards PPPs has not been well described in the existing literature. Political ideology affects the procurement methods and it has resulted in the acceptance and rejection of PPP projects. The political bias affects not only the approval of PPP projects, but also the subsequent evaluation of them. Ex-post evaluations need to consider the political bias when legitimising PPP projects.

4.7 Theme 7: Stakeholders’ Expectations
What is important about the PPP for the public authority, the private consortium, the user, or the community can change over time, and this might affect the ex-post evaluation. This is conceptualised as the change in expectations of the stakeholders. This change is relevant because, in practice, assessing the project by their original objectives is not the only way to legitimise the public investment. Projects that have been operating for 20 years can have a new surrounding environment and conditions that affect the judgement of the people involved in the project; for example, a change in the macro-economic conditions (affecting the consortium), or the availability of recent technology (affecting users’ perception of quality). The ex-post evaluation should address this change of expectations and trace, from the conceptualization to the completion of the project, how the expectations have varied, and possibly what unforeseen impacts occurred during the project implementation.

Another difficulty for evaluating PPPs is the impossibility to declare transparent interests for the different stakeholders that are involved in the PPP. The legitimate profit driver of the private company is in many cases hid from the general public. This transparency is consistent with the idea that the process for providing a public service should be known by the public audience; by the taxpayer. The interest declaration is also applicable for the government agencies that have different specific objectives towards the same PPP project. The objectives can be related to urgency, to relevance, to budget control, to political revenue, etc.

4 Conclusion
PPP ex-post evaluation is a topic that has not been well addressed by the existing literature; it is considered a gap in knowledge. Therefore, the aim of the article is to explore the topic and pursue better ex-post evaluations for existing and future PPPs.

From the 7 themes, it is possible to conclude that still there is limited development in terms of ex-post evaluations. Additionally, the political component influences the technical approach of
PPPs, particularly when performing the value for money assessment. The stakeholder’s perspective evaluation is something new, but it is recognised as a feasible way to address the complexity of PPPs. The findings contribute to the theoretical development of PPP ex-post evaluation methods. It points out several issues that need to be addressed when attempting to evaluate PPPs beyond the financial and contractual parameters.

Further research to explore in detail each of the themes is suggested. However, in this topic a more prescriptive approach in which evaluation method and frameworks are proposed is considered more relevant than a descriptive study of how evaluations are made.

References


Housing the Young People: Their housing stress and willing to stay

Yiguan Ma 1, Ping Lyu 2*

Abstract Housing issues of the younger generation in China, especially in the mega cities, have drawn public attention in recent years. Chinese local government announced to provide subsidized housing to the young working population as the methods to retain them. However, at the current stage, answers to the following questions are still out of reach: how stressful are the young people in affording housing? What are the key factors to be considered in the policy making? And what are the salient factors influential on young people’s actions? To provide depth in understanding this multi-faceted issue, based on large-scale questionnaire survey findings in Tianjin, this paper mainly explores the youth housing issues from two aspects: quality of young peoples’ life in the housing perspective, and the influential factors on the young people’s perception and actions. That is, their perceived stress on affording housing, their satisfaction toward the current living condition, and their attitude of staying in the city. Regression analysis suggests that perceived housing problems have significant influences on the young people’s perception of housing affordability stress and on their satisfaction toward the living condition. When it comes to their decision of whether to stay in this city, nonetheless, the housing factors showed no significant effects.

Key words: Urban youth housing; quality of life; housing affordability; China
Introduction

Since late 1960s, contrast to focusing on physical environment, part of the academia attention was given to the ‘soft environment’ of the city development. One of the significant indicator, used for implying the livability of the city, is the quality of life (QOL) of the residents (Arif and Hamid, 2009; Maurer and Christenson, 1982). Nowadays, QOL is seen as the main aim of sustainability development, and is the standard indicators of the quality of life usually include not only wealth and employment, but also the built environment, physical and mental health, education, recreation and leisure time, crime rate and social belonging, freedom, human rights, and happiness (Felce and Perry, 1995). Concern to the diversified needs and requirements, quite a few of the existing research of QOL was focused on a group with special needs, or is under challenges. Such as the QOL of physical challenged residents in the special designed community; or focusing on the chronically mentally ill and providing suggestion on residential neighbourhood design, which aims at helping the elderly residents who are facing the risk of Alzheimer or other mental illness (Lehman, 1988). With the current work in concern, few of the researches paid attention on the young working people in the big cities. However, development and residency of the young people, especially those migrating from other places, should not be ignored.

Rapid urbanization resulted in large scale migration as well as aggregation of population in the big cities around the world. The young people undoubtedly comprising a significant part of the group. Research over the housing needs of the global financialization process in the past decade has pointed out that the inequitable distribution of homeownership has resulted in increasing disparities inter and intra generations, with especially disadvantaged prospects among younger generation (Arundel, 2017). The disadvantages cover different aspect, ranging from inadequate public services and facilities, to the deprived opportunities of moving upward on the social ladder (Aalbers, 2016).

Housing issues and the concern over the quality of life of China’s young people under the country’s rapid urbanization is a case in point. During the past decades, rapid urbanization in China drove the young workers concentrating to the cities, which represented a process of population migration that was not only from rural sector to urban sector (Chen et al., 2011), but also from small cities to mega cities (Xu and Yeh, 2010). Nonetheless, as observed by Arundel (2017), inequitable distribution of housing wealth among the younger generation also emerged in China. It is concerned by some scholars and the Chinese government that the so-call ‘demographic dividend’, which is seen as the foundation of China’ rapid urbanization and economic growth, would be diminished due to the soared housing price (Huang and Tao, 2015). The folk talk of ‘escaping from Bei Shang Guang (represents three first tier cities: Beijing, Shanghai and Guangzhou)’ drew the local government’s attention during the past three years. People are worrying that the poor housing situation, as well as the low housing affordability would push the young people out of the big cities.

By this concern, local government of the big cities, especially the first and second tier cities, conducted subsidized housing projects to specially provide to young workers in the cities. Such as in Shenzhen, a first tier city that witnessed a double of its housing price, the government proposed to constructed 400 thousand subsidized housing units to accommodate the young talented workers. Similar projects were also proposed in other cities, such as Shanghai and Tianjin. Despite the emerging local practices, only few of the current research is focused on housing issues of the young people in the big cities. To the contrast, more attention was given to the housing needs of the rural to urban migrants (He et al., 2010; Qin, 2010). What are the housing conditions of the young people in the big cities? Will their decision of whether to stay in the big city be affected by their housing condition? And what are the influential factors of the housing stress perceived by the young people? Answers to these questions are significant not only for understanding the quality of young people’s life in the big cities, but also for making policy implications for local practice to precisely provide subsidized housing for the young workers.

In order to provide depth in understanding this multi-faceted issue, this paper took Tianjin as a case to explore the quality of young people’s life from the housing perspective, based on which, the question of how were
their decisions of staying in Tianjin influenced by the housing situation would also be answered. For this purpose, a questionnaire survey was conducted by Renmin University of China Housing Research Center over the young workers in Tianjin in December 2016.

The investigation was conducted at individual level, referring to the young workers involved in the secondary and tertiary industries in Tianjin. Questionnaire survey was conducted in twelve large scale commercial areas in the city proper and Economic Zone Area, and eight secondary enterprises in the Economic Zone Area in Tianjin. With the circumstance in concern, this investigation scale is believed to be valid for statistical analysis and for elucidating the young people’s quality of life and perception of housing stress in Tianjin.

Overall, as shown in Table 1, 914 valid questionnaires were collected. Among the respondents, more than one-third of them (36.1%) were with educational level at college or above, while less than half of them were married. Most of respondents were earning income at the scale between 2,000 to 16,000 RMB/month, and around 80% of them are living in the city proper or in the Economic Zone, which located at the coastal line of Tianjin.

Table 1. Socio-demographic characteristics of the respondents

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Respondents</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>476</td>
<td>52</td>
</tr>
<tr>
<td>Female</td>
<td>438</td>
<td>48</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>514</td>
<td>56</td>
</tr>
<tr>
<td>Married</td>
<td>400</td>
<td>44</td>
</tr>
<tr>
<td>Only Child</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>433</td>
<td>47.4</td>
</tr>
<tr>
<td>Other</td>
<td>481</td>
<td>52.6</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illiteracy</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Primary</td>
<td>5</td>
<td>0.6</td>
</tr>
<tr>
<td>Secondary</td>
<td>77</td>
<td>8.4</td>
</tr>
<tr>
<td>High School</td>
<td>157</td>
<td>28.1</td>
</tr>
<tr>
<td>College or above</td>
<td>330</td>
<td>36.1</td>
</tr>
<tr>
<td>Average income (RMB/month)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 2,000</td>
<td>45</td>
<td>4.9</td>
</tr>
<tr>
<td>[2,000, 16,000]</td>
<td>854</td>
<td>93.5</td>
</tr>
<tr>
<td>&gt;16,000</td>
<td>15</td>
<td>1.6</td>
</tr>
<tr>
<td>Residency in Tianjin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>City proper</td>
<td>406</td>
<td>44.5</td>
</tr>
<tr>
<td>Suburb</td>
<td>194</td>
<td>21.2</td>
</tr>
<tr>
<td>Economic Zone</td>
<td>313</td>
<td>34.3</td>
</tr>
<tr>
<td>Working place</td>
<td></td>
<td></td>
</tr>
<tr>
<td>City proper</td>
<td>431</td>
<td>47.2</td>
</tr>
<tr>
<td>Suburb</td>
<td>123</td>
<td>13.5</td>
</tr>
<tr>
<td>Economic Zone</td>
<td>359</td>
<td>39.3</td>
</tr>
</tbody>
</table>

Factor analysis method was adopted in order to construct an empirical evaluation system to evaluate the housing quality of young people, which focuses on not only the physical situation, but also the perception of the young people. For this purpose, twenty-four indicators were grouped into two factors. Since the purpose of this analysis was identifying the minimum number of factors that could significantly explain the variance of the total data set, the principled component analysis method was used to exact the reduced number of factors (Kline, 2014).

Following content in this paper first elucidates the housing situation of the young people in Tianjin; then establishes an empirical evaluation index for evaluating the young people’s housing quality; finally, the influential factors over young people’s perception of housing stress, their satisfaction toward living quality, and their decision of whether to stay in Tianjin are examined through regression analysis.
Quality of the young people’s living from housing perspective

Young people’s living condition in Tianjin

According to the investigation in Tianjin, only one-third of the young people purchased their own housing. Among them, 31.8% of the young people purchased from the private market, while another 2.5% purchased the subsidized housing. For the others, 24.18% rent housing from private market, 10.94% renting subsidized housing, and the reminded are staying in free dormitory provided by their companies or living with their parents.

The living condition of the young people in this paper refer to two aspects: the physical condition, and the perceived disadvantages. The physical living condition of the young people refers to: 1) the situation of the housing, such as the living area, the structure of the housing, whether it was High-rise, multi-storey, or cottage, or etc., and the ownership of the housing; 2) the basic indoor facilities, such as the pipeline gas, the central heating, the telecommunications and the network, the kitchen, the bathroom, and the bathing facilities; 3) the commuting situation of the young people, including their commuting time and mode of commuting; and 4) the other features of the young people’s housing in Tianjin, such as whether they are sharing flat with other flat mates, etc..

Around one-third (27.4%) of the young people are living in flat with an area between 30 to 60 m², while only 17.27% of them are not sharing flat with others. As a result, around 65% of the respondents’ per capita living space were less than 30m², which is the average living space of urban residents in Tianjin in 2017. 58.8% of young people are living in housing with poor situation, such as cottage, multi-storey residential, simple room or activity board room, basement and or loft. When it comes to the tenants among the respondents, the proportion increased to 69%. According to the investigation, not all the young people can get full access to all the facilities (figure 1). Besides, commuting of the working young people is also concerned. According to the investigation, 24.57% of the youth people need to spend no less than 1 hour on the way to work and back home. 5% of them are travelling more than 2 hours for commuting each day.

The disadvantages of housing quality perceived by the young people can provide useful information for the policy maker in understanding the needs of young people (table 2). As shown in the table below, inadequate living space, inadequate indoor facilities, and the hygiene problem are the top three issues concerned by the young people.

![Figure 1. The indoor facilities provided to the young people](image-url)
Table 2. The perceived problem by young people

<table>
<thead>
<tr>
<th>Perceived problem</th>
<th>Percent</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property rights</td>
<td>25.8%</td>
<td>0.438751</td>
</tr>
<tr>
<td>Contract</td>
<td>6.5%</td>
<td>0.246333</td>
</tr>
<tr>
<td>Inadequate living space</td>
<td>63.4%</td>
<td>0.482896</td>
</tr>
<tr>
<td>Too dark</td>
<td>22.0%</td>
<td>0.415656</td>
</tr>
<tr>
<td>Ventilation</td>
<td>21.0%</td>
<td>0.408177</td>
</tr>
<tr>
<td>Indoor facilities</td>
<td>31.7%</td>
<td>0.466644</td>
</tr>
<tr>
<td>Insecurity</td>
<td>16.7%</td>
<td>0.373684</td>
</tr>
<tr>
<td>Hygiene problem</td>
<td>27.4%</td>
<td>0.447311</td>
</tr>
<tr>
<td>Commuting problem</td>
<td>24.2%</td>
<td>0.429411</td>
</tr>
<tr>
<td>Public facilities</td>
<td>16.1%</td>
<td>0.368791</td>
</tr>
<tr>
<td>Too noisy</td>
<td>13.4%</td>
<td>0.342011</td>
</tr>
<tr>
<td>Crowded</td>
<td>19.9%</td>
<td>0.400269</td>
</tr>
<tr>
<td>Others</td>
<td>9.7%</td>
<td>0.296448</td>
</tr>
</tbody>
</table>

With the above finding in concern, it is still difficult to draw a clear picture of how are the quality of young people’s housing influenced their actions. For this purpose, in the following section, the factor analysis method is adopted to clustering the above twenty-five indicators, so as to establish an empirical index. Based on this, the third section can systematically evaluate the effects of quality of living on Young people’s satisfaction, perceived housing stress, and on their decision making of whether to stay in the city.

**Clustering the indicators**

A factorability test should first be conducted to see whether these indicators are suitable for factor analysis. The anti-image correlation matrix shows that all of the twelve items were significantly correlated with more than one other item, confirming the factorability of the sixteen indicators. The Bartlett test of sphericity also suggested the intercorrelations among the indicators (Chi-square: 1081.123, df: 231, sig.: 0.0000)\(^1\). In addition, the Kaiser-Meyer-Olkin measure of sampling adequacy (0.719) confirmed that the provided data set was appropriate for factor analysis\(^2\).

The initial eigenvalues in the results suggested that a four factor solution was appropriate\(^3\), which explained 63.1% of variance. During several steps, three items, including ‘the type of housing’, the ‘property rights of the flat’, and ‘the living space is small’ were excluded, because the factor loadings of these items did not satisfy the 0.6-0.4 rule\(^4\). Then, a principal components analysis was conducted again with the remaining twelve items. The second round eigenvalues in the results suggested a two factor solution, and 50% of the variance could be explained by the model. All of the twenty-two items had a primary factor loading well above 0.4. Table 3 shows the results of the principal components analysis.

---

\(^1\) Bartlett’s test of sphericity is to test whether the items are intercorrelated enough to be used for factor analysis. If the probability value is less than 0.05, the data set is considered as suitable for factor analysis (Reinard, 2006).

\(^2\) Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy indicates the proportion of common variance in the variables. If KMO value is lower than 0.5, it is not suitable for applying factor analysis with the given data set (Reinard, 2006; Smith, 2002).

\(^3\) Eigenvalues refer to how much the variance is explained by factors.

\(^4\) There is no fixed rule on the adequate level of factor loadings to be interpreted. In social science, however, items which have a primary loading on one factor of 0.6 or greater and, at the same time, do not have loadings on other factors of 0.4 or above are usually considered reliable for interpretation (Reinard, 2006; Stevens, 2002). Hence, this study also followed this conventional guideline.
Table 3. Factor loadings representing young people’s housing quality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Factor1</th>
<th>Factor2</th>
<th>Factor3</th>
<th>Factor4</th>
<th>Uniqueness</th>
</tr>
</thead>
<tbody>
<tr>
<td>livingarea</td>
<td>0.6332</td>
<td></td>
<td></td>
<td></td>
<td>0.5116</td>
</tr>
<tr>
<td>gas</td>
<td>0.6928</td>
<td></td>
<td></td>
<td></td>
<td>0.4639</td>
</tr>
<tr>
<td>heat</td>
<td>0.5367</td>
<td></td>
<td></td>
<td></td>
<td>0.5443</td>
</tr>
<tr>
<td>telnet</td>
<td>0.7416</td>
<td></td>
<td></td>
<td></td>
<td>0.3624</td>
</tr>
<tr>
<td>kitchen</td>
<td>0.8108</td>
<td></td>
<td></td>
<td></td>
<td>0.3058</td>
</tr>
<tr>
<td>toilet</td>
<td>0.8256</td>
<td></td>
<td></td>
<td></td>
<td>0.2713</td>
</tr>
<tr>
<td>bath</td>
<td>0.7498</td>
<td></td>
<td></td>
<td></td>
<td>0.3599</td>
</tr>
<tr>
<td>disindofac-y</td>
<td>-0.4569</td>
<td></td>
<td></td>
<td></td>
<td>0.6263</td>
</tr>
<tr>
<td>dissmall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.7790</td>
</tr>
<tr>
<td>disdark</td>
<td>0.5778</td>
<td></td>
<td></td>
<td></td>
<td>0.5838</td>
</tr>
<tr>
<td>disvantil</td>
<td>0.5681</td>
<td></td>
<td></td>
<td></td>
<td>0.5684</td>
</tr>
<tr>
<td>dissafty</td>
<td>0.6008</td>
<td></td>
<td></td>
<td></td>
<td>0.6253</td>
</tr>
<tr>
<td>dishygen</td>
<td>0.5874</td>
<td></td>
<td></td>
<td></td>
<td>0.5590</td>
</tr>
<tr>
<td>dispublicf-y</td>
<td>0.4211</td>
<td></td>
<td></td>
<td></td>
<td>0.6818</td>
</tr>
<tr>
<td>disnoise</td>
<td>0.4513</td>
<td></td>
<td></td>
<td></td>
<td>0.7691</td>
</tr>
<tr>
<td>discommuting</td>
<td>-0.6957</td>
<td>-0.4327</td>
<td></td>
<td></td>
<td>0.4076</td>
</tr>
<tr>
<td>commutime</td>
<td>-0.6957</td>
<td>-0.4327</td>
<td></td>
<td></td>
<td>0.4076</td>
</tr>
<tr>
<td>livealong</td>
<td>0.6303</td>
<td></td>
<td></td>
<td></td>
<td>0.5364</td>
</tr>
<tr>
<td>disproportion-t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.7262</td>
</tr>
<tr>
<td>discontrac-k</td>
<td>0.5628</td>
<td></td>
<td></td>
<td></td>
<td>0.6174</td>
</tr>
<tr>
<td>discrowd</td>
<td>-0.5364</td>
<td></td>
<td></td>
<td></td>
<td>0.6418</td>
</tr>
<tr>
<td>homesource</td>
<td>-0.4716</td>
<td></td>
<td></td>
<td></td>
<td>0.5592</td>
</tr>
</tbody>
</table>

(Blanks represent abs(loading)<.4)

Based on the variables under the respective factors, the four factors were labelled as ‘indoor living conditions’ (labeled in tables as ‘indoorfacility’), ‘the perceived disadvantages in housing quality (labeled in tables as ‘needimprovement’)’, ‘commuting mode’ (labeled in tables as ‘commuting’), and ‘housing status’.

1) **The indoor living conditions**: The factor of indoor living condition refers to the living space of the respondent, as well as all the necessary facilities for a flat, such as toilet, gas, and connection to internet. Since Tianjin is located in the North China area, heating system is also considered as important (Table 3).

2) **The perceived disadvantages in housing quality**: This factor represent the young people’s perceived problems, mentioned in the previous content. The inadequate living space is excluded due to the 0.4-0.6 rule.

3) **The commuting mode**: The residency-to-job situation is a big concern of the working population. Two indicators are included in this factor: the commuting time, and the perceived dissatisfaction toward commuting.

4) **The housing status**: The housing status factor refers to four indicators: whether the respondent is sharing flat with the others, whether he/she perceived stability in living, whether the living place is perceived crowded, and the source of providing housing to him/her.

Would the four factors be influential to the housing affordability stress of the young people, and how the decision of staying in Tianjin were influenced by the four factors and other indicators? Answers to the two questions would be discussed in the following section.
The influential factors on young people’s housing stress, satisfaction, and willing to stay

The respondents were asked to make choice among a five Likert selection to represent their satisfaction toward the living condition and their perceived housing stress. Besides, they were also asked to provide an answer on whether they would continue to stay in Tianjin or they were planning to leave this city (figure 2-4). As shown in the below figures, almost half (45.7%) of the respondents reported to feel stressed on affording housing, less than one-third of the respondents felt dissatisfied toward their living condition, and half (49.4%) of them reported that they were planning to leave the city.

Table 4 to 6 represents the results of regression analysis, showing how are the young people’s perception of affording housing, their satisfaction toward housing, and their decision to stay in Tianjin affected by various predictors. Independent variables are grouped into three categories. The first category includes the four factors of housing quality. The second category is the demographic characteristics of the respondents, including their educational level, marital status, children, and whether they are the only child of the origin family. The third category includes the socio-economic indicators, which are the monthly income and the major sources of the respondents’ income.

First, there is a look at the regression model for the perceived stress onaffording housing by the young people in Tianjin. For the four quality of housing factors, the perceived problems (need improvement) and the housing status are the two factors that were found exerting significant influence. For the demographic characteristics, the educational level and being the only child of the origin family is found be significant. That is, the higher
the educational level, the less stress they perceived on housing affordability. And being the only child can help release the stress. For the socio-economic status, monthly income and whether the respondents are still counting on income from agricultural production are found to be significant. Similar findings were also provide by studies conducted in other cities of China (Chen and Feng, 2011). As expected, the more income, the less stress. And respondents with agricultural production as one of their major income sources are found to be more stressed.

Location of young people’s housing refers to two factors in the study: ‘commuting’, which indicates the job-residency distance; and ‘needimprovement’, which includes the surrounding public facilities and community security. Although it housing price is generally believed to be varied among different locations, location is found of insignificant influence on the housing stress perceived by young people in this study. The possible explanation of this phenomenon is that there is no significant difference of housing price or rents faced by the respondents, since most of them are living in city proper or Economic Zone Area, whose average housing price is higher than the overall level in Tianjin.

In table 5, there is the regression model for the respondents’ willingness to stay in Tianjin. It is surprised to see that except the educational level and the housing status, or the other factors are not significantly influencing young people’s willingness to stay in Tianjin. The respondents with higher education level and better housing status tend to be more willing to stay.

Table 6 represents the regression analysis result for the living satisfaction of the respondents. As expected, the four factors of quality of housing are found most significant. Besides, an interesting phenomenon was observed. That is, if the respondent is from the one-child family, he or she tends to be more easily to be dissatisfied toward the living condition. This may be explained as the only child in China are more possible to be living in the urban area with better living condition and better care from their parents. As a result, after entering the society, they tend to diagnose a stronger sense of loss.

Table 4. Linear regression result of the perceived stress on affording housing

<table>
<thead>
<tr>
<th>parm</th>
<th>estimate</th>
<th>stderr</th>
<th>dof</th>
<th>t</th>
<th>p</th>
<th>stars</th>
<th>min95</th>
<th>max95</th>
</tr>
</thead>
<tbody>
<tr>
<td>needimprovement</td>
<td>-0.32</td>
<td>.04368027</td>
<td>900</td>
<td>-7.3123902</td>
<td>5.798e-13</td>
<td>***</td>
<td>-0.41</td>
<td>-0.23</td>
</tr>
<tr>
<td>indoorfacility</td>
<td>0.02</td>
<td>.04523519</td>
<td>900</td>
<td>.46612524</td>
<td>.64123865</td>
<td></td>
<td>-0.07</td>
<td>0.11</td>
</tr>
<tr>
<td>commuting</td>
<td>-0.08</td>
<td>.0484757</td>
<td>900</td>
<td>-1.6222178</td>
<td>.10510695</td>
<td></td>
<td>-0.17</td>
<td>0.02</td>
</tr>
<tr>
<td>housingstatus</td>
<td>-0.17</td>
<td>.04413572</td>
<td>900</td>
<td>-3.8623822</td>
<td>.00012033</td>
<td>***</td>
<td>-0.26</td>
<td>-0.08</td>
</tr>
<tr>
<td>marital</td>
<td>-0.12</td>
<td>.1089074</td>
<td>900</td>
<td>-1.1113538</td>
<td>.2667129</td>
<td></td>
<td>-0.33</td>
<td>0.09</td>
</tr>
<tr>
<td>child</td>
<td>0.26</td>
<td>.08986134</td>
<td>900</td>
<td>2.8443024</td>
<td>.00455177</td>
<td>**</td>
<td>0.08</td>
<td>0.43</td>
</tr>
<tr>
<td>children</td>
<td>-0.00</td>
<td>.07476322</td>
<td>900</td>
<td>-.03316458</td>
<td>.9735507</td>
<td></td>
<td>-0.15</td>
<td>0.14</td>
</tr>
<tr>
<td>edu</td>
<td>-0.16</td>
<td>.04185727</td>
<td>900</td>
<td>-3.9223604</td>
<td>.0009435</td>
<td>***</td>
<td>-0.25</td>
<td>-0.08</td>
</tr>
<tr>
<td>monthinc</td>
<td>0.08</td>
<td>.0253707</td>
<td>900</td>
<td>3.2323548</td>
<td>.00127238</td>
<td>**</td>
<td>0.03</td>
<td>0.13</td>
</tr>
<tr>
<td>incomesalary</td>
<td>0.18</td>
<td>.29185028</td>
<td>900</td>
<td>.60703629</td>
<td>.54397994</td>
<td></td>
<td>-0.40</td>
<td>0.75</td>
</tr>
<tr>
<td>incomeagri</td>
<td>-1.16</td>
<td>.53512488</td>
<td>900</td>
<td>-2.175509</td>
<td>.0298516</td>
<td></td>
<td>-2.21</td>
<td>-0.11</td>
</tr>
<tr>
<td>incomeasset</td>
<td>0.51</td>
<td>.28530952</td>
<td>900</td>
<td>1.7890495</td>
<td>.07394304</td>
<td></td>
<td>-0.05</td>
<td>1.07</td>
</tr>
<tr>
<td>_cons</td>
<td>3.20</td>
<td>.36590408</td>
<td>900</td>
<td>8.7488234</td>
<td>1.048e-17</td>
<td>***</td>
<td>2.48</td>
<td>3.92</td>
</tr>
</tbody>
</table>

Legend: * p<.05; ** p<.01; *** p<.001

Table 5. Linear regression result of the willing to stay in Tianjin
Table 6. Linear regression result of the young people’s satisfaction toward the living quality

<table>
<thead>
<tr>
<th>parm</th>
<th>estimate</th>
<th>stderr</th>
<th>dof</th>
<th>t</th>
<th>p</th>
<th>stars</th>
<th>min95</th>
<th>max95</th>
</tr>
</thead>
<tbody>
<tr>
<td>needimprovement</td>
<td>-0.03</td>
<td>.02315431</td>
<td>411</td>
<td>-1.1098818</td>
<td>.26769893</td>
<td>-0.07</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>indoorfacility</td>
<td>0.02</td>
<td>.02549106</td>
<td>411</td>
<td>.60818539</td>
<td>.54340046</td>
<td>-0.03</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>commuting</td>
<td>0.05</td>
<td>.02784271</td>
<td>411</td>
<td>1.654275</td>
<td>.09883512</td>
<td>-0.01</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>housingstatus</td>
<td>0.06</td>
<td>.02459637</td>
<td>411</td>
<td>2.2762947</td>
<td>.02334198</td>
<td>0.01</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>marital</td>
<td>0.11</td>
<td>.05757507</td>
<td>411</td>
<td>1.9090726</td>
<td>.05694885</td>
<td>-0.00</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>child</td>
<td>-0.04</td>
<td>.05210023</td>
<td>411</td>
<td>-0.8282327</td>
<td>.40801941</td>
<td>-0.15</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>children</td>
<td>0.04</td>
<td>.03511151</td>
<td>411</td>
<td>1.0990193</td>
<td>.27240302</td>
<td>-0.03</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>edu</td>
<td>0.07</td>
<td>.02211558</td>
<td>411</td>
<td>3.2374172</td>
<td>.00130396</td>
<td>0.03</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>monthinco</td>
<td>-0.03</td>
<td>.01440686</td>
<td>411</td>
<td>-1.8519278</td>
<td>.06475311</td>
<td>-0.06</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>incomesalary</td>
<td>0.11</td>
<td>.14925704</td>
<td>411</td>
<td>0.7446268</td>
<td>.45692291</td>
<td>-0.18</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>incomeasset</td>
<td>-0.10</td>
<td>.13572608</td>
<td>411</td>
<td>-0.7517477</td>
<td>.45263033</td>
<td>-0.37</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>incomeagri</td>
<td>0.09</td>
<td>.24786201</td>
<td>411</td>
<td>3.4693675</td>
<td>.72881641</td>
<td>-0.40</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td>incomeasset</td>
<td>0.04</td>
<td>.14709531</td>
<td>411</td>
<td>2.907743</td>
<td>.77137062</td>
<td>-0.25</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>_cons</td>
<td>0.08</td>
<td>.18684797</td>
<td>411</td>
<td>4.3831145</td>
<td>.66139081</td>
<td>-0.29</td>
<td>0.45</td>
<td></td>
</tr>
</tbody>
</table>

Legend: * p<.05; ** p<.01; *** p<.001

Conclusion

Based on the findings from questionnaire survey in Tianjin, this paper investigated both the physical housing situation as well as the housing satisfaction and stress perceived by the young people. Data shows that quite a few of the young people in Tianjin are still living with adverse conditions with inadequate facilities. The most urgent issues reported by the investigated respondents refer to inadequate living space, short of interior facilities, and hygiene problems. Evidence from the investigation also shows that almost half of the young people in Tianjin are living under the stress of affording housing, whether for renting or paying mortgage loan. At the meantime, nonetheless, commuting problem, desire for home ownership, and some other issues are also rated high by the young people as problem they have been encountered with.

This phenomenon was also noticed by relevant research, as well as by the local government. With limited land resources and budget, the government was seen to be struggling to find the optional point that can balance the varied desire of the young people. This study, with statistical analysis, tested several the significance of...
different factors on influencing young people’s perceived quality of life, the perceived housing stress, their desire to stay in Tianjin, as well as the housing satisfaction.

Factor analysis was used to cluster twenty-two indicators into four major aspects for evaluating the quality of young people’s life from the housing perspective. Among those aspects, holding the property right of the flat (i.e. ownership of the flat) was found to be insignificant on influencing young people’s perception of quality of life. With this finding in concern, aiming at improving the quality of life of the young people, it would be sensible for the government to give more attention on developing public rental housing with better facilities, instead of on providing subsidy on increasing young people’s home ownership rate.

The regression analysis shows that, together with the commonly perceived quintessential key factors (i.e. the demographic and socio-economic factors analyzed in the above contents), the perceived problems in living condition, the physical indoor facilities, the commuting situation, as well as the housing conditions all can significantly influence the young people’s perception of housing stress and their satisfaction toward the environment. However, the regression analysis also shows that, the young people’s decision making of whether to stay in the city or not has no significant relationship with the above factors. This finding shows that, housing subsidy, which providing young people with better housing condition, may not be helpful in attracting them to the city. With the limited resources in concern, the local government may need to make a decision between two choices in subsidized housing development: to provide more rooms/flats in order to attract ‘new blood’ and retain them, or to provide better facilities for the young people who are willing to stay but are under dissatisfaction and housing stress.

References

Acculturation of Project-Induced Immigrants: A Gender Difference Perspective

Yang Wang.1*, Jing Liu.2 and Han Liu.3

Abstract: Acculturation of project-induced immigrants is an important issue in developing countries’ urbanization process and construction of large-scale engineering projects. This article examines the hypotheses that gender has a significant effect on acculturation of project-induced immigrants and that the formation mechanism of acculturation is considerably affected by gender differences. Analysis of the resettlement questionnaire survey data (N=231, Male=106, Female=125) revealed that the acculturation of male and female immigrants is similar, while there are remarkable gender differences on adaptive mechanisms, and showed that living conditions, discriminations and debit and credit are the most concerned factors, which have significant impacts on acculturation of project-induced immigrants. However, our research uncovered that the acculturation of male immigrants is mainly affected by economic income and employment, while female is more concerned with the family development after relocation.

Keywords: Project-Induced Immigrant; Acculturation; Gender Difference; Three Gorges Dam.

1* Yang Wang
Corresponding author, Department of Construction Management, School of Civil Engineering, Wuhan University, Associate Professor, China
E-mail: wangyang.whu@foxmail.com

2 Jing Liu
School of Civil Engineering, Wuhan University, China

3 Han Liu
School of Civil Engineering, Wuhan University, China
1 Introduction

With the expansion of global population and desire to quality of living conditions, mega construction projects, such as dams, airports, ports, industrial park and etc., are booming these years, especially in developing countries\(^1\)[3][4]. The benefits derived from construction projects have been considerably aiming at economic development, rational resources utilization and poverty reduction, which are regarded as important measures to improve people's livelihood\(^5\)[6][7]. However, these projects are often accompanied by heated controversies, and beyond ecological and physical impacts related to transformation of land utilization patterns or changes of river flows, the disputes also focus on social and economic impacts, as they have also changed the lifestyles of the majority and improved public welfare\(^5\)[6][8]. A large amount of land requisition induces the displacement and resettlement of native inhabitants; the so-called project-induced immigrant is considered as one of the most significant social impact led by construction projects\(^9\)[10][11].

In the past two decades, there are about 250-300 million project-induced immigrants due to the mega construction around the world, only the Three Gorges Project, the world famous hydro-power dam, has contributed to as many as 1.3 million project-induced immigrants directly\(^9\)[12][13][14]. Project-induced immigrants are forced to remove due to the construction projects, and thus are confronted with the disintegration of social organizational structure, they have been considered as high-risk groups, who may face the risks of landlessness, homelessness and poverty\(^3\)[7][8][15].

Resettled nearby and displaced long distances are two main types of relocation and resettlement, and because of the differences in languages, social norms and other customs, their family structures, employment opportunities, resource allocations, social network and cultural inheritance are all undermined by the construction project, project-induced immigrants impose a great impact and influence on the production and livelihoods of native inhabitants\(^10\)[17][18]. These discrepancies cause segregations and conflicts as well as social prejudices and discriminations between different social groups\(^19\)[20][21]. They confront the recovery of production and work, as well as the readjustment and acculturation of psychology and livelihoods in an unfamiliar condition\(^19\)[22][23][24]. Therefore, they generally have a strong sense of special citizenship, a tightened reliance on governments, a lower sense of recognition of future social roles, and a poor sense of conscious activity to adapt to the society, which was likely to lead to a series of acculturation problems\(^3\)[21][25][26][27].

In the post-project period, the adaptation to new environment decides on whether they could return to normal livelihood levels. Acculturation is the process of adapting to the new environments by continuing socialization, and adjusting their behavior patterns and mental states. Acculturation is an important aspect of social development, covering livelihoods, productions, psychological adjustment and other specific factors. At the same time, there are also significant differences in the process of acculturation, which manifest as not only the environmental factors, such as residential communities, social environments, social services and economic development conditions, but also the social and psychological factors, such as the type of migration, age, occupation, education and culture. Especially the differences in cultural identities, social psychology, status and economic conditions caused by gender differences are more likely to lead to great differences in their acculturation. In 2000, International Finance Corporation (IFC) suggested that new policies on project-induced immigration are suggested to focus more on poverties and recoveries of production and livelihood of marginal groups, such as women\(^28\).

2 Literature review

2.1 Acculturation

Facing with changes of the environment, human beings subjectively and dynamically adjust to deal with environmental changes, showing acculturation\(^29\). It is defined that acculturation is a change process of social behavior, in which the floating population, including sojourners, refugees and immigrants respond to the external requirements to the host community. Aleksandra defines acculturation as a way of dealing with new social-culture, which is relevant to social norms, values, and cultural heritage of the receiving society. American psychologist Leland considers acculturation as a social and psychological behavior that the individual interact with the social
environment and gradually achieve a relatively stable and harmonious state, which is making psychological and behavioral response to social culture, values and life style changes. They also divided this complex adjustment process into two dimensions, namely, psychological and socio-cultural adjustment. These two aspects do not exist independently, but have lots of interactive effects: psychological adjustment affect the subjective initiative of socio-cultural adjustment, while good socio-cultural adjustment improves the psychological satisfaction of immigrants.

2.2 Cultural identity
Culture is an important way for human beings to adapt to the social and natural environment in order to survive and develop. When the objective environment has changes, the cultural atmosphere will undoubtedly change. This is the unanimous consensus of anthropologists. Immigrants are rejected by indigenous culture in different extent, and consequently maintain on the psychological distance with indigenous people, experiencing a variety of acculturative cultural identities such as inadequacy in the language, unsatisfying situation, and reduced opportunities for social interaction, which lead to the isolated "immigration island" [30]. Changes in language refer to behavioral acculturation and more overt changes in the daily life of immigrants [31]. In this sense, acculturation is the change process of original value system through continuous interaction and connection between different cultural groups.

2.3 Psychological adaptation
Psychological adaptation mainly reflects the individual's physical and mental status, which is severely affected by personal factors, such as by personality variables, social support, and life changes. Acculturation pays more attention to personal social skills, as well as the ability of acquisition of new social values and norms. And it reflects from these two dimensions of mental health and social-culture, as it is a complex process of the interaction between individuals and social environment, and it manifests the individual's psychological comfort and the acquisition of social norms, values and culture. Housing condition, the precondition of the resettlement, is a critical factor that affects immigrant’s living. Together with the neighborhood structure, housing condition will make a difference in future expectation in immigrants’ homogenization and psychological adaption [32]. Generally, welfare and expected wealth will decide the immigrants’ residential choice and psychological adaption [33]. Also, from the perspective of psychological satisfaction, social environment and public service are closely related to the immigrants’ well-being. Therefore, policy on resettlement always focused on social environment and services in order to pursue the tradeoff between the heritage and host living style [34].

2.4 Gender differences in acculturation
Gender issues, which have been normally neglected in the research of acculturation, are of critical importance. The impact of project-induced immigrants is unlikely to be gender-neutral and there is a growing recognition of gender-based vulnerability to immigration and consequent acculturation and adaptive capacity. And the academia lacks empirical studies to arrive at a consistent conclusion about what and how gender factors impact acculturation. Thus there is a need to study the impact of different factors on acculturation under gender gap. And it is important to formulate gender-specific adaptation policies to identify resources that help migrants overcome stress factors in acculturation. Gilligan's research shows that individuals form different psychological behavior patterns due to gender differences from infant, which will continue to affect the individual's social performance. Armando also argued that gender differences affect individuals’ decision-making because male and female have different social values and psychological characteristics. For example, the East Asian culture is a typical male-dominated culture, although the traditional role has changed, there are also some continuations. Berry defines acculturation as a long-term and complex adaptation process that involves acquiring new languages, reorganizing social networks, integrating social values and lifestyles.

3 Research design
3.1 Index system
This paper quantitatively analyzes the impact of acculturation on immigrants from four aspects:
culture, psychology, identity and economy. Cultural factors refer to the changes of a group after continuous contact with groups from different cultural backgrounds, where dialects and customs are important aspects of acculturation. Scholars have pointed out that housing is an important reason for the stability of immigrants living in a stable place, and the degree of government concern for migrants is closely related to subjective well-being, so the living conditions, social environment and social services are chosen to show psychological satisfaction of project-induced immigrant. In terms of identity factors, discrimination, to a certain extent, hinders immigrants' recognition of mainstream society, the higher the frequency and intensity of social interaction, the higher the level of social integration. Meanwhile, the equality of immigrant children has a significant impact on the subjective satisfaction of immigrants. In terms of economic factors, we built seven indicators to reflect the fact, such as a stable job, employment, non-agricultural skills, living costs, price levels, debt status and loan environment.

3.2 Research methods

In this paper, the T test is used to analyze the factors influencing the acculturation of project-induced immigrants and gender differences. One of the basic characteristics of a continuity variable is the infinity of a variable value. In the social science research, this type of data measurement is suitable for describing the concentrated trends and the number of discrete observations. T test is the analysis of continuous variables, through the difference between two variables average to test the difference of two variables.

At the same time, this paper uses the acculturation as the dependent variable, and the multiple linear regression analysis was used to explore the relationship between variables. In order to further explore whether there are gender differences in acculturation and whether these differences are based on other factors, the hierarchical regression model was applied to stratify the factors and enter the regression model to confirm whether there is a relationship between variables and mediation. Through the comparative research of the two regression models, the paper discusses the mechanism of gender differences on the acculturation of project-induced immigrants.

3.3 Case selection

Zigui County is the first county of the overall relocation during the Three Gorges project for its geographical location in the dam. At the same time, Zigui is a state-level poverty-stricken county, and the resettlement period of the project resettlement is earlier. There are some projects immigration problems, which is a major construction project involuntary immigration project due to the relocation time, the low compensation standard, the state-owned enterprise reform and other factors. The representative sample area in the study is in accordance with the needs of this paper. The data used in this paper are based on the questionnaire survey conducted by the researchers in Zigui County project resettlement area in March 2016. The samples were resettled by the local relocation mode. In this survey, 300 questionnaires were distributed and 232 were recovered. One invalid questionnaire was removed. There were 231 valid questionnaires, and the effective recovery rate was 77%.

4 Results

4.1 Reliability and validity analysis

Reliability refers to the degree of consistency or stability of the questionnaire. The common method is Cronbach's α coefficient method, α value between 0 and 1, the larger the value of α, the higher the consistency of the internal consistency of the questionnaire. It is generally believed that and α value greater than 0.8 indicates an excellent internal consistency, α value of 0.6 to 0.8, and a lower than 0.6 indicates poor internal consistency. The analysis shows that the overall Cronbach's alpha coefficient is 0.611; the questionnaire has internal consistency within the reasonable range.

Validity refers to the correctness of the survey results, that is, the degree of proximity between the survey results and the target. The commonly used validity index is surface validity, content validity, criterion correlation validity, structural validity, aggregation validity and discriminant validity. It is usually considered that structural validity is the most effective evaluation index. In this paper, the factor survey method is used to carry out KMO sampling suitability test and Bartlett spherical test. KMO values are between 0 and 1, the greater the value
of KMO, the better validity is. A KMO value less than 0.4 indicates a poor questionnaire, which is not suitable for factor analysis\textsuperscript{[40]}. The results show that the KMO value is 0.633, greater than 0.4. Bartlett spherical test significance reached a significant level, which is 0.000, less than 0.05, indicating that the questionnaire structure is basically reasonable.

4.2 Descriptive statistical analysis

This paper makes a descriptive statistical analysis of the basic characteristics of male and female migrant workers, and the cultural, psychological, identity and economic factors which affect their acculturation by comparing the mean value of statistical data and T test. The results show that the characteristics of male and female migrants’ differences in significance and adaptability of subjective differences in factors.

After the dealing of data consistency, high sub-scores means that the group subjective feels good and the conditions are more favorable. The average age of male and female samples is too large, indicating that the distribution of migrants in the existing district is hollowing out, the second generation of project-induced immigrants more defected to large and medium cities, making migrants tend to age\textsuperscript{[41]}. Both in the dialect mastery, custom integration, living integration, exclusion of discrimination and living costs and other aspects of higher scores, there are Pratt & Whitney characteristics.

The analysis shows that there are significant gender differences in the three aspects of project resettlement, non-agricultural skills and loan environment. Men's economic factors on the subjective feelings are generally better than women and their acculturation is stronger than women, which is consistent with the findings of the previous literature, indicating that women migrant workers do have the characteristics of lack of economic and income strength, performance for the employment capacity, non-agricultural skills to master and poor career status.

From the perspective of traditional women's social roles, female project-induced immigrants pay more attention to family’s development or family’s care, which makes their employment stability and employment in the male project-induced immigrants at a significant disadvantage\textsuperscript{[42]}.

At the same time, the mean value of acculturation for male project-induced immigrants was 3.01, the standard deviation was 0.811, the mean value of acculturation was 3.02 and the standard deviation was 0.963. The homogeneity test of social fitness variance in the two groups showed that the two groups variance of acculturation is different (F = 6.138, P = 0.014). After comparing these two groups of T test values, the results show that although the male acculturation mean is slightly smaller than women, there is no statistically significant difference between the two, which to some extent reflect that the two in the overall society after the move shows no significant difference in the degree of acculturation.

4.3 Hierarchical regression model analysis

Hierarchical regression is a generalization of the statistical characteristics of the overall sample without considering the differences of other factors. The path of the impact of social factors driven by gender factors in project-induced immigrants is discussed in depth. According to the specific hierarchical relationship between variables, the basic idea is to put the variable of interest in the last step into the model to examine the exclusion of other variables in the conditions of the variable the contribution, according to the purpose of research and specific in order to analyze the various factors. The model is divided into five layers, the sample social demographic characteristics are the basic level, and then the cultural, psychological and identity factors are stratified into the model in turn, and the economic factors are the most important factors influencing the acculturation of the project-induced immigrants.

In the stratified strati-graphic regression analysis, there was a significant negative correlation between age and acculturation, indicating that the acculturation decreased with age, and the educational level was positively correlated, which is consistent with previous findings that education is a key factor in acculturation\textsuperscript{[43]}. The second stage of cultural factors shows that the factors involved in the survey have no significant impact; on the third stage of psychological factors, only living housing factors showed a significant positive relationship, which shows that the better housing conditions are, the better the acculturation of the project-induced immigrants is; on the fourth stage of identity factor analysis, the exclusion of discrimination and neighborhood exchanges showed a significant positive correlation, indicating that the less discriminatory discrimination and the more frequent neighborhood contacts, the better the immigration is; Stage
economic factors, employment issues, non-agricultural skills, price levels and loan environment are significantly positively correlated with the acculturation of project-induced immigrants. The results show that gender has no significant effect on acculturation in the first stratified regression analysis, without controlling other factors.

4.4 Multiple regression model analysis

The multiple linear regression models are divided into three groups. The three sample levels of male and female, background, culture, psychology, identity and economic factors are used as independent variables and acculturation as the dependent variable. The impact of the relevant factors on the acculturation of different project-induced immigrants groups is analyzed. The results are shown in Table 1.

Table 1 Multivariate Regression Analysis of Acculturation of Project-Induced Immigrants

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Acculturation</th>
<th>Overall</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>β</td>
<td>B</td>
<td>β</td>
</tr>
<tr>
<td><strong>Background factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>0.087</td>
<td>0.048*</td>
<td>-0.006</td>
<td>-0.09*</td>
</tr>
<tr>
<td>Age</td>
<td>-0.006</td>
<td>-0.09*</td>
<td>-0.002</td>
<td>-0.036</td>
</tr>
<tr>
<td>Education level</td>
<td>0.016</td>
<td>0.018</td>
<td>-0.022</td>
<td>-0.017</td>
</tr>
<tr>
<td><strong>Cultural factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dialect mastery</td>
<td>-0.084</td>
<td>-0.055</td>
<td>-0.146</td>
<td>-0.105</td>
</tr>
<tr>
<td>Custom into</td>
<td>0.152</td>
<td>0.116</td>
<td>0.05</td>
<td>0.043</td>
</tr>
<tr>
<td><strong>Psychological factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living conditions</td>
<td>0.23</td>
<td>0.212**</td>
<td>0.109</td>
<td>0.109*</td>
</tr>
<tr>
<td>Residential environment</td>
<td>0.025</td>
<td>0.023</td>
<td>0.153</td>
<td>0.143</td>
</tr>
<tr>
<td>Public service</td>
<td>0.016</td>
<td>0.014</td>
<td>0.247</td>
<td>0.238</td>
</tr>
<tr>
<td><strong>Identity factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living fusion</td>
<td>-0.121</td>
<td>-0.114</td>
<td>-0.197</td>
<td>-0.203</td>
</tr>
<tr>
<td>Discrimination</td>
<td>0.152</td>
<td>0.184**</td>
<td>0.259</td>
<td>0.341**</td>
</tr>
<tr>
<td>Children education</td>
<td>0.098</td>
<td>0.083</td>
<td>0.003</td>
<td>0.003</td>
</tr>
<tr>
<td>Neighborhood contacts</td>
<td>0.138</td>
<td>0.187**</td>
<td>0.252</td>
<td>0.367</td>
</tr>
<tr>
<td><strong>Economic factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stable job</td>
<td>0.131</td>
<td>0.133</td>
<td>0.11</td>
<td>0.116</td>
</tr>
<tr>
<td>Employment</td>
<td>0.135</td>
<td>0.107*</td>
<td>0.025</td>
<td>0.023*</td>
</tr>
<tr>
<td>Non-agricultural skills</td>
<td>0.052</td>
<td>0.059*</td>
<td>-0.081</td>
<td>-0.099*</td>
</tr>
<tr>
<td>Cost of living</td>
<td>-0.028</td>
<td>-0.022</td>
<td>0.171</td>
<td>0.151</td>
</tr>
<tr>
<td>Price level</td>
<td>0.013</td>
<td>0.01**</td>
<td>0.032</td>
<td>0.03**</td>
</tr>
<tr>
<td>Debt status</td>
<td>0.064</td>
<td>0.112</td>
<td>0.053</td>
<td>0.103</td>
</tr>
<tr>
<td>Loan environment</td>
<td>0.169</td>
<td>0.144*</td>
<td>0.113</td>
<td>0.111*</td>
</tr>
</tbody>
</table>

**p<0.01; *p<0.05

In the results of the above-mentioned stratification regression, the gender factor in the multiple regression analysis has a significant positive effect on the acculturation of the project-induced immigrants, which indicates that when the factors of the acculturation of male and female migrant workers are taken into account. The impact of these factors influence each other and the overall sample did not show significant differences. However, the mechanism and influence degree of each factor were not the same when the gender differences were analyzed separately in the background, culture, psychology, identity and economic factors. Studies show that when other conditions are the same, women are more adaptable to migrant life than men, but with the growing of their age, women's acculturation is declining, and this trend is not obvious among male immigrants. In the multiple regression analysis, the cultural factors in the dialect mastery and customization into the two variables did not show a significant impact.

Among the psychological factors, the living conditions were significant in the overall, male and female migrant samples, and the acculturation of women was more sensitive to the living conditions. The coefficient of influence was 0.228, which was about twice the male value. At the same time, unlike male, female immigrant groups are more sensitive to public service; the impact coefficient also reached 0.204. It can be seen that women are more concerned with living conditions and public services than those of male migrant workers. These factors directly affect their psychological satisfaction and ultimately affect the acculturation of family-based immigrant groups.
Among the identity factors, the discriminatory discrimination was significant in the overall, male and female migrant samples. Meanwhile, the acculturation of males was more sensitive to exclusionary discrimination, with a coefficient of influence of 0.341, about four times the number of females. Unlike male, female immigrant groups are more sensitive to neighborhoods, with a coefficient of influence of 0.121, while male migrant groups are almost insensitive to this, indicating that neighborhoods are more frequent and conducive to the acculturation process of female migrant groups.

Economic factors, employment issues, non-agricultural skills, price levels and loan environment have a significant impact on the acculturation of project-induced immigrants. In the employment issues and non-agricultural skills factors, male project-induced immigrants showed a unique impact, indicating that economic factors, male project-induced immigrants is still the predicament of employment issues, compared to a stable job, the employment issues are easy to influence them more and this is directly related to the degree of non-agricultural skills to master. At the same time, the two acculturations are affected by the price and loan environment, but compared to financing, the impact of the price level of the two is not high. Financing is to raise the difficulty of production and living funds, female coefficient of 0.235, about 2 times the male, indicating that women immigrant groups in the process of acculturation more attention to financing and income and other economic factors.

Multivariate regression analysis shows that the influence of background, culture, psychology, identity and economic factors on the acculturation of the two is not exactly the same. The age had a negative effect on the acculturation of female migrants, but had no effect on male migrants. The education level had a negative effect on the acculturation of male migrants, but had no effect on female immigrants. Identity and economic factors are important factors that affect the acculturation of project-induced immigrants. Men are more sensitive to discrimination in terms of discrimination, and neighborhood communication is more conducive to the process of acculturation of female migrants; employment issues and non-agricultural skills to male immigrant society There is a significant impact, but the female immigrants do not have a significant impact on the price level and the loan environment on both acculturations have an impact, but the impact of varying degrees.

5 Conclusion

Public service, neighborhood communication and loan environment are the most important factors when concerning acculturation of female project-induced immigrants. It can be seen that factors which are closely related to psychology, identity and economic turn out to be the dominant to acculturation. For psychological satisfaction, the project-induced immigrants groups are more concerned about the living conditions, but the performance of female immigrants is particularly evident, especially when the living conditions are associated with public services. Because of the clear division of labor, women are often in inferior position in their work, and they leave the labor market more easily intermittently because of childbearing responsibilities, childcare and family maintenance, accompanied with less work experience and lower job skills. Female migrants live in the limited circle, so that social interaction is more dependent on the living life-based neighbors, making the neighborhood an important channel of acculturation. The loan environment not only shows the current income and financial status of the family, but also the continuous improvement of family production and life, which, from a female perspective, makes it a symbol of life improvement and comprehensive integration into the of urban life.

The most important factors that attached to acculturation of male project-induced immigrants are the exclusionary discrimination, employment issues, and non-agricultural skills, which making identity and job related factors the main contribution to acculturation. In terms of identity factors, whether or not local residents accept or exclude immigrants are directly related to their integration into local life, while men are the mainstay of entrepreneurial employment, which is more likely to be marginalized and discriminated against in the new employment environment. In terms of economic factors, some scholars have made it clear that economic income is the basis and fundamental of the project resettlement, and the economic income of most migrant families has declined in different degrees [36]. This paper points out that the main effects of employment and non-agricultural skills are mainly exerted on male project-induced immigrants. At the same time, non-agricultural skills have a negative impact on their acculturation, because the migration are included in different industrial and commercial activities before migration, after the economic
environment changes, the original non-agricultural skills in employment and acculturation did not play a greater role, which is not in accordance with the previous study. Therefore, assistance policies such as skills and job training should focus on supporting rural migrants.

Factors such as living conditions, exclusionary discrimination, and loan environment are common in migration group. Among them, the satisfaction degree of the living conditions after the relocation is the biggest influential factor of the overall acculturation of the sample, which indicates that the migration due to the major construction projects, the improvement of living conditions which intend to meet their psychological expectations directly affect their urbanization and acculturation process. The exclusion of discrimination is the eternal topic of acculturation of project-induced immigrants, which is the most prominent in the labor market, especially in male project-induced immigrants, which is consistent with the acculturation conclusion of migrant workers in the related research. Compared with factors such as psychological and identity, project-induced immigrants groups are sensitive to the loan environment, indicating that whether the male production activities concerned about the reoperation, or woman's living conditions continue to improve, the funds are to provide a boost to its development. In the hope of the improvement of the loan environment will facilitate a better integration of project-induced immigrants groups into new urbanized life in order to achieve a comprehensive acculturation.

It is worth mentioning that previous studies have shown that cultural factors represented by dialect mastery and custom integration are also important aspects of acculturation to project-induced immigrants [44][45], but this study shows that cultural factors have no significant impact on acculturation. According to the case of Zigui County, Yichang County, Hubei Province, most of the research samples belong to the local resettlement. This kind of migration is close to the original production and living area of which the customs and cultural dialect are not much different. In the study of project-induced immigrants and compensation assessment, the researchers further pointed out that there is no language barrier in the migration of migrant workers who moved within the province [39]. This is coinciding with the previous studies.

In conclusion, this paper examines the acculturation of project-induced immigrants from the perspective of gender differences through descriptive statistics, tiered regression and multiple regression analysis. The results show that the acculturation of male and female migrants is basically the same, while the acculturation the formation mechanism is not exactly the same, there exists more significant diversities in gender characteristics. The analysis shows that the acculturation of project-induced immigrants plays different roles, such as relocation mode, migration distance and time transition, which need further study in the future. As the acculturation is a cross-discipline research, accompanied with multiple influential factors, the index system remains to be further optimized. It turns out to be complicated as the problems of project-induced immigrants and other social problems brought about by the process of urbanization mingled together, while this paper focuses on the acculturation of project-induced immigrants from the perspective of gender differences in the setting of socialization, thus exploring a new path of immigration social integration.

6. Acknowledgement
This research is granted by National Natural Science Foundation of China (Grant No. 71373190).

References


[34] J. Guardiola, F. Garcia-Quero, Buen Vivir (living well) in Ecuador: Community and environmental satisfaction without household material prosperity?, Ecological Economics 107 (2014) 177-184.


Analysis on Coupling Relationship of Financing Capability and the Competitiveness of Real Estate Enterprises in China

Liu, N.1*, Wu, Y.Z.2 and Zheng, S.3

Abstract: With the increasingly fierce competition in China's real estate industry, enterprise competitiveness becomes more important for real estate enterprises. As real estate industry is a capital-intensive, two major resources of real estate business development and operation are: funds and land, which are related to the financing capacity of real estate enterprises. Therefore, the financing capacity of enterprises on the real estate business competitiveness is very important. In the context of restricting the financing channels of real estate enterprises in China, this study proffers an empirical investigation of 87 major Chinese real estate enterprises listed on China Shanghai Stock Exchange and Shenzhen Stock Exchange in 2015, by firstly analyzed the multiple causal relationship between financing capability and enterprise competitiveness and selected the respective indicators, followed by the application of the structural equation model (SEM) to verify said relationship.

Keywords: China; Construction industry; Contracts; Competition.

1* Liu, N.
Corresponding author, Department of Land Management, School of Public Affairs, Zhejiang University, China
E-mail: liu.na.1994523@163.com

2 Wu, Y.Z.
Department of Land Management, School of Public Affairs, Zhejiang University, China
E-mail: wuyuzhe@zju.edu.cn

3 Zheng, S.
Department of Land Management, School of Public Affairs, Zhejiang University, China
E-mail: shengzheng@zju.edu.cn
1 Introduction

The real estate industry has always been an important industry in the national economy of concern to China. At present, China's real estate industry competes more fiercely. Compare to other industries, with capital-intensive features, indicating that the funds on real estate business very important. In China, the real estate business competition began to compete from the land elements. Only when the real estate enterprises in the land auction market to obtain land, which means that real estate companies can hold land to occupy the future market. In the land auction process, the fund is an important factor in the acquisition of land. It can be said that the two factors, land and capital, that determine the future development of the firm, are finally related to the financing capacity of the enterprise.

In the past two years, the Chinese government put out new policies on real estate financing and investment to tighten channels on financing. Although many scholars have studied the financing capacity and competitiveness of real estate enterprises, most of these scholars studied the index or impact of these two factors respectively, but no coupling relationship between competitiveness and financing capacity.

This paper addressed on the coupling relationships of financing capacity and competitiveness in real estate industries and quantified the relationship.

2 Theoretical analysis of coupling relationship

2.1 Concepts

Financing is a company's fund-raising behavior. According to the needs of funds required in production and operation and the current state of funds and the company's future business, companies have to raise funds to raise their own needs. In the past, scholars divided the financing into internal financing, debt financing and equity financing according to their source of funds.

The competitiveness of enterprises refers to the real estate enterprises in the corresponding development and operation of the environment to use their own resources and external resources and achieved higher than the industry standard unique competitive advantage resources.

2.2 Coupling relationship

Financing ability is an important factor in the competitiveness of real estate enterprises. In the development process of real estate enterprises, from the purchase of land, construction and sales to marketing links, if the funds have problems, which will lead to the real estate business capital chain crisis. Funds have a powerful impact on the future development of real estate business.

Various factors of financing capacity affect the competitiveness of real estate enterprises such as capital operation capacity of real estate. The better the capital operation capacity, the more stable the cash flow of the enterprise, which means the company can get more advantages in the future competition.
The competitiveness of real estate companies also has an impact on financing capacity in turn. That is because if an enterprise has more advantages in the competition than other enterprises, then it will be more vulnerable to investors favor and easier to raise funds.

3 Research methods and indicators selection

3.1 Research methods

According to the above research, the various factors of financing capacity of the real estate enterprises will have the impact on competitiveness. These factors are often measured between the indicators of endogeneity. In this paper, the number of dependent variables is not unique, and the relationship between indicators and indicators is often not a single relationship, which may involve multiple relationships. A structural equation model (SEM) approach is selected and further developed in this study for both identifying and quantifying the influence of factors (and/or layers of factors) on financing capacity and competitiveness. An advantage of the SEM is that it is a powerful analytical tool which helps to clarify the causal relationships between these latent and observed variables included in this paper. SEM provides coefficients for direct, indirect, and total (direct plus indirect) effects of variables on one another.

This paper used Amos software to build SEM model and used SPSS to generate estimations results.

3.2 Indicators selection

According to the previous scholars’ research on the financing ability of real estate and the index variable of financing ability, the indicators selected in this paper represent the internal financing ability, equity financing ability and debt financing ability of real estate enterprises respectively. These indicators are showed in Table 1 and measured by several indexes, which also showed in Table 1. Previous research on the competitiveness of enterprises without a recognized indicator, it is difficult to use the real estate business sales area or sales unit price to measure competitiveness of real estate enterprises separately. Therefore this article chooses the enterprise’s Growth of Operating profits (Growth), the sales area (Sale) and the finished area (Complete) in 2015 to measure the market competitiveness of the enterprise. (See Figure 1). Therefore, 17 indexes are selected to establish an evaluation index system of financing capacity and competitiveness.

\[ \text{Growth of Operating profits (Growth)} = \frac{\text{Salesincome}_{t}\text{Salesincome}_{t-1}}{\text{Salesincome}_{t}} \times \text{industry sales income growth rate} \]
3.3 Data sources and index processing

This paper selected major Chinese real estate enterprises listed on China Shanghai Stock Exchange and Shenzhen Stock Exchange, whose main business is real estate management and development. The data included in the model are gathered from the following sources: CSMAR database. Having removed companies with missing or abnormal data, 87 companies are included for further analysis. And this paper only selected data of these 87 companies in 2015.

Because the indexes chosen in this paper involve different dimensions and different indexes, they affect the reliability and validity. So, the indicators are firstly standardized using the following formula:

\[ y_i = \frac{x_i - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \]

Table 1 Evaluation index system of financing capacity and competitiveness

<table>
<thead>
<tr>
<th>Types of Financing</th>
<th>Factors</th>
<th>Index</th>
<th>Index code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity financing</td>
<td>Operating capacity</td>
<td>Accounts receivable turnover</td>
<td>W1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Working capital turnover rate</td>
<td>W2</td>
</tr>
<tr>
<td>Profitability</td>
<td></td>
<td>ROE</td>
<td>F1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operating profit</td>
<td>F2</td>
</tr>
<tr>
<td>Internal financing</td>
<td>Equity expansion capability</td>
<td>Capital reserve per share</td>
<td>C1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retained earnings per share</td>
<td>C2</td>
</tr>
<tr>
<td>Equity financing</td>
<td>Growth</td>
<td>Net profit growth rate</td>
<td>G1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total profit growth rate</td>
<td>G2</td>
</tr>
<tr>
<td>Debt financing</td>
<td>Solvency</td>
<td>Asset-liability ratio</td>
<td>D1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liquidity ratio</td>
<td>D2</td>
</tr>
<tr>
<td></td>
<td>Asset &amp; Size</td>
<td>Under construction area</td>
<td>A1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land reserve</td>
<td>A2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Assets</td>
<td>A3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Market value</td>
<td>A4</td>
</tr>
</tbody>
</table>

Prior to the principal component analysis and after the indicators standardized, a KMO (Kaiser-Meyer-Olkin) test is conducted to the test for the suitability of the data samples. The results shows that the KMO value is 0.782 (greater than 0.5) and P value is 0.000 (less than 0.005) which means the standardized data are suitable for principle components analysis. Also, a Reliability Statistics test is applied to check whether the indicators are reliable (See Table 2).

Table 2 The results of Reliability Statistics

<table>
<thead>
<tr>
<th>Types of competitiveness</th>
<th>Index</th>
<th>Index code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profitability</td>
<td>Growth of Operating profits</td>
<td>Growth</td>
</tr>
<tr>
<td>Market Competitiveness</td>
<td>the sales area</td>
<td>Sale</td>
</tr>
<tr>
<td>Operational competitiveness</td>
<td>the finished area</td>
<td>Complete</td>
</tr>
</tbody>
</table>
Variable | Chronbach’s α | N of items
---|---|---
Finance | 0.798 | 14
Competitiveness | 0.701 | 3
All | 0.872 | 17

As shown in Table 2, all Cronbach’s α value are greater than 0.6 or 0.7, which indicates all indicators we used is reliable.

3 The SEM for the coupling relationship

3.1 General idea of model building

Based on the theoretical analysis above, there are multiple relationships between financing capacity and competitiveness. In order to fully illustrate different effects from financing capacity to competitiveness, “financing capacity” is set as a latent variable and its measurement index is taken as 14 indexes listed in the Table 1. Three indexes are measured competitiveness and the Growth of Operating profits (Growth) is the main index, the other two indexes (Sale and Complete) are auxiliary indicators.

Figure 1. Initial model path

We set an initial acting path of how latent variable (financing capacity) affects competitiveness in Figure 1. And the output of the structural equations shows the direct and indirect coefficients of the acting path. Meanwhile, we set the measurement index of the financing capacity for direct path of competitiveness to measure the direct effect that each indicator acts on competitiveness.

3.2 Equation calculation

Not all the initial path coefficients are significant, and the results of different types of initial model fitting index are not very good. So, I have to adjust the model and change the path until the results of fitting index can match the boundary standard value and the suggestion of parameter estimation.
After many adjustments, I have removed the insignificant several paths in the final model, the revised model fitting index are showed in the Table 3. We can find that the results of fitting indexes are good and the indexes reach the boundary standard value.

Table 3 Fitting index of SEM model: absolute and relative.

<table>
<thead>
<tr>
<th>Fitting index</th>
<th>Absolute fitting index</th>
<th>Relative fitting index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chi-square</td>
<td>RMR</td>
</tr>
<tr>
<td>Evaluation standard model results</td>
<td>P&gt;0.05</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Model results</td>
<td>P=0.19</td>
<td>0.005</td>
</tr>
</tbody>
</table>

The final model is showed in the Figure 2.

3.3 Analysis of results

The estimated coefficient of each path in the revised model is showed in Table 4. The values of each path’s estimated coefficient P in the revised model are significant at the level of 0.1. Thus, every path in the revised model (final model) is significant. The model fits well.

Table 4 Estimates results of SEM fitting model.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>S.E.</th>
<th>C.R.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2</td>
<td>Finance</td>
<td>0.791</td>
<td>2.331</td>
<td>0.602</td>
</tr>
<tr>
<td>A4</td>
<td>Finance</td>
<td>0.902</td>
<td>1.262</td>
<td>4.375</td>
</tr>
<tr>
<td>A1</td>
<td>Finance</td>
<td>0.208</td>
<td>1.432</td>
<td>0.908</td>
</tr>
<tr>
<td>G2</td>
<td>Finance</td>
<td>0.211</td>
<td>0.123</td>
<td>1.234</td>
</tr>
<tr>
<td>F1</td>
<td>Finance</td>
<td>0.464</td>
<td>4.321</td>
<td>2.123</td>
</tr>
<tr>
<td>W2</td>
<td>Finance</td>
<td>0.276</td>
<td>0.123</td>
<td>4.012</td>
</tr>
<tr>
<td>Competitiveness (Growth)</td>
<td>Finance</td>
<td>0.321</td>
<td>1.683</td>
<td>4.703</td>
</tr>
<tr>
<td>Competitiveness (Growth)</td>
<td>Sale</td>
<td>0.441</td>
<td>2.897</td>
<td>3.123</td>
</tr>
<tr>
<td>Competitiveness (Growth)</td>
<td>Complete</td>
<td>0.531</td>
<td>3.428</td>
<td>3.421</td>
</tr>
<tr>
<td>Competitiveness (Growth)</td>
<td>A3</td>
<td>0.226</td>
<td>2.341</td>
<td>1.280</td>
</tr>
</tbody>
</table>
The regression results of the structural equation model show that among all 14 indicators, W1 (Accounts receivable turnover) and G1 (Net profit growth rate) are not significant at the level of 90%. The other 12 indicators are significant, among which, C1 (Capital reserve per share), A2 (Land reserve), A3 (Total assets) and A4 (Market value) all have significant and big effects on competitiveness. As expected on measured indicators of competitiveness, Sale (Sale area) and Complete (Completed area) both have a significant effects on competitiveness indicator, which is Growth of Operating profits based on the enterprises.

This paper applied the standardized estimations in the analysis for convenient in the comparison. In all indicators reflects on financing capacity, F2 (Operating profit), A4 (Market value), A2 (Land reserve), C2 (Retained earnings per share) and F1 (ROE) have a significant and big effects on financing capacity and the estimated coefficients are 0.89, 0.90, 0.47, 0.79 and 0.46 respectively. Other indicators, namely W2 (Working capital turnover rate), A1 (Under construction area) and A3 (Total assets) have significant but small effects on financing capacity.

Among all indicators that reflect on competitiveness, the results are as expected, financing capacity really has significant effects on competitiveness, and the direct and indirect coefficients are big. The results are similar with the reality. The market value, financing capacity (latent variable), Sale area and Completed area all have big effects on competitiveness and the estimated coefficients are 0.71, 0.32, 0.44 and 0.53 respectively.

To our expected, the new land reserve has smaller effects on real estate enterprise competitiveness and the estimated coefficient is only 0.17. According to the reality of real estate development, I suppose that there is time lag when the new land reserve reflects on financing capacity because it takes long time for the real estate enterprise to get the new land and construct on the land and finally sale the buildings on the land. Therefore, the new land reserve has small effects.

Only Asset-liability ratio has a significant but negative effect on financing capacity. When Asset-liability ratio is high, the company finances hard. Because creditors or lenders worry about the high debt ratio of enterprises insolvent, and the company cannot repay their funds. The higher the asset liability ratio, the higher probability indicating that the enterprise cannot repay debt.

### 4 Conclusions
Based on the actual data of 87 companies listed on China Shanghai Stock Exchange and Shenzhen Stock Exchange, this study verifies the relationship between financing capacity and competitiveness.

Firstly, according to the results of all indicators reflecting on the financing capacity, the Profitability, Equity expansion capability and assets size of real estate have big effects on financing capacity, while the Operating capacity, Growth and Solvency have smaller effects on financing capacity than expected. From this point, we know that real estate enterprises finance more by Internal financing and Debt financing as Equity expansion capability and assets size of real estate have a big effects on financing. Actually, when I found some data in Company annual report of real estate, it’s a common phenomenon that most companies get money by mortgaging land and construction under construction.

Secondly, according to the results of indicators reflecting on the competitiveness, we find that Market value, Sale area and Completed area have significant and big effects on competitiveness, especially market value. But to our expected, the new land reserve has smaller effects on competitiveness. We infer that it is because it takes time to transform the new land to buildings and sale the buildings, which measure the competitiveness.

Thirdly, we find that there are four indicators included Capital reserve per share, Land reserve, Total assets and market value have effects both on financing capacity and competitiveness, which offer an approach for real estate enterprises to improve their financing capacity and their competitiveness. Also, we find that other indicators reflect competitiveness by influencing the financing capacity and multiple relationships exist.

**Acknowledgements**

The research is supported by the National Natural Science Foundation of China (No. 71373231).

**References**


On-site Productivity in Construction Projects: Key Constraints and Improvement Measures

Hasan, A.1*, Elmualim, A.2, Rameezdeen, R.3 and Baroudi, B.4

Abstract: The importance of productivity in reducing the cost and generating profit is central across all industries including the construction industry. Consequently, construction productivity has remained a major research area in the construction management discipline. Researchers from different countries have tried to identify the most important factors impeding productivity in construction projects. This continuous effort in this direction has produced a significant amount of research. The present study undertakes a comprehensive systematic review of mainstream studies on factors affecting activity-level construction productivity published in the last fifteen years (2001–2016). A total of thirty-six articles from different sources were identified and reviewed. The outcomes of this study would help researchers and practitioners by providing the findings of previous studies in a concise manner. It is further expected that the findings will help in directing a more focused approach on productivity improvement efforts.

Keywords: Construction industry; construction projects; construction productivity; labour productivity

1* Hasan, A.
Corresponding author, Ph.D. Candidate (Construction Management), School of Natural and Built Environments, City East Campus, University of South Australia, Adelaide, Australia - 5000
Email: abid.hasan@mymail.unisa.edu.au

2 Elmualim, A.
Professor, School of Natural and Built Environments, City East Campus, University of South Australia, Adelaide, Australia – 5000
Email: Abbas.Elmualim@unisa.edu.au

3 Rameezdeen, R.
Program Director, School of Natural and Built Environments, City East Campus, University of South Australia, Adelaide, Australia – 5000
Email: Rameez.Rameezdeen@unisa.edu.au

4 Baroudi, B.
Senior Lecturer, Entrepreneurship, Commercialisation, and Innovation Centre, Faculty of the Professions, University of Adelaide, Adelaide, Australia - 5000
Email: sam.baroudi@adelaide.edu.au
1 Introduction

Despite the fact that the construction industry is a significant contributor to the economy of most of the countries \cite{[1-6]}, its productivity is still low compared to services and other industries such as manufacturing. Unlike other industries, the construction industry employs a large number of unskilled workers and lags in the adoption of modern technologies \cite{[7]}. Consequently, productivity in construction projects is mainly dependent upon human effort and performance \cite{[8]}. Previous studies show that productivity in the construction industry is facing weak or negative growth in many countries and it usually lags other industries \cite{[9][10]}. The problem of low construction productivity has remained as one of the most important issues in the construction industry \cite{[11]}.

An in-depth and comprehensive understanding of factors affecting productivity could help in focussing and directing more research efforts, thereby maximising the opportunity for productivity improvement. To ensure that the diversity of construction productivity scholarship is completely captured, a three-stage process was adopted to select articles to review. In the first stage, the review method used by previous researchers was adopted to determine the major research outputs for the chosen topic \cite{[4][12][13]}. A comprehensive desktop search was conducted under the “title/abstract/keyword” field of the major search engines such as Scopus and Science Direct to identify the scholarly works published in the area of activity-level construction productivity during the period 2001-2016. Keywords for searching were construction productivity, labour productivity, labour performance, labour efficiency, factors, and determinants.

In the second stage, the desktop search was further refined by making reference to the ten peer-reviewed journals which frequently publish scholarly papers in the field of construction productivity. This included: Journal of Construction Engineering and Management; Construction Management and Economics; International Journal of Project Management; Engineering, Construction and Architectural Management; Journal of Management in Engineering; Automation in Construction; International Journal of Productivity and Performance Management; Construction Innovation; International Journal of Construction Management; and Journal of Civil Engineering and Management. At this stage, 26 articles were selected to include in this review.

Finally, in the third stage, a reverse search technique was employed in which additional papers were sourced from the citations in the selected journal papers. This snowballing technique generated a further 10 papers. Thus, a total of 36 relevant studies were identified, all reported in the bibliography. After compilation of the literature material, the authors critically analysed these articles to identify the common issues raised by the previous writers.

2 Most Common Factors Affecting Construction Productivity

Identification of the pertinent factors affecting labour productivity is a prerequisite for any attempt to increase productivity in the construction industry \cite{[14][15]}. As a result, a large number of variables influencing construction productivity have been identified by previous researchers in different countries. However, a close examination of previous studies shows that relative occurrence rates and significance of few factors are more as compared to others. Figure 1 shows the ten most common factors impeding construction productivity on a global scale. The first six factors have been explained below in more detail.
Material shortage has been identified as a universal problem causing a significant degrading effect on construction productivity. Since materials are essential for the construction process, ineffective material management leads to inefficient use of craft labour due to disruption of the work force momentum \cite{16}\cite{17}. Material shortage not only result in idle times and cost overruns \cite{18} but also raise the master craftsmen’s demotivation level \cite{19}. Working under an incompetent supervisor reduces the motivation of the workers \cite{20} and often results in unproductive activities, poor quality work or rework, frequent unscheduled breaks, and increased idle time of resources \cite{11}\cite{16}\cite{21}. Inexperienced supervisors also slow down work thereby lowering labour productivity \cite{22}. The worker-supervisor ratio also affects the quality of supervision \cite{18}\cite{23}.

Construction productivity is highly reliant on the skills and experience of the workforce \cite{15}. Lack of skills seriously affects the completion time, cost and the quality of construction work \cite{20}\cite{24}. A shortage of suitably trained skilled workers and supervisors, a large unskilled foreign workforce, and a weakening local workforce base forces the construction companies to employ low experienced staff that severely affects construction productivity \cite{25}. Equipment shortages cause major idle time at construction sites \cite{26}. Contractors who rely on rental equipment need to consider lead time to avoid delays in delivery to site \cite{27}. Previous studies have identified issues such as old and obsolete construction equipment, shortage of spare parts, poor equipment maintenance, and inefficient operator as the most significant causes that lead to poor productivity \cite{8}\cite{20}\cite{23}.

Ineffective communication amongst site management and workers reduces the morale of the construction workers \cite{20}. Due to poor communication, technical details and site instructions are often poorly interpreted or misinterpreted \cite{16}\cite{22}. This leads to several other issues such as delays in decision making, resource shortages, and rework \cite{25}\cite{28}. Poor communication is also largely attributed to the low levels of literacy of the workers and insufficient training \cite{24}. Incomplete technical specifications, drawing errors, and lack of buildability result in continuous requests for clarifications and thereby, interruptions to the work progress \cite{16}\cite{17}\cite{20}\cite{23}. One of the main reasons behind incomplete, unclear, and impractical designs is limited time and budget allocated to the designers by the clients in a haste to expedite the bidding process \cite{19}\cite{28}. Another significant problem
causing productivity loss is late issuance of construction drawing by the consultants [26].

3 Construction Productivity Improvement

In an attempt to address the issue of low activity-level productivity in construction projects, following broad measures could be derived from Figure 1.

3.1 Effective material management

Construction projects cannot make satisfactory progress in the absence of a regular supply of materials on site. To avoid any kind of delays in the material delivery by the supplier, lead time in material procurement needs to be taken into consideration [22]. However, in construction projects in densely populated urban areas, early delivery of materials result in double handling due to inadequate storage spaces, hence causes the loss of man-hours [26]. Therefore, efficient planning, use of advanced system integration, and automation of site materials tracking practices could lead to significant improvements in material management on construction sites.

The local government should enhance the accessibility to construction materials, either through local availability or by direct imports [29]. Shortening of the travel distance from material storage area to active construction worksite and protection from theft or environmental damage could address a large number of material related problems [15]. The material wastage on site could be reduced if design changes were kept to a minimum during the construction work [4].

3.2 Adequate supervision

The labour-intensive nature of construction projects demands effective supervision of the workforce. By implementing in-house training and correct selection procedures, the effect of incompetent supervisors on productivity could be much reduced [28]. A smaller span of control during supervision fosters worker’s interference [18]. Thus, continuous supervision of labour is necessary to maximize productivity and to avoid faulty work [30]. However, some other studies suggest that workers feel embarrassed and pressed with the existence of tight audits and multiple tiers of field supervision [18].

3.3 Skill development

The construction industry is facing acute shortage of skilled workers in many countries due to rapid pace of infrastructure development. A proper ratio of craft or skilled workers to common labourers or helpers in the crew should be maintained to minimise the impact of skill shortage on productivity [15]. Training and developing their labour and staff has remained a challenged for the construction industry in developing countries due limited number of training institutions [27]. The local government could also play an important role in skill development by introducing technical schools and apprentice programs [24]. Moreover, policy makers and labour agencies should screen out the unskilled and inexperienced labour force during the recruitment process [30][31].

It was found that trained workers’ productivity was about 10 per cent higher relative to untrained workers [32]. Training and motivation also increase worker productivity [33]. Contractors should provide strong assistance and support regarding the continual training of their craftsmen [29][30]. More collaboration between academia and industry is essential to design and implement effective training programs [4].

3.4 Proper tools and equipment
The availability and use of proper tools and equipment are essential to maintain a steady productivity rate in construction projects. The occurrence of lack of tools and equipment and cost of repair can be reduced by implementing preventive maintenance measures on construction sites [28][34]. There is a need for good garages and workshops to ensure quick repair of faulty tools and plants [22][24]. The use of more reliable equipment, on-site training for mechanics, and maintenance contract for speedy repair could minimise the productivity loss [27]. Therefore, the equipment management policy of the company regarding the selection of equipment has substantial influence on productivity [4].

3.5 Proper communication

Like any other industry, the role of communication and timely availability of information is of paramount importance in the construction industry. The role of foremen in facilitating proper communication between construction workers and managers is essential to reach high levels of productivity [8]. In order to overcome poor communication, documentation such as work procedures, guidelines and manuals should be used instead of informal verbal communication [28][34]. Proper communication channels between the various parties must be established during the planning stage [25]. The use of information technology in construction projects will improve coordination, collaboration, and communication processes and thereby, construction productivity [35][36].

4 Conclusion and Further Research Suggestions

It is of common interest amongst contractors, consultants, employers, and policymakers to improve the productivity level of the construction sector. The purpose of this paper was to present the findings of previous studies in a concise and meaningful manner in order to provide some useful insights into factors affecting productivity and measures to overcome those issues in construction projects. It was found that an overall reasonable consensus exists on few significant factors such as lack of materials, inadequate supervision, and skill shortage, as discussed in this paper. The findings show that a focussed approach to ensure effective material management, adequate supervision, skill development, proper tools and equipment, and proper communication in construction projects could lead to significant improvements in productivity rates.

While these areas represent opportunities for improvement in construction productivity, further investigation is needed to unearth causes behind these factors. For example, unavailability of material appears to be caused by many reasons such as multi-handling of material, shortage of material in the market, difficulty in tracking material, and poor coordination. Some of the identified factors seem to be inter-related and therefore, their relative criticality needs to be established. For instance, poor communication and incomplete specifications often result into poor quality work and lead to another significant impediment to productivity, i.e. rework.

Emerging technologies such as Building Information Modelling (BIM), virtual reality, surveillance technologies, automation and robotics, and mobile information and communication technologies have potential to resolve some of these issues by enhancing coordination and communication in construction projects. However, the industry needs to embrace them as assets, not liabilities. Therefore, future research studies should investigate impacts of the adoption of these modern technologies and other optimization techniques such as lean construction and value engineering on construction productivity. Moreover, this paper only reviewed the previous studies addressing construction productivity at the activity level in construction projects and thereby, did
not include literature that report productivity at the level of industry or total factor productivity.

Acknowledgments

The authors want to thank the Australian Government’s financial support through an “Australian Government Research Training Program Scholarship” for Ph.D. studies and support from the University of South Australia. Without both contributions, this research would not have been possible.

References (*indicates paper relevant to Figure 1)


Economy, 18(1), 99-116.


Waste Management Practices in Australia: Comparison of Strategies

Jayasinghe, R.S. 1*, Rameezdeen, R.1 and Chileshe, N.1

Abstract: Waste management is a process of systematically collecting, segregating, transporting, reprocessing and disposing of waste according to the waste management hierarchy. Effective and efficient waste management practices are necessary for optimum resource recovery and sustainable outcomes. This is facilitated by the waste management strategies established by the government and regulatory bodies in a country. The waste management practices in Australian states/territories are governed by different strategies, policies, regulations and guidelines established by the state governments. However, there is a deficiency of knowledge on inter-state analysis of the waste management strategies to reveal the synergies between waste management practices in Australia. Therefore, the aim of this paper is to investigate the synergies between waste management practices adopted by different states/territories, their operations, infrastructure and stakeholders, based on the waste management hierarchy. To accomplish this aim, a systematic document review of strategies, policies, standards, and other documents in each state was undertaken using a systematic approach. The review developed a waste management process mapping based on the waste management hierarchy, which is a solid framework in line with the infrastructure facilities and stakeholders. The process needs to be stimulated by approaches like integration, collaboration, management, regulation, documentation and information, which have the potential to mitigate the impediments and govern the existing practices towards sustainability. The study encourages the adoption of zero waste and waste-to-energy concepts, which are strengthened by integrated infrastructure, changed levy applications, the proximity principle and up-to-date regulations and policies with the collaboration and community engagement to develop a sustainable Australia.

Keywords: Waste Management; Waste management hierarchy; Resources recovery; Infrastructure; Stakeholders; Sustainability

1 * Jayasinghe, R.S
Corresponding author, School of Natural and Built Environments, University of South Australia, Australia
E-mail: ruchini.senarath_jayasinghe@mymail.unisa.edu.au

1Rameezdeen, R. and Chileshe, N.
School of Natural and Built Environments, University of South Australia, Australia
1 Introduction

Waste generation creates detrimental environmental, economic and social impact. Waste management is therefore implemented under a waste management hierarchy for optimum and effective resources recovery. The waste management practices are governed by strategies, policies, standards, and legislation with the collaboration of government, regulatory bodies, industrial groups and the general public. In Australia, the National Waste Policy targets waste management and resources recovery from 2010 – 2020. National Waste Policy aims to “avoid the generation of waste, reduce the amount of waste (including hazardous waste) for disposal, manage waste as a resource, ensure that waste treatment, disposal, recovery and re-use is undertaken in a safe, scientific and environmentally sound manner, and contribute to the reduction in greenhouse gas emissions, energy conservation and production, water efficiency and the productivity of the land”[11]. According to statistical analysis of Australian waste management practices[2], Victoria is one of the highest waste generators, including 11.95 million tonnes (mt) of construction and demolition waste and 8.94mt of commercial and industrial waste[2]. New South Wales has the highest population growth and illustrates the highest construction and demolition waste and commercial and industrial waste recovery, which are 5.2mt and 3.3mt respectively. Noticeably, Northern Territory (0.3mt) and Tasmania (0.65mt) are the lowest waste generators[2]. Waste management practices, therefore vary between the states, which have established long-term strategies based on legislations and policies, for sustainable waste management[1]. However, there is a deficiency of knowledge on inter-state analysis of the waste management strategies to reveal the synergies between waste management practices in Australian states/territories. Therefore, the aim of this research is to investigate the synergies between waste management practices adopted by different states/territories, their operations, infrastructure and stakeholders, based on the waste management hierarchy. The paper is structured as follows. Section 1 – introduction to Australian waste management practices; section 2 – explanation of the research methodology; section 3 – thematic analysis; section 4 – waste management process mapping; section 5 – conceptual framework; section 6 – implications for future directions; and section 7 – conclusions.

2 Research Methodology

To accomplish the aim systematic documents review was conducted, which develops empirical knowledge by evaluating relevant documents both in printed and electronic forms[3]. Firstly, document selection is conducted within the boundary of waste and resources recovery practices in all eight states in Australia. The selection is based on the recently published strategies, policies and documents on waste and resources recovery. These should either be published by or published at the request of the government or a regulatory body like the Environmental Protection Authority. Table 1 presents the summary of selected documents. The random selection of the papers under the given boundary found more documents in South Australia compared to other states. Secondly, the selected documents are analysed under content and thematic analysis[3]. Content analysis is based on the main categories of the documents and it entails identifying the effective text from the documents. The thematic analysis involves a careful re-reading of documents to create an effective and rigorous discussion. In this paper the results of the thematic analysis is provided based on the main stages in the waste management hierarchy

<table>
<thead>
<tr>
<th>Types of Document</th>
<th>Victoria</th>
<th>Australian Capital Territory</th>
<th>New South Wales</th>
<th>Queensland</th>
<th>South Australia</th>
<th>Western Australia</th>
<th>Northern Territory</th>
<th>Tasmania</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategies and Policies</td>
<td>9</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Other documents (waste and resources recovery)</td>
<td>4</td>
<td>1</td>
<td>10</td>
<td>4</td>
<td>23</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>4</td>
<td>14</td>
<td>5</td>
<td>26</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>69</td>
</tr>
</tbody>
</table>
3.0 Waste management and resources recovery Process Mapping: Thematic Analysis

The thematic analysis covers the main themes based on the waste management hierarchy as shown in Figure 1, including waste management operations, stakeholders and infrastructure facilities. Waste generation at the end-of-life of products is classified based on the sources of waste, such as municipal solid waste, construction and demolition waste and commercial and industrial waste, and its characteristics, such as solid waste, liquid waste, contaminated and non-contaminated waste, and as a mixture of both categories[10,13,18,71,41,42,43,44,45]. Victoria discusses prescribed industrial waste (Category A (Banned from landfill), B, C)[10]. New South Wales defines the waste containing radioactive material and acid sulphate soils according to the Protection of the Environment Operations Act 1997. Queensland’s proposed waste framework and Northern Territory have dealt with hazardous waste reduction, safe transportation and site management[38,39]. Therefore, standard classifications are required to decide on suitable resource recovery. Waste and resources recovery are supported by infrastructure facilities including physical infrastructure (collection, resource recovery, reprocessing, hazardous waste and disposal) and soft infrastructure (waste strategies, training and development, data collection and management, online web platforms and marketing) in waste management, which depend on each other[70,10,54]. Victoria, South Australia, New South Wales and Australian Capital Territory have conducted an evaluation of physical infrastructure. Victoria has nearly 500 infrastructure facilities, and South Australia has around 400 licensed facilities for resources recovery and disposal[59,20]. The ‘Waste Less, Recycle More’ program in New South Wales had invested $250 million over five years and had over 650 infrastructure facilities[57]. These facilities are supported by internal and external stakeholders such as government, regulatory bodies, industry practitioners, supporting partners and the general community.

![Figure 1: Waste management hierarchy](image)

3.1 Waste Avoidance

Waste avoidance is the most preferred stage in the waste management hierarchy, supported by soft infrastructure. The zero waste concept seeks to minimise waste and maximise resources recovery to achieve sustainability. In Victoria, this is supported by ‘Sustainable Victoria’ and in South Australia ‘Zero waste’ and ‘Green Industries South Australia’ statutory bodies[73,10,2]. Green Industries South Australia further assists economic stability through waste management[71]. The Environmental Protection Authority in each state has directions towards best practice guidelines, regulatory frameworks for waste avoidance through economic incentives, product stewardship schemes, education and community support[8,53,13,46].
3.2 Waste recovery and reprocessing
If avoidance is not achievable, waste recovery and reprocessing is the next stage, where the generated waste is collected using collection methods depending on the source of waste. The kerbside collection system, or three bin system, is commonly used for residual, commercial, garden and hard waste collections. Skip bins are used for the collection of bulk municipal solid waste and commercial and industrial waste. Heavy construction and demolition waste collection is done by collection vehicles or tip trucks. Contaminated garden and food organics are disposed to landfill. Hence Victoria and Australian Capital Territory have separately discussed organic waste collection to ensure lower technical risk using in-vessel composting technology. The collection systems are supported by access routes and collection point proximity to the storage facilities and market demand. In Victoria, storage facilities for tyre waste are supported by the waste management policy (Storage of Waste Tyres). Undercover storage facilities and stockpiling support the maximum resources recovery of non-inert waste streams in between the main operational stages under the legislative compliance. Demand for feedstock and collection providers are significant, while locations for storage facilities and pre-sorting are still lacking. The stakeholders involved are waste collection contractors, who should be licensed to transport waste, particularly contaminated waste. Local government is the responsible party for municipal solid waste and, construction and demolition waste commercial and industrial waste collection is undertaken by contractors in the private sector.

The collected waste is then transported for resources recovery. Resources recovery centres or transfer stations, first sort the mixed waste and then consolidate it, based on its characteristics. Compared to construction and demolition waste and commercial and industrial waste, municipal solid waste is found to be less complex. Recovered construction and demolition waste and commercial and industrial waste items are sold in re-sale centres operated by the local government. Drop-off facilities are used for the waste that cannot be collected in a bin. Material recovery facilities are of two types, such as ‘clean’ Material recovery facilities, and ‘dirty’ Material recovery facilities, particularly used to compact and blade the items and then transport them to off-site processing facilities. Residual waste Material recovery facilities are designed to accept mixed solid waste to separate designated recyclable materials. The leftovers are sent directly to landfill or may be used to produce a refuse derived fuel. The demand for the resources recovery facilities depends on the demand for recovered products, which is supported by investment in advanced resource recovery technologies or pre-treating residual waste.

Materials from collection points or resources recovery facilities are further sorted and physically converted into usable products at reprocessing centers. The type of reprocessing is based on feedstock supplied by the resources recovery center. Municipal solid waste, construction and demolition waste and commercial and industrial waste use different reprocessing methods and however lack integrated reprocessing. Comparably, construction and demolition waste has the highest recovery future targets. Table 2 contains reprocessing activities based on the type of material. According to the Environment Protection (Scheduled Premises and Exemptions) Regulations 2007, Victoria needs at least 100 tonnes per month of licensed input organic waste recycling. It is supported by the Industrial waste management policy and waste management policy (Movement of Controlled Waste between States and Territories) for controlling environmental pollution and ozone-depleting substances. The Waste Management Policy (Used Packing Materials) applies to the recovery of packing materials under product stewardship schemes. South Australia’s guideline for composting for organic products targets siting, designing, operating and closure and manage of relevant infrastructure to support the composting operators, planning and regulatory bodies. The state discusses asbestos waste in municipal solid waste, its collection, composting at the end of resources recovery and disposal, while Western Australia has the Asbestos Management Plan. The concept of waste-to-energy is another reprocessing method for residual waste streams supported by anaerobic digestion and direct combustion. In thermal conversion facilities, dry feedstock is subjected to combustion to generate electricity and fuel. The New South Wales Energy from Waste Policy Statement, Victoria’s waste management policy (Solid Fuel Heating), and South Australia’s Environment Protection (Waste to Resources) Policy 2010 address thermal treatment of waste or waste-derived materials for the recovery of energy. Reprocessing should be underpinned by risk assessment, on-site inspections, and stockpile and dust management. It is stimulated by mixed waste advanced resource recovery technologies, product stewardship schemes and a landfill levy.
main stakeholders are recycling operators, resources recovery centres and transfer stations operators and remanufacturing industry partners and transportation organisations.

<table>
<thead>
<tr>
<th>Reprocessing material (biodegradable waste)</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Include garden, food, timber and paper or cardboard waste</td>
<td></td>
</tr>
<tr>
<td>Decomposition releases methane gas, a greenhouse gas</td>
<td></td>
</tr>
<tr>
<td>Conduct centralised composting and use source separation technologies and produce renewable energy and organic fertilisers</td>
<td></td>
</tr>
<tr>
<td>For wood waste, pyrolysis is a possible treatment process and can be used as mulch for the home garden and large road projects and processed into refuse derived fuel</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concrete, brick, aggregates, masonry &amp; asphalt</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Include concrete, brick rubble, asphalt, rock, homogenous materials</td>
<td></td>
</tr>
<tr>
<td>Crush and screen to produce recycled aggregate for road bases (Ex: Victoria, VicRoads)</td>
<td></td>
</tr>
<tr>
<td>Recycled concrete, bricks and rubble are used for roads bases and pavements</td>
<td></td>
</tr>
<tr>
<td>Recovered bricks can be easily reused</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plasterboard</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushed to create more plasterboard and sold to the agricultural sector as a soil conditioner</td>
<td></td>
</tr>
<tr>
<td>Can be converted to billets for packing</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plastics</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reprocessed into valuable packaging, construction, household and automotive goods</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asbestos</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos is processed to separate out organic fraction, remove residual plastic or contaminants, then dewatered, to be sent for beneficial reuses</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Reprocessing based on the type of material
(Source: [10,60,56,12,74,25])

3.3 Waste Disposal

The least preferred stage is waste disposal. Effective and secure disposal is facilitated by engineered landfills which are located close to transfer stations and reprocessing centres for optimum transportation[10]. Landfills should be licensed by the Environmental Protection Authority to receive off-site and problematic waste[47,50]. Truck wash facilities are established at the landfill site to routinely clean the trucks and fencing over the boundary of the landfill to avoid contaminated surroundings[52]. The landfill buffer is controlled under the 500m distance[24]. Landfill operators are the main stakeholders commonly under the resources recovery and reprocessing operators[33]. However, due to unacceptable practices, states have developed practice guidelines like Victoria’s best practice guidelines under the Waste Management Policy (Siting, Design and Management of Landfills)[35]. It includes siting, designing, construction, operation, maintenance, closure and post-closure of landfills. Closure of small landfills encourages residual waste into larger landfills[10,32,19]. South Australia’s closed-landfill risk assessment and post-closure management is done under Development Regulations 2008[24]. These practices support best economic, environmental and public health. Table 3 presents best practice considerations for landfills.

Table 3: Best practice considerations for landfill
(Source: [33,12,50,15,9,52,32,19])

South Australia conducts a disposal based survey and Tasmania conducts visual edits for commercial and industrial waste and construction and demolition waste entering the landfill[71]. Queensland conducts a cost-benefit analysis to compare the effect of landfill bans for particular materials, under the type of recovery, product stewardship schemes and market availability[61]. Victoria particularly tries to reduce the number of landfills due to government and community interest for resources recovery and due to strict regulatory requirements[10]. A landfill levy has been...
introduced to control the waste disposed to the landfills. The levies are varied based on the state’s waste management practice. Levy amounts are higher in metropolitan areas compared to regional areas and contaminated waste has a comparably lower levy. For example, New South Wales has the highest waste levy compared to the other states: $135.70/t in metropolitan areas whereas $78.20/t for regional areas in 2017. South Australia’s $76/t is the second largest followed by Victoria’s levy of $62.03/t. Queensland and Western Australia have similar levies, where $35/t is charged for construction and demolition waste and commercial and industrial waste, $0/t for municipal solid waste. Tasmania only has a voluntary local government levy of $2 per tonne[5]. Northern Territory does not apply levies for landfills. The payment is made by the licensed landfill holder under the regulatory guidelines and Acts such as Waste Avoidance and Resource Recovery Levy Act 2007, Environment Protection (Distribution of Landfill Levy) Regulations 2010 and Environment Protection (Distribution of Landfill Levy) Regulations 2010. The levy is an investment for the waste management infrastructure development and it is stimulated by weighbridge facilities, volumetric and topographical surveys and accurate documentation[34,51,31]. It is a financial incentive for recycling and estimates the impacts on the profit margin; specifically, the Australian Capital Territory NOWaste Commercial Waste Credit Policy discusses financial incentives which can apply in waste operations and disposal[4,62].

3.4 Transportation

Transportation is the physical connector of the main stages in the waste management hierarchy. The proximity principle facilitates optimum transportation and reduces the environmental and health impacts[49]. South Australia’s Environment Protection (Movement of Controlled Waste) Policy 2014 and Victoria’s waste management Policy (Ships’ Ballast Water) support transportation of contaminated solid and liquid waste streams[65]. However, there are limited data on transportation in commercial and industrial waste and construction and demolition waste[10]. To resolve this, ‘waste tracking systems’ being used as a source of information and a waste transport certificate is issued for the trackable waste[7]. This is supported by South Australia’s Environment Protection (Movement of Controlled Waste) Policy 2014 and Tasmania’s Environmental Management and Pollution Control (Controlled Waste Tracking) Regulations 2010[26,71].

4 Waste management process mapping

The waste management process mapping (Figure 2) illustrates the interrelationships between the waste management hierarchy, infrastructure facilities and stakeholders as discussed in section 3.0. This demonstrates the interaction between the main stages with physical and soft infrastructure and stakeholders during waste avoidance, collection, recovery and reprocessing and disposal at the end of optimum recovery.

5 Conceptual framework

The essence of the Australian waste management practices with infrastructure and stakeholders arrangement under the waste management hierarchy is presented in the conceptual framework (Figure 3). The framework highlights the interrelationship of six approaches: integration, collaboration, management, regulation, documentation and information. The waste should be managed with the integration of its operations and infrastructure. This is supported by close collaboration between the stakeholders. An information flow through the process, supported by up-to-date documentation under regulations related to waste management, is essential. The strong combination of these approaches underpins optimum waste management and sustainability.

6 Implications or future directions

Following are the main areas to be improved for sustainable waste management.

6.1 Zero waste and waste-to-energy

‘Zero waste’ maximises and ensures safe resources recovery and facilitates the environmental, economic and social
Figure 1: Waste management process mapping
sustainability. Resources recovery strategies target fill materials, concrete, brick, asphalt and timber, and promote on-site source separation under product stewardship guidelines and regulations\cite{10}. Innovative approaches for hazardous and contaminated waste management should be introduced\cite{27,28,29}. Waste-to-energy should be promoted by the Environmental Protection Authority and policies using best practice guidelines\cite{13,14,48}. This is supported by a greenhouse gas inventory to provide information on gas emissions and for future predictions\cite{13}.

6.2 Changes to levy

Changes to the existing levy system should be made according to waste classifications and demographics concerning levy rebates for recycling\cite{34}. This is stimulated by cost-benefit analysis to check the financial impacts. The optimum levy amount is calculated using \textit{Waste Business profit}=$\text{Waste receipt (collected gate fee)}+\text{Recovered products revenues}-(\text{processing cost}+\text{Disposal charges of residual waste to landfill})$\cite{27}. Upfront levy liability is a novel concept currently used in New South Wales and avoids long-term stockpiling. It is supported by mass balance reporting, where the levy liability would be incurred on the receipt of waste at the depot. The liability is extinguished at the lawful recovery and would fall at the disposal\cite{27}.

6.3 Proximity principle

The proximity principle is an efficient way of handling waste at the closest possible location to its origin. It avoids the risks and costs associated with long-distance transportation and supports exporting waste between states or overseas\cite{27,7}.

6.4 Infrastructure development

Infrastructure mapping databases to identify the locations of accessible facilities and technologies are essential. Specific infrastructure is required to deal with liquid and contaminated waste\cite{53}. Integrating the waste management infrastructure is essential as a hubs and spokes network where the land is zoned to avoid unauthorised land uses\cite{59}. Local hubs support regional hubs and both support state hubs. Spokes include a sequence of activities, like the collection, transportation and sorting before the waste is transported to hubs. Both are located proximally to support feedstocks and markets. ‘Vertically integrated’ infrastructure offers a mix of collection, transportation, resources recovery and disposal\cite{27}. Particularly, construction and demolition waste and commercial and industrial waste require well-equipped infrastructure to handle mixed bulk loads\cite{10}.
6.5 Up-to-date policy and regulatory support

Existing standards require up-to-date future publications on reprocessing specifications and liquid waste management guidelines, risk management, quality control and a market base in line with international approaches[29,27]. Noticeably, Australian Capital Territory, Western Australia, Northern Territory and Tasmania further require regulatory support and all states require information management systems for decision making, transparency and reliability.

6.6 Collaboration and community engagement

Close collaboration between the stakeholders optimises waste management and promotes community engagement, development of local policies, and procurement for mixed and integrated waste management[10,72]. This requires community education, awareness and partnership programs with industry practitioners, government and regulatory bodies[10]. For example, the Australian Sustainable Schools Initiative Australian Capital Territory (AuSSI ACT) encourages waste management among schools, and ACTSmart Office and Business programs measure waste generation and the resources recovery rate[13].

7 Conclusions

The systematic document review explored explores the synergies between Australian waste management practices based on recently published strategies, policies and standards and other documents on waste and resources recovery. The thematic analysis is conducted in accordance with waste management hierarchy Victoria in line with infrastructure facilities and stakeholders. Waste avoidance is supported by long-term strategies and policies, such as Zero waste concept, Green Industries South Australia and Sustainability Victoria. The generated waste is collected and recovered in resources recovery centers and transfer stations and reprocessed under advanced resource recovery technologies and product stewardship schemes. Material recovery facility is an advanced approach for residual waste recovery and supports waste-to-energy. Organic and asbestos waste reprocessing require a special technological atmosphere to avoid environmental harm. Transportation and storage facilities are essential for quality feedstocks[72]. Waste tracking systems record information on waste transportation. This study suggests six main approaches: integration, collaboration, management, regulation, documentation and information to facilitate sustainable waste management. To implement this integrated approach, this paper highlights future directions, such as zero waste and waste-to-energy, changes to waste levy, infrastructure development, the proximity principle, up-to-date policy and regulatory support, and collaboration and community engagement, which set productive grounds for sustainable waste management.

References


[27] Environment Protection Authority South Australia (2015a). Reforming waste management – Creating certainty for an industry to grow, Government of South Australia, Australia.


[34] Environment Protection Authority Victoria (2016). Calculating the landfill levy and recycling rebates, Victorian government, Australia.


Determinants of Labour Absenteeism in Indian Construction Industry

Ayesha, A.1*, Dyaram, L.2 and Kalidindi, S.N.3

Abstract: Manual work (labour), is the most preferred resource for construction activities in India, thereby making the construction industry labour-intensive. Most labour are inter-state migrants and are encountered with surfeit problems in the construction sites leading to absenteeism from work. The factors leading to absenteeism are related to both construction – onsite factors (workplace relationships, safety, work front and work culture) and offsite factors (basic needs, socio-cultural needs, self-identity and personal lifestyle). This cross-sectional study examines these factors in a systematic way along with labour characteristics to understand and further explore the biggest challenge faced by most Indian contractors.

Data was collected from 124 construction workers across six large construction sites in a metropolitan city from southern part of India. An Importance Performance Analysis (IPA) was carried out for assessing the conditions of work as perceived by the workers providing some key insights for contractors to focus on regulating labour absenteeism. Some of the critical areas needing contractors’ intervention were reported to be around basic provisions (such as sustenance, water, lodging, sanitation and leave of absence) and provision for expression of self-identity (such as identity cards, bank deposit account and insurance coverage). ANOVA results indicate significant differences in absenteeism rate with varied arrangements providing for basic needs and need for self-identity across the construction sites. We present managerial implications towards addressing labour absenteeism.

Keywords: Absenteeism, Construction, Labour, Basic Needs, Self-Identity, IPA

1* Ayesha, A.
Corresponding author, Masters Student, Department of Management Studies, Indian Institute of Technology Madras, Chennai, India.
E-mail: ayesha.iitm@gmail.com

2 Dyaram, L.
Associate Professor, Department of Management Studies, Indian Institute of Technology Madras, Chennai, India.

3 Kalidindi, S.N.
Professor, Department of Civil Engineering, Indian Institute of Technology Madras, Chennai, India.
1 Introduction
The construction industry in India has emerged as one of the vital economic drivers in the last two decades, accounting for 8.2% of the nation’s Gross Domestic Product (GDP). It is predicted that this growth in industry will expand up to INR 11954 billion by the end of 2017\cite{1}. A distinctive feature of the construction industry is substantially low levels of mechanization owing to surplus labour\cite{2}. The construction sector has thus remained predominantly traditional in nature, employing more than 45 million men and women workers with a high inter-state migration pattern\cite{1}. Employment in this industry is characterized by lack of any formal contract between the workers and the contractor\cite{3}. In most construction projects, it is sub-contractor who liaisons between the main contractor and the workers.

Word of mouth and informal hiring of labourers is an indication that workers of the construction industry in India come under the purview of unorganized sector\cite{3}. Further, there is no formal skill training provided to the labourers employed, resulting in a majority of these employed migrant labourers being either semi-skilled or unskilled at work. In addition, poor labour management practices\cite{4} and the unfavourable working conditions influence work commitment resulting in high rates of unscheduled voluntary labour absenteeism and turnover\cite{5}. Thus, absenteeism becomes one of the major issues that directly impact the productivity of any construction site and create subsequent economic loss and delay in the project completion\cite{4}\cite{5}. Further, in recent times, there is growing attention from academia and industry in studying this phenomenon and address the key issues of labour absenteeism to augment effectiveness and efficiency at worksites. Given this, we explore some of the key attributions of absenteeism as reported by the workers themselves and highlight areas that require attention from the contractors to enable commitment, increased productivity and regulate absenteeism.

2 Labour Absenteeism in construction sites
Absenteeism is any unscheduled absence from work, either for short or long periods. Extant research on absenteeism establishes that employee absenteeism is related to various personal, attitudinal and organizational characteristics\cite{6}\cite{7}. While scheduled labour absenteeism is legitimate, more often than not absenteeism owing to poor work environment or lack of work commitment is cited to have adverse impact on construction operations and profitability in India\cite{4}\cite{3}. Construction projects in India are labour – intensive and more than 40% of capital cost of large projects is spent on labour. Given this, unscheduled labour absenteeism becomes highly detrimental to project performance and inhibits efficient cost utilisation.

A domino effect of performance impediment due to absenteeism occurs at a worker level as well as at the contractor level. Absenteeism has implications for workers themselves in terms of disruption in workflow, overload, increased overtime which often leads to low morale and fatigue-led spill-over\cite{5}. This delays key decisions often forcing contractors to recruit and train new set of workers. This is known to reduce productivity at site, underutilisation of capital investments, besides loss in man-hours leading to cost and schedule overruns\cite{4}. In light of these significant social and economic costs that absenteeism entails, understanding the patterns and factors that govern work absence can provide valuable inputs for the construction management and labour motivation and commitment.

While literature highlights plethora of conditions leading to absenteeism at the construction
sites such as health, working conditions at the construction sites, safety, attitudes and commitment to work, macroeconomic conditions, family obligations and other psychosocial determinants, these studies are replete with employer and management perspectives [3][5]. Further, rate of absenteeism is often derived by acquiring number of workers scheduled to work and the number actually present. Considering the poor working conditions and other attitudinal factors plaguing this industry, we chose to study workers view of their work and working conditions to explain their presence or absence to work. Paucity of studies focussing on issue of absenteeism from the perspective of the workers, makes the present study unique and contribute to the indigenous body of literature on labour absenteeism in construction industry. Although various workplace - onsite and offsite attributes contribute to absenteeism, basis literature, 8 factors were identified to contributing to voluntary labour absenteeism. We validated these factors for their applicability and relevance with field surveys and discussions with site labourers enabling refinement and development of the questionnaire. Table 1 lists the eight constructs and their attributes.

### Table 1: Study Constructs and their attributes

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Attributes and their sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplace Relationships (WR)</td>
<td>Supervisor ([4], [8], [9], [10]); Crew (co-worker) ([5], [8], [9], [11]); Labour sub-contractor ([3]–[5], [10]).</td>
</tr>
<tr>
<td>Safety and Climate (SF)</td>
<td>Safe working conditions ([5], [9], [11]–[14]); Provision of PPE (Personal Protective Equipment) ([5], [9], [12], [14]); Provision of safety training ([12], [14]); Provisions for working in unfavourable weather conditions ([4], [5], [8], [11]).</td>
</tr>
<tr>
<td>Work Front (WF)</td>
<td>Availability of tools ([5]); Adequate work load ([5]); Excessive rework ([5]); Provision of skill training [13].</td>
</tr>
<tr>
<td>Work Culture (WC)</td>
<td>Working overtime ([5], [3], [14]); Timely payment ([3], [5], [11]); Taking leave on day after pay day ([15]); Rewards for work (Self); Flexibility at work [4].</td>
</tr>
<tr>
<td>Basic Needs (BN)</td>
<td>Provision of food ([3], [4], [15]); Drinking water facilities ([4], [10], [14]); Accommodation - labour colony ([3]–[5], [10], [14]); Medical facilities ([3], [4], [10], [14]); Sanitary facilities ([3], [4], [10]); Leave provisions ([4], [10]).</td>
</tr>
<tr>
<td>Self-Identity (SI)</td>
<td>Providing ID cards (Self); Opening bank account (Self); Insurance provisions ([3], [10])</td>
</tr>
<tr>
<td>Socio Cultural needs (SC)</td>
<td>Attending family functions [4]; Going home for festivals ([4], [5]); Voting in elections (Self); Performing religious rituals ([4], [5], [15]); Going out with co-workmen (Self); Meeting non-workplace friends (Self); Spending time with spouse/family[4]; Going home for agricultural harvest ([4], [5], [15]); Group absenteeism[5].</td>
</tr>
<tr>
<td>Personal Lifestyle (PL)</td>
<td>Alcoholism ([4], [5], [9], [11], [15]); Ability to maintain health conditions([3]–[5], [9], [15]); Work fatigue ([4], [5]); Watching movies (Self); Owing debts [4].</td>
</tr>
</tbody>
</table>

### 3 Methodology

Towards determinants of absenteeism as reported by workers, we sought consent from a government organization (client) for whom 6 large scale private contractors were involved in residential building construction. The six sites (S1 to S6) were chosen based on the single client with a homogenous governing norms of contract and from those of the state (Tamil Nadu). Questionnaire consisted of 5 sections pertaining to demographics, absenteeism, job-satisfaction, workplace- onsite and offsite factors. The onsite and offsite factors were measured on a bidirectional, Importance-Performance, 5-point Likert scale. Content validity was established through a sixteen member (8 from academia and 8 from construction industry) expert validation
panel on the parameters of clarity, relevance, comprehensiveness and representativeness of the items in the questionnaire. Following expert validation, the questionnaire was translated into a common language (Hindi) for ease of understanding by the migrant workers in these construction sites. This was done with the assistance of bilingual translators proficient in both English and Hindi. A three step iteration of forward and backward translations was done to converge on the equivalent Hindi version of the questionnaire. Workers were administered the questionnaire in person. Further, as no single worker’s particulars were sought, workers’ anonymity and confidentiality of the data was assured limiting social desirability and self-report bias specially for factors such as workplace relationships. Workers represented various activities of construction life cycle including masonry, painting, carpentry, plumbing, tiling, and rebar workers.

### 3.1 Descriptive statistics

The sample consisted of 124 labourers (94% men and 6% women), aged between 18 to 60 years (M=28.2, SD=9.6). About 50% were married and 63% had more than 5 dependents in their family. 96% were migrants from different cities of various states of India (45% Bihar, 23% Orissa, 11% West Bengal, 7% Tamil Nadu (intra-state migration), 6% Madhya Pradesh, 4% Andhra Pradesh, 2% Jharkhand and 2% Uttar Pradesh) with only 15% of the labour residing with their family. Sample represented linguistic differences (25% Hindi, 23% Maithili, 21% Odia, 11% Bengali, 9% Bhojpuri, 6% Tamil and 6% Telugu).

Their prior construction related work experience ranged from 0 to 30 years (M=6.9, SD=6.6) and wide disparity in their education levels; 19% had no schooling, 31% had completed only primary education, 47% completed their high school and 3% had an undergraduate degree. Their occupational status indicated that 72% were unskilled workers, 10% semi-skilled workers and 18% skilled labour. All the workers were sub-contracted in nature; working 8 to 12 hours per day on an average and received work payment on daily/weekly basis. The contractor provided lodging facility outside the site premises, were occupied by 82% workers and 18% stayed in own/rented housing. 63% commute to the site by company provided transport.

### 3.2 Importance Performance Analysis (IPA) and One-way ANOVA Analysis

Data was analysed using diagnostic tool Importance – Performance Analysis (IPA)[16] IPA helps in a) factors that need to be prioritized/improved, b) factors that require more attention/ deployment of resources, c) factors that are satisfactory in nature, and d) factors that are given greater attention[17]. IPA was used to assess simultaneously- the level of Importance (I) assigned to an attribute by the workers as well as their perceptions of the contractor’s Performance (P) on that attribute. An IP matrix was plotted at a construct level using the means (Figure 1). For a four quadrant IP matrix, the grand mean of all the attributes on the I-P scale was used as hair points. The quadrants into which the attributes are plotted give an indication of its potential to either encourage or moderate absenteeism.

**Quadrant 1 - Keep up the good work:** The constructs of Safety & climate and Work-front appeared in this quadrant suggesting that the expectations of the labourers in terms of safe working conditions and their daily work load matched their expectations to an extent.

**Quadrant 2 - Potential Overkill:** This implies that the labourers remain absent for socio-cultural reasons, regardless of whether their absence is scheduled or not. Also, it is noted that the supervisors at the site usually do not have a say in workers leaving to attend cultural festivals or other miscellaneous activities in their native as not allowing has implications in terms of labour
turnover.

Quadrant 3 - Low priority: Work-culture and Personal lifestyle attributes are matched in terms of importance given and its performance.

Quadrant 4 - Concentrate here: Most absenteeism is due to the lack of basic facilities and self-identity attributes. The site management must consider to improve on these attributes to curb absenteeism.

3.2.1 IPA - Gap Analysis

Gap analysis was carried out to identify attributes that have significant Importance-Performance difference (I-P ≥ 1.5) values which indicate that greater the difference, higher is the dissatisfaction relating to that construct. The mean values for each construct’s importance and performance along with the I-P difference is shown in Table 2.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Importance (I)</th>
<th>Performance (P)</th>
<th>I-P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workplace Relationships (WR)</td>
<td>4.15</td>
<td>4.18</td>
<td>0</td>
</tr>
<tr>
<td>Safety and climate (SF)</td>
<td>4.53</td>
<td>3.17</td>
<td>1.4</td>
</tr>
<tr>
<td>Workfront (WF)</td>
<td>4.40</td>
<td>3.19</td>
<td>1.2</td>
</tr>
<tr>
<td>Workculture (WC)</td>
<td>3.78</td>
<td>2.86</td>
<td>0.9</td>
</tr>
<tr>
<td>Basic Needs (BN)</td>
<td>4.77</td>
<td>2.42</td>
<td>2.4</td>
</tr>
<tr>
<td>Self – Identity (SI)</td>
<td>4.53</td>
<td>1.55</td>
<td>3.0</td>
</tr>
<tr>
<td>Sociocultural factors (SC)</td>
<td>4.22</td>
<td>3.50</td>
<td>0.7</td>
</tr>
<tr>
<td>Personal lifestyle (PL)</td>
<td>3.60</td>
<td>2.94</td>
<td>0.7</td>
</tr>
</tbody>
</table>

The analysis revealed that constructs - Self-identity and Basic needs have significant I-P differences whereas the safety and climate construct is in the acceptable range (Table 1). Hence an in-depth gap-analysis was carried out at an item level to find specific attributes (I-P>1.5) that require attention (Table 3).
The respondents rated all six attributes of the Basic Needs (BN) construct as performing lower than expected. The workers of all six sites arrange for their subsistence needs such as meals or tiffin on their own as it is not provided by the site management. Further, drinking water impurities and contamination are rampant in S4 and S5. Lodging facilities provided were not habitable in sites S4, S5, S6. Sanitation and hygiene were of great concern in sites S2, S4, S5. While first aid was arranged on the sites, medical emergency and treatment costs were often borne by the workers. Moreover, with no clear casual/medical leave processes, workers end up in loss of pay owing to absence for medical and health reasons across the sites. The Self-Identity (SI) attributes underperformed as well – labour force could not be identified or differentiated from site to site as there were no provisions for worker identification such as provision of identity cards, attendance system aligned to it across S1, S2, S3 and S5; with no provision for cash deposit in bank often led to deprivation of social security benefits such as accident insurance coverage across S2, S3, S4, S5, and S6. Further, most workers were not skilled or trained for required skills at the site often skills picked up on the job or from other workers. Hence, workers were found to voice for minimum training for safety measures for them to stay longer at the work site indicating issues of (WF4) and (SF3). Dire conditions at the work sites were also indicated with no respite from extreme weather conditions where temperature (SF4) often exceeds 40°C or with no feedback or recognition for a job well done (WC3). All of the above had important implications in terms of labour health, absenteeism and turnover. At the least, addressing these basic provisions would bring in a sense of workmanship among labourers enabling them to curb unscheduled absenteeism.

### 3.2.2 One way ANOVA

The independent between groups ANOVA yielded a statistically significant effect among all the six sites with respect to absenteeism. The F value of 9.15 significant at 0.05 level, indicates that there are logistic and operational differences across sites contributing different reasons for absenteeism.

Attendance records were observed at sites for a period of three months (January –March 2017) for the absenteeism rate, as reported in Table 4. This observed absenteeism rate complements the measured absenteeism (through worker reports). The highest absenteeism was observed at construction site S4 with a mean value of 3.6 and absenteeism rate of 43%. The reason for such high absenteeism could be attributed to the working conditions discussed above across the sites. Table 4 provides the independent between groups ANOVA yielding a statistically significant effect among all the six sites with respect to Absenteeism, Basic necessities and Self-identity. Equality of means by Welch’s statistic and Levene’s statistic for test of homogeneity among the variance were significant at 0.01 level, indicating that there are operational differences across sites explaining varied attributions for absenteeism.
### Table 4: ANOVA results of Absenteeism (Observed and Measured) rate comparison between sites

<table>
<thead>
<tr>
<th>Variable</th>
<th>Site</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Levene F Value</th>
<th>Welch F Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absenteeism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>16</td>
<td>2.56</td>
<td>22%</td>
<td>0.76</td>
<td>6.025</td>
<td>0.00</td>
</tr>
<tr>
<td>S2</td>
<td>27</td>
<td>3.21</td>
<td>34%</td>
<td>0.40</td>
<td>1.05</td>
<td>0.00</td>
</tr>
<tr>
<td>S3</td>
<td>16</td>
<td>3.17</td>
<td>31%</td>
<td>0.55</td>
<td>1.05</td>
<td>0.00</td>
</tr>
<tr>
<td>S4</td>
<td>24</td>
<td>3.56</td>
<td>43%</td>
<td>0.40</td>
<td>1.05</td>
<td>0.00</td>
</tr>
<tr>
<td>S5</td>
<td>17</td>
<td>3.29</td>
<td>37%</td>
<td>0.44</td>
<td>1.05</td>
<td>0.00</td>
</tr>
<tr>
<td>S6</td>
<td>24</td>
<td>2.65</td>
<td>26%</td>
<td>0.93</td>
<td>1.05</td>
<td>0.00</td>
</tr>
<tr>
<td>Basic Necessities</td>
<td>16</td>
<td>2.56</td>
<td>1.05</td>
<td>13.964</td>
<td>0.00</td>
<td>12.339**</td>
</tr>
<tr>
<td>S1</td>
<td>27</td>
<td>2.84</td>
<td>0.53</td>
<td>0.32</td>
<td>0.32</td>
<td>0.41</td>
</tr>
<tr>
<td>S2</td>
<td>16</td>
<td>2.48</td>
<td>0.32</td>
<td>0.46</td>
<td>0.32</td>
<td>0.41</td>
</tr>
<tr>
<td>S3</td>
<td>24</td>
<td>2.05</td>
<td>0.32</td>
<td>0.46</td>
<td>0.32</td>
<td>0.41</td>
</tr>
<tr>
<td>S4</td>
<td>17</td>
<td>2.89</td>
<td>0.41</td>
<td>0.46</td>
<td>0.32</td>
<td>0.41</td>
</tr>
<tr>
<td>S5</td>
<td>24</td>
<td>1.90</td>
<td>0.46</td>
<td>0.46</td>
<td>0.32</td>
<td>0.41</td>
</tr>
<tr>
<td>Self Identity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>16</td>
<td>2.42</td>
<td>1.21</td>
<td>16.817</td>
<td>0.00</td>
<td>17.154**</td>
</tr>
<tr>
<td>S2</td>
<td>27</td>
<td>2.05</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
</tr>
<tr>
<td>S3</td>
<td>16</td>
<td>1.4</td>
<td>0.63</td>
<td>0.63</td>
<td>0.63</td>
<td>0.63</td>
</tr>
<tr>
<td>S4</td>
<td>24</td>
<td>1.03</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>S5</td>
<td>17</td>
<td>1.28</td>
<td>0.37</td>
<td>0.37</td>
<td>0.37</td>
<td>0.37</td>
</tr>
<tr>
<td>S6</td>
<td>24</td>
<td>1.22</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
</tr>
</tbody>
</table>

**p<0.01; Note: S1 to S6 refers to Site 1 to Site 6 from where data was collected for the study.**

4 Limitations and Future scope

Cross sectional study nature limits the generalizability of the study findings. Hence there is a need for a longitudinal study of performance parameters as observed by the labourers for a comprehensive understanding of the phenomenon of labour absenteeism. Though labour anonymity was maintained, reliability of self-report measures is questionable. Likewise, multi-source and multi-method data would be promising than study’s reliance on single data source and method as IPA technique is often characterized by arbitrary measurement of importance. Future studies may examine absenteeism in construction sites of small/medium scale contractors. As India is ethnically and geographically diverse, location and period of observation could also play a key role in accounting for absenteeism studies. With a broader perspective in understanding labour issues in general and absenteeism in particular, policy changes could also emerge in systematizing the Indian construction industry.

5 Conclusion

With several labour issues plaguing the Indian construction industry, study contributes toward a dip stick view to address the issue of labour absenteeism systematically. It is evident from this study labour absenteeism can stem from contractor’s poor performance in providing basic needs for the labour; and behavioural rationale such as lack of motivation among the labour workforce. Often, the contractors fail to ascertain the importance of those attributes in increasing labour productivity and reducing absenteeism levels. IP mapping distinctively presents that basic needs
and self-identity as the factors to be worked upon to reduce absenteeism. Hence, a top down approach from the contractors is required to address the needs of labour by emphasizing the use of regulated methods from contractual agreements in employing them to providing facilities towards skill building and productive construction workforce.

References

Motivations for Green building development in Vietnam

Hong-Trang Nguyen1, Ayokunle Olubunmi Olanipekun2, Martin Skitmore2, Tanya Tyvimaa2

Abstract

The Vietnamese construction market has witnessed slow green building development to date. The motivations for enhancing green building practices that lead to increased green building development (IND1-IND9) are generic and not yet verified in the Vietnamese context. Therefore, the extent to which these motivations apply to the Vietnamese construction industry is currently unknown how. This study responds by surveying the opinions of 166 construction professionals covering the education, public and industry sectors in Vietnam. The findings reveal that all IND1-IND9 are very influential, with mean scores >3.77 out of a maximum possible 5.00. Of these, monetary benefits are the most influential, followed by societal gratification and improved human well-being, while the least influential is government regulation. Furthermore, financial incentives and economic benefits are the most influential motivators of construction professionals in each of the education, public and industry sectors. It is concluded that motivation is very important for encouraging green building development among construction professionals in Vietnam and that the government needs to focus more on providing financial and/or economic incentives as a means of increasing green building development in the country.

Keywords: Construction professionals, Green building, incentives, motivation, Vietnam

1 Corresponding author, School of Civil Engineering and Built Environment, Science and Engineering Faculty, Queensland University of Technology (QUT), AUSTRALIA. Email: hongtrang.nguyen@hdr.qut.edu.au
2 School of Civil Engineering and Built Environment, Science and Engineering Faculty, Queensland University of Technology (QUT), AUSTRALIA.
1 Introduction

Green buildings are those embracing the principles of lower environmental impact through greater energy efficiency, lower energy demand, reduced water usage, improved indoor quality and minimised construction waste throughout the building’s lifecycle\(^1\). Many developed countries such as the UK and the U.S., have formulated their own green building (GB) guidelines and certification systems\(^2\), as well as regulated incentives for GB. In Vietnam, a developing country, attempts at the development of GB are very limited\(^3\). A small proportion of the construction industry - sensitive to the pressure and demands from international investors and sophisticated buyers - has gradually attempted to seek GB certificates that have been developed by industrialised countries\(^4\).

Incentives are part of the motivators to encourage construction stakeholders to integrate GB techniques into their projects\(^5\). These are generally defined as instruments that motivate people to act in certain ways\(^5\). Several studies have pointed out that incentives are crucial in promoting GB\(^5\text{-}9\), especially when the beneficiaries manage to utilise incentives to offset the premium cost of GB or gain a competitive advantage over their rivals. Despite the importance of incentives in GB’s development, the government of Vietnam has not yet provided a clear and strong signal that could encourage GB. Supporting policies are fragmented in different sectors, consisting of policies for climate change adaptation and environmental protection, promotion of advanced technology and energy efficiency, and the direction of green growth and sustainable development.

Olubummi et al.\(^5\) reveal the incentives provided by the government, and those not related to the government, that can serve as motivation for enhancing green building practices in the construction industry. In response, therefore, this study verifies this by a questionnaire survey of 173 construction professionals - revealing the specific motivation variables that can be relied on by different construction professionals in different sectors to enhance green building practices in Vietnam.

2 Development of green building in Vietnam

The Vietnam Green Building Council (VGBC) was established in 2007 in response to the GB movement worldwide, initially from a program of Green Cities Fund, Inc., an international non-profit organisation based in California, USA\(^10\). Table 1 presents VGBC information and its associated GB certification systems – LOTUS\(^11\).

<table>
<thead>
<tr>
<th>Green Building Council</th>
<th>Associated Green Building Rating System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam Green Building Council</td>
<td>LOTUS</td>
</tr>
<tr>
<td>Year of establishment: 2007</td>
<td>The assessment tools include:</td>
</tr>
<tr>
<td>World Green Building Council</td>
<td>- LOTUS-NR for non-residential buildings;</td>
</tr>
<tr>
<td>(WGBCN) Member type: Associated Group</td>
<td>- LOTUS-R for residential buildings;</td>
</tr>
<tr>
<td></td>
<td>- LOTUS-BIO for Buildings in Operation;</td>
</tr>
<tr>
<td></td>
<td>- LOTUS Small Interiors;</td>
</tr>
<tr>
<td></td>
<td>- LOTUS Small Buildings;</td>
</tr>
<tr>
<td></td>
<td>- LOTUS Multi-family Residential;</td>
</tr>
<tr>
<td></td>
<td>- LOTUS Homes.</td>
</tr>
</tbody>
</table>

The first GB in Vietnam was certified in 2010 with the Leadership in Engineering and Environmental Design (LEED) rating system developed by the United States Green Building Council (USGBC). This prompted more action and the construction industry started to shift towards more environmentally friendly buildings. Three years later there were 41 certified GB with 6 different systems including LEED, EarthCheck, Green Globe Certification (the US), Green Star (Australia), Green Mark (GM) (Singapore) and LOTUS (Vietnam)\(^3\). In 2017, the Vietnam Green Building Council published data on the number of projects being registered with different GB certifications from 2007 to 2017 (Figure 1), showing a stronger trend towards international certification and limited recognition of the localised sustainability assessment tool.
In a paper published in the Journal of Vietnamese Architecture in 2015, Pham\textsuperscript{14} state that “the green building movement in Vietnam is only at the initial stage”. This is corroborated by Solidiance and VGBC\textsuperscript{3} and Nguyen et al.\textsuperscript{15}. There are two possible reasons. First, the delivery of GB projects often requires such advanced techniques as energy modelling or well-thought-out designs to utilise natural lighting and ventilation. While this should be done with the cooperation and coordination of multidisciplinary project participants with added competencies, it does lead to higher costs\textsuperscript{16}. Second, the benefits of GB are realised in a long period up to its lifecycle (usually 50 years), while property developers are more likely to focus on short term advantages\textsuperscript{3}. These problems have attracted the attention of the Vietnam government and various policies have been formulated as identified in Table 2. Notably, GB supporting policies in Vietnam are fragmented in different sectors and implemented under various administration agencies.

As the practice of GB concerns the conservation of resources, environment protection and sustainable development, it is generally encouraged by a number of regulations (Table 2). Nevertheless, none of these regulations addresses GB incentives directly, nor is there a specific policy or program being enacted as a single point to guide GB practices. Recently, the Vietnam Ministry of Construction proposed an internal draft entitled \textit{Decision on Green Building’s Evaluation and Certification Procedure} that is currently being evaluated.

Table 2: Policies and programs issued by the Vietnam government relating to GB\textsuperscript{12}

| Strategic planning | 1. Target Program to Respond to Climate Change 2010-2015  
2. Climate Change Adaptation Strategy 2011  
|-------------------|--------------------------------------------------------------------------------------------------|
| Coercive regulations | 1. Law on Economical and Efficient use of Energy 2010  
2. National Energy Efficiency Program 2010  
3. Energy Label Program 2010  
| Monetary instruments | 1. Accelerated depreciation tax relief for renewable energy projects 2013  
2. Preferential procurement measures towards contractors or projects/products using advanced technologies or environmentally-friendly methods (Decree 19/2015) |
| Advocacy incentives | 1. Supporting research into environmentally friendly technologies  
2. Green Lotus Hotel Programme 2012  
3. National Green Architecture Prize |
| International Programs | 1. Clean Technology Fund 2009  
2. Renewable Energy Development Project |

Energy conservation and energy efficiency policies are the only schemes being considered as an important strategy to ensure energy security, but constraints are still being faced. The energy efficiency program has been on the government agenda since 2009, and has become the
mandatory requirement for buildings with an area over 2,000 m². These energy features of GB are also weighted relatively high in GB certification – e.g. 33/110 points in 8 evaluation aspects of LEED BD-C and 31/130 points in 10 evaluation aspects of LOTUS NR. GB, therefore, can possibly benefit from energy efficiency programmes. In 2012, the government addressed the development of green building or building energy efficiency as part of its green growth strategy. These sequential policies allow GB practices and products to be encouraged through preferential procurement measures, which is a common tool employed to promote energy efficiency practices.

However, the central government maintains its control over electricity tariffs, as electricity is considered a critical commodity, so that the price may not reflect production costs and the supply-demand relationship. This makes low electricity price one of the biggest hindrances to implementing energy efficiency practices in buildings. The prices of energy fuel and electricity are also cross-subsidised through various structures. The cross-subsidies and lack of a market-based tariff pose a disincentive against adopting energy efficiency practices and green technologies. Based on the GB incentives literature, the government may employ a different approach to promote GB in the coming years along with researching a new way to manage electricity prices.

3 Literature review

This study is based on Olubunmi et al., which identifies the incentives provided by the government, and those not related to the government, that can serve as motivation for enhancing GB practices in the construction industry. As highlighted in Table 3, the first is financial incentives (IND1), which increase the financial gains for project owners in the form of tax reduction and relief, preferential loans, special funds and grants, rebates and subsidies. This incentive compensates for the high costs of sustainable building measures involved in GB projects. Similarly, the second is monetary or economically beneficial, such as relief from the compulsory fees for building development (IND2). The third is government regulations, often in the form of construction codes to enforce GB development (IND3). The fourth is administrative assistance (IND4) offered by the government to ease the administration and technical appraisal process associated with GB development proposals. The fifth is improvements to healthy and comfortable living in GB projects due to environmentally sustainable features (IND5). The sixth is the very high open market appeal of GB projects (IND6), which translates to high demand, rental values and profits. The seventh is the enhanced reputation from the ownership and/or use of GB projects (IND7). The eighth is value based, in the form of altruistic beliefs that unsustainable practices and emphasis on short-term benefits worsen general human life and the environment (IND8). The last is the inspiration and/or persuasion to adopt sustainable practices and behaviours derived from leaders in top positions or highly reputable advocates of GB development (IND9). The motivations for delivering GB projects are summarised in Table 3.

Although there are different incentives for GB practices, it remains unclear how construction professionals in Vietnam can be most influenced. This study provides an understanding of the motivations for GB practices in the Vietnam construction industry.

<table>
<thead>
<tr>
<th>Table 3: Variables of Motivation for Delivering Green Building Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Descriptor</strong></td>
</tr>
<tr>
<td><strong>External incentives provided by the government</strong></td>
</tr>
<tr>
<td>IND1</td>
</tr>
<tr>
<td>IND2</td>
</tr>
<tr>
<td>IND3</td>
</tr>
<tr>
<td>IND4</td>
</tr>
<tr>
<td><strong>Internal incentives</strong></td>
</tr>
<tr>
<td>IND5</td>
</tr>
</tbody>
</table>
IND6 High market appeal of green buildings  
Market appeal of green building projects  
e.g. high demand from private and corporate users, potentially high rental values or profit accrual to green building owners and/or developers

IND7 Societal gratification  
The enhancement of image or reputation attached to the ownership or usership of green buildings

IND8 Altruistic or personal moral norms and values  
The altruistic or personal moral norms and values that are pro-environmental and provoking green building intent

IND9 Conditional inspiration or persuasion to adopt green building and practices  
Persuasive influence of green advocacy champions or leaders  
e.g. governmental-led championing of green building practices

4 Questionnaire design and administration

This paper is a part of an on-going research project that aims to investigate the opportunities to develop policies for promoting GB in Vietnam. A well-designed questionnaire is used to survey the opinions of construction professionals. The first part of the questionnaire consists of questions eliciting the background of the respondents. The second part contains the main questions concerning the motivations that can influence construction professionals to engage in GB practices. These questions are presented to the construction professionals in the form of a 5 point Likert scale ranging from 1 (not at all influential) to 5 (extremely influential) with a side choice of 0 (don’t know)\(^2\). The questionnaire was designed into an online web format and the online web link was sent to potential respondents. A total of 224 questionnaires were completed during a 3-month period.

5 Analysis and Discussion

5.1 Data screening

Rigorous data screening is used. Of the 224 questionnaires completed, 8 duplicates were removed, 5 were not used because they have more than 3 motivation items unranked or answered as 0 as, according to Hair\(^3\), samples missing over 30% of critical data are deemed to be inappropriate for analysis. Furthermore, 41 more questionnaires with a zero standard deviation are also removed because all the motivation variables are scored the same and therefore cannot add value to the study. Four further questionnaires that do not indicate the type of organisation are also removed, leaving 166 for analysis.

5.2 Respondents’ characteristic

The respondents’ profiles are summarised in Table 4. The majority of the survey participants (about 83%) work in multi-cities/provinces and more developed locations. Industry respondents account for the largest percentage of samples (42.8%), followed by government officers (34.9%) and the education sector making up the 22.3% remainder. All groups have more than 30 valid responses, which satisfies the minimum sample size needed for any group\(^4\). 50.0% of the participants work at the directorial and managerial level, 43.4% are at the expert level and approximately 72% of all the participants have more than 5 years of experience in construction and/or real estate.
Table 4: Demographic characteristics of respondents

<table>
<thead>
<tr>
<th>Demographic characteristics</th>
<th>Frequency</th>
<th>Valid Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organisation scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>International</td>
<td>28</td>
<td>16.9%</td>
</tr>
<tr>
<td>National</td>
<td>72</td>
<td>43.4%</td>
</tr>
<tr>
<td>Multi-cities/provinces</td>
<td>44</td>
<td>26.5%</td>
</tr>
<tr>
<td>Within a province/city</td>
<td>28</td>
<td>16.8%</td>
</tr>
<tr>
<td>Types of organisation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>37</td>
<td>22.3%</td>
</tr>
<tr>
<td>Government</td>
<td>58</td>
<td>34.9%</td>
</tr>
<tr>
<td>Industry players</td>
<td>71</td>
<td>42.8%</td>
</tr>
<tr>
<td>Position in organisation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directorial level</td>
<td>23</td>
<td>13.9%</td>
</tr>
<tr>
<td>Managerial level</td>
<td>60</td>
<td>36.1%</td>
</tr>
<tr>
<td>Expert level</td>
<td>72</td>
<td>43.4%</td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
<td>6.6%</td>
</tr>
<tr>
<td>Years of experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 5 years</td>
<td>46</td>
<td>27.7%</td>
</tr>
<tr>
<td>5 - 10 years</td>
<td>44</td>
<td>26.5%</td>
</tr>
<tr>
<td>10 - 15 years</td>
<td>21</td>
<td>12.7%</td>
</tr>
<tr>
<td>15 - 20 years</td>
<td>32</td>
<td>19.3%</td>
</tr>
<tr>
<td>More than 20 years</td>
<td>23</td>
<td>13.9%</td>
</tr>
</tbody>
</table>

n=166

5.3 Descriptive analysis

The minimum, maximum, mean, standard deviations and normality of the 9 motivation items were computed and are presented in Table 5. Although the respondents use all options provided, from 1 to 5, all the motivations IND1-IND9 are very influential in Vietnam with mean value >3.77 out of 5.00.

Table 5: Descriptive features of GB motivations

<table>
<thead>
<tr>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Statistic</th>
<th>Std. Error</th>
<th>Statistic</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>IND1</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>4.07</td>
<td>.931</td>
<td>-.739</td>
<td>.188</td>
<td>.375</td>
<td>-.151</td>
<td>.375</td>
</tr>
<tr>
<td>IND2</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>4.05</td>
<td>.907</td>
<td>-.991</td>
<td>.188</td>
<td>.375</td>
<td>1.095</td>
<td>.375</td>
</tr>
<tr>
<td>IND7</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>3.92</td>
<td>1.075</td>
<td>-.837</td>
<td>.188</td>
<td>.375</td>
<td>.021</td>
<td>.375</td>
</tr>
<tr>
<td>IND5</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>3.87</td>
<td>.957</td>
<td>-.697</td>
<td>.188</td>
<td>.375</td>
<td>.192</td>
<td>.375</td>
</tr>
<tr>
<td>IND6</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>3.86</td>
<td>.900</td>
<td>-.677</td>
<td>.188</td>
<td>.375</td>
<td>.543</td>
<td>.375</td>
</tr>
<tr>
<td>IND8</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>3.84</td>
<td>1.124</td>
<td>-.964</td>
<td>.188</td>
<td>.375</td>
<td>.375</td>
<td>.375</td>
</tr>
<tr>
<td>IND9</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>3.82</td>
<td>1.053</td>
<td>-.832</td>
<td>.188</td>
<td>.375</td>
<td>.101</td>
<td>.375</td>
</tr>
<tr>
<td>IND4</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>3.79</td>
<td>1.061</td>
<td>-.552</td>
<td>.188</td>
<td>.375</td>
<td>-.534</td>
<td>.375</td>
</tr>
<tr>
<td>IND3</td>
<td>166</td>
<td>1.0</td>
<td>5.0</td>
<td>3.77</td>
<td>1.063</td>
<td>-.571</td>
<td>.188</td>
<td>.375</td>
<td>-.406</td>
<td>.375</td>
</tr>
</tbody>
</table>

The most influential incentive is IND1 (financial benefits provided by the government) with a mean of 4.07, followed by IND2 (economic benefits provided by the government) (4.05). This implies that the construction stakeholders are concerned with monetary issues relating to GB projects, and a soft loan or reduction in tax/fee can strongly drive them towards GB practices. IND7 (societal gratification) and IND5 (improved human well-being) are ranked next with a mean of 3.92 and 3.87 respectively, higher than IND6 (high market appeal of green buildings) (3.86). The results reveal that, internally, it is concerns regarding a better organisation image and better living/work environment that motivate the construction professionals and firms to engage in GB projects rather than the potential higher rental/sold values. The lowest mean values belong to IND4 (non-financial incentives and non-monetary gains provided by the government) (3.79), IND3 (leadership and assistance and regulatory requirements, technical standards and energy code) (3.77) respectively.

Standard deviations ranging from 0.900 to 1.124 indicate a lack of consistency in responses and that the opinions of the respondents vary greatly. There is also a tendency for negative skewness, although all incentive items are normally distributed, which is ranked more towards the higher end of the scale\[^{25}\], implying that the majority of the respondents considers this factor as being highly influential.
Comparing the means of the three groups of respondents: education, government and industry, it is noteworthy that the opinions of industry players are only slightly different from the others, with IND1 and IND2 being ranked the highest motivations with same mean value of 4.13. A number of industry players reveal a sceptical attitude to the possibility of a direct grant or soft loan from the government, being more optimistic about the likelihood of a tax reduction or fee waiver being implemented. Overall, for each group, the monetary benefits from the government are still ranked the highest of all incentives.

Table 6: Comparison of mean values

<table>
<thead>
<tr>
<th>GROUP</th>
<th>IND1</th>
<th>IND2</th>
<th>IND3</th>
<th>IND4</th>
<th>IND5</th>
<th>IND6</th>
<th>IND7</th>
<th>IND8</th>
<th>IND9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>4.16</td>
<td>4.14</td>
<td>3.84</td>
<td>3.73</td>
<td>4.03</td>
<td>3.67</td>
<td>3.78</td>
<td>4.00</td>
<td>4.02</td>
</tr>
<tr>
<td>Government</td>
<td>3.95</td>
<td>3.90</td>
<td>3.81</td>
<td>3.73</td>
<td>3.86</td>
<td>3.76</td>
<td>3.69</td>
<td>3.84</td>
<td>3.78</td>
</tr>
<tr>
<td>Industry</td>
<td>4.13</td>
<td>4.13</td>
<td>3.74</td>
<td>3.83</td>
<td>3.90</td>
<td>4.04</td>
<td>4.06</td>
<td>3.75</td>
<td>3.75</td>
</tr>
</tbody>
</table>

6 Conclusions and recommendations

The development of GB practices in Vietnam has attracted the growing attention of construction professionals and the government. The industry has responded to the worldwide GB movement by establishing the VGBC and subsequently developing LOTUS as a localised GB assessment tool. However, stronger motivation is needed to encourage construction professionals in Vietnam. The study reveals that financial and economic incentives provided by the government are generally considered greatly influential based on perspectives of both education sector, government officers and industry players. Therefore, the government could help by focussing more on providing such financial and/or economic incentives as preferential loans or tax reductions to accelerate GB development. Based on the current policies listed in Table 2, these incentives could be integrated into the monetary instruments (tax relief or greener procurement). However, there is a strong need to identify which GB projects need to be supported through regulating green labelling. Nguyen et al.[15] suggest that the government should pilot incentives at the local level first to test the reaction of the market before implementing supportive policies nationwide.

Acknowledgement

The study was supported by Queensland University of Technology, Australia and Institute of Environmental Science and Engineering, National University of Engineering, Vietnam. The authors would like to express their gratitude to USAID Vietnam Clean Energy Program and Mientrung University of Civil Engineering and all the survey participants for their great support in data collection. The authors would like to also thank the reviewer for providing in-depth comments and invaluable contributions.

References


What’s the “New CBD” strategy in urban renewal? 
based on Blue Ocean Strategy analysis

Wei, L.Z.¹*, Liu, G. W²

Abstract: Urban development in mainland China has changed from the previous expansion focusing on scale into the extension like content development and urban renewal. As an important way in the process of urban organic development, urban renewal plays a role in helping to solve the problems of urban natural and social environment emerging from rapid urbanization, optimizing the land use structure and releasing the potential value of urban land. On one hand, although a rat race shown in traditional real estate market caused by urbanization, as the new approach for real estate development, with the functional transformation and comprehensive renovation for the purpose of urban renewal project are becoming hot spots and making characteristics changes in terms of development rights acquisition, project design, financing mode and profit model. On the other hand, new value seems to be redefined in both urbanization and real estate development. This paper investigates key factors of new type CBD in Chengdu, which is also an urban renewal real estate project, analyzes its value innovation using the Blue ocean strategy to help business real estate investment conforming to future urban development and planning for in mainland of China.

Keywords: Urban renewal; Real estate investment project; Central Business District; Blue ocean strategy

¹Wei, L.Z
Corresponding author, Department of Construction Management and Real Estate, Chongqing University, China
E-mail: me7mo@qq.com; l.wei@cqu.edu.cn

²Liu, G.W
Department of Construction Management and Real Estate, Chongqing University, China
1 Introduction

The development of the city must be from a single function to the evolution of modern multi-functional evolution, material space and non-material space need to constantly adapt during the process of urban evolution. And urban renewal is a key approach to solve the decay of the region in terms of the demolition, urban transformation, investment and construction, to help the city style reshaping and economic prosperity through the rational allocation of urban resources and to improve the quality of urban development, which is also the inevitable stage of urban development path. Then the process of urbanization in mainland of China has also entered the process of continuously optimizing the urban spatial structure and social development of resource allocation process. With the transformation of economic system and the land system innovation, China's urbanization has also turn into marketization process, various urban renewal actions have been promoted in different scope cities. By the early 1990s, in order to improve the living environment and promote the economic development of the city, the "demolition one to build three" renovation is the main way to solve the problem of more people living with minimal funds. Since the 21st century, most cities in mainland of China have basically completed the process of rapid urbanization. However, the inner city, which has been neglected due to urban expansion, has become a hot spot for urban development again where full of urban issues like the lack of public space and facilities, the loss of diversity of the community, the destruction of historical and cultural streets and the homogenization of cities. Moreover, China's first-tier cities are facing multiple pressures including the land scarce and low utilization rate, industrial structure simple and others.

As the critical development method and important economic engine, real estate industry has experience a boom era and entered recession stage as well, its investment growth rate from 33% to 6.9% (from 2010 to 2016)\textsuperscript{11}. On the one hand, recent national policy asks real estate business to improve their own competitiveness. On the other hand, inventory pressure of commercial housing challenge new real estate investment. A rat race has shown most of first and second-tier cities market after a rapid development in different types from residence housing to commercial city complex.

This paper aims to figure out what is the new plan for real estate investment and building in city area focusing on central business district under a blue ocean strategy perspective. When confronting fierce competition and culture recall demands during urban renewal and reconstruction, culture and historical characteristic might be the new labels to develop urban. This paper uses the blue ocean strategy to evaluate a successful urban renewal project in Chengdu, which also new real estate investment strategy in national-scale scope. Section 2 describes the urban renewal environment in China and fierce competition in current market. Section 3 explains the blue ocean strategy including critical success factors in case study, as well it presents the four-action framework and strategy canvas suggestions. Section 4 shows the conclusion.

2 Urban Renewal Environment in China

2.1 Urban renewal environment

As an increasing number of Chinese city have accomplished basic urbanization process, they are transferring to modern urbanization stage focusing multi-functional connotation improvement
instead of extension through infrastructure and housing construction. To achieve the space optimization, industrial upgrading, social harmony, low-carbon ecology and other multi-city construction goals, in 2008, the State Council issued the Notice on Promoting Saving Intensive Land. In 2009, Guangzhou took the lead in starting the pilot project of "three old transformation". Subsequently, Shenzhen, Guangzhou, Shanghai and other municipal governments have set up a city renewal management agencies, to promote the implementation of urban renewal. It could be proved that urban renewal through the demolition of the main reconstruction, function upgrades, supplemented help to optimize the land use structure, the release of the old city land supply and potential use value. In 2008, the urban renewal of the demolition and construction market costs more than 1 trillion yuan [2]. In 2009, “Shenzhen City Renewal Plan in 2010-2015” urban renewal fixed asset investment target was 350 billion yuan to the cumulative promote GDP 7000 hundred million yuan, of which the city's transformation scale of 180.6km², through the demolition of urban village 12.7km² to provide residential land 6.9km², industrial land 4.6km², commercial service land 5.7km², municipal public facilities, road plaza, green space and other land 5.8km²[3].

The expansion and dismantling of large-scale urban construction land has accelerated the process of urban renewal. Urban development has entered a new transition period, that is, urban renewal also entered a large-scale, rapid development stage. In 2014, the CPC Central Committee promulgated the "National New Urbanization Plan (2014-2020)" clearly "revitalize the use of existing urban stock construction, promote the old city, old plant, urban village transformation and protective development."[4] Economic revival Oriented functional upgrading and industrial upgrading of urban renewal, and promote the adjustment of urban industrial structure, and further realize the differentiation of urban development. In January 2016, the Central City Work Conference [5] pointed out that the new development period of China's cities should be based on the principle of "revitalizing the stock and making excellent increments" to improve the quality of urban development and achieve sustainable goals.

2.2 A rat race in current market

After a large number of commercial housing construction, real estate development investment hot spots transfer to the "urban complex" commercial real estate model over the past decade that experienced a period of vigorous construction. As one common appearance of urban complex, CBD (central business districts) was first proposed by the Chicago school representative Burgess proposed[6]. CBD has undergone decades of development, gradually developed from the traditional CBD for the late type, that is to emphasize the main functions of business office, and showing a high land development intensity, high architectural and new, large population flow, traffic efficiency highly distinctive features. Moreover, traditional critical factors when invest an urban CBD include project scale, consumption demand, location, project characteristics, operating mode, construction and facilities management.

However, with the large number of the CBD development to enhance the urban image and economic development, its long-term weakness gradually emerged caused by large-scale and independent characteristics, which is not conducive to the development of the surrounding ecology, undermining the integrity of urban life and continuity, while affecting the use of urban public space efficiency. On the other hand, in context with the gradual rise in land prices, the slow pace of economic development and the strike of Internet business, some of companies face the challenge of obviously
increasing investment risk. In recent years, with the city center area of continuous exposure, people began to reflect on the past too much emphasis on the CBD function of the intensive. So today there are scholars put forward the concept of multi-functional complex CBD, that emphasizes multi-functional such as business, Entertainment, living and other functions of a variety of new CBD, indicating human resource would be the new capital as well.

Obviously, the previous CBD investment model has encountered bottlenecks while slowed down investment growth in real estate and lack of urban construction land. In this saturated situation, China's real estate market development is also facing the transformation needs, should be consistent with the trend of "cities for all" development. Additionally, in May 2017, China's urbanization thinks tank summit forum proposed "the city to start to bid farewell to the business CBD development model"[7] this view, the future development of real estate should be closely linked to the city's new drivers, namely, people and innovation. Commercial real estate development and society will be combined in order to more reflect the complex and diversified.

3 A “Blue Ocean Strategy” In Urban Renewal Environment

Kim and Mauborgne (2005) indicate a “blue ocean strategy” that emphasizes avoiding competition while creating value innovation that drives down costs while driving up value for buyers. Refering to this theory, Red ocean strategy means an existing market space, beating the competition, exploiting existing demand while blue ocean strategy is the goal of finding new customer values and creating an uncontested marketplace. [8]

3.1 Blue ocean strategy and competition

In order to protect the historical and cultural elements of our country, the earliest protection of historical blocks in our country was in 1986 and published a list of historical cities. And then have promulgated the relevant policies and regulations, such as the Ministry of Construction, "historical and cultural city protection planning norms" to promote the city center area of historical and cultural blocks of protection and re-planning [9]. In addition, in the "Tenth Five-Year" development plan, the CPC Central Committee clearly pointed out that "improve the cultural industry policy, strengthen the cultural market construction and management, and promote the development of cultural industries." The "cultural industry" has become important part in the city's economic development. Therefore, with this opportunity, the development of urban renewal from the big demolition to the functional replacement and comprehensive renovation of the change, which also to the development of the real estate market has brought new opportunities. The new value should be defied in both urbanization and real estate industry.

Value innovation as the cornerstones in Blue ocean strategy which should be unique and hard to imitate. According to the "China Tourism Real Estate Development Report (2015-2016)" data show that in 2015 China's new 723 tourism real estate projects in the real estate development and construction of the main business of about 80% of the business. It is clear that the brigade project has become a kind of real estate development enterprises keen way.

It can be said that the development of urban culture is the inevitable path of future urban renewal. Based on local culture excavation, combining tourism, recreation and commercial could be a new real estate investment approach. Then, according to Red Ocean phenomenon shown in real estate
market in mainland of China recently, the commercial real estate model investment need innovation and market boundary remodeling.

### 3.2 Case study of Chengdu city

Whatever the fact in past decades or planned in new urban development strategy of china, Chengdu city has played a leading role in west southern area, making significant economic contribution and occupied critical transport location. Then the real estate investment and urbanization process there are typical and attracting extensive attention. Then, this paper chose one new CBD project called Taikoo Li Chengdu as a case, which is also well knew as a successful urban renewal project, then deeply discuss its distinction and new value investment with Blue ocean strategy analysis tool in following section.

#### 3.2.1 Overview of CBD in Chengdu

There are more than 150 CBD in Chengdu reported by Sichuan commercial real estate association, Chengdu commercial complex total area planned to reach 27.57 million square meters in 2015 that are more than 1.5 times in 2012. After a CBD construction boom in Chengdu, it seems become a stock CBD market and some of them are homogenization. A business survey reports that top three popular CBD with their building characteristic in Chengdu are MIXC, New Century Global Center, EGO square. The main problems in CBD development of Chengdu include: 1) similar of product positioning and business model, the overlap of project formats brand introduction, homogeneous competition between investment operations and lack of culture background; 2) lack of long-term policy and manage mechanism system for CBD construction in Chengdu such as capital inclusive; 3) few experience have shown in CBD development and operation like lack of human resource; 4) the challenges caused by electric business seem increase the risk.

However, Taikoo Li Square as an urban renewal project has several differences with previous CBD in Chengdu, such as development rights acquisition, project design, financing mode, profit model and so on. The project well knew as Sino-Ocean Taikoo Li Chengdu is considered to be "a new form of development of contemporary metropolitan centers, not a traditional urban complex or a commercial center." During the trial business, usual footfall was up to 8,000 while holiday passenger flow were 20,000 people.

#### 3.2.2 Critical characteristic of Taikoo Li Square

The grant Daci temple is located in the heart of the city with deep cultural heritage, built between the 3rd and 4th centuries that is the cultural and business center of Chengdu even in the Tang and Song dynasties. Close to Chunxi Road and Hongxing Road, it is the cultural and business center of Chengdu with 1600 years of history background. However, due to the disorderly development of the urban area in the past, the historical buildings and street patterns of the Daci Temple Area were broken, and a large number of urban poverty groups were gathered before the transformation. In 2003, Chengdu clear the historical and cultural city protection system, and the introduction of "Chengdu City Master Plan 2003 - 2020" along with multi-drive like policy environment, original value recall, demand of residents, as a new city card positioning and industrial upgrading power, it was being regenerated into a low density and open-space commercial travelling district by the Swire Properties and Ocean Group in 2008.

The several critical characteristics contributed to meet the differentiation and creative goal, as
summarized as following:

(1) It is in accordance with the renovation plan of the history section of the grand Daci temple, and meet the goal and positioning of entire city. Chengdu city has been given both economic zone and “Travelocity” label, as an important urban renewal project, resources of the grand Daci temple area obviously are redeveloped to new city scene.

(2) It reserved residential groups in the west, sharing marketplace business district in spatial level, contain local life atmosphere and views in central city, which also shown residents-led concept in modern urban planning.

(3) Multi-function buildings have been well redesigned during urban renewal, it combines different elements such as finance, shopping mall, recreation and residence. In addition, it presents well interaction with original commercial zone there.

(4) As shown in Table 2, the old building has been saved and blend in multiple modern business patterns through redesign [17], provided a great number of public space for “buyers”. It seems to gather local citizens and attract travelers, which makes Visitors Flow Rate to become one of main competition ability of this CBD.

Table 2. Historical building protection and Function replacement in Taikoon Li

<table>
<thead>
<tr>
<th>Historical Building</th>
<th>Historical Background</th>
<th>Renovation Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangdong Hall</td>
<td>Built in the early years of the Republic, was used in Chengdu, Guangdong people gathering venues, watching Cantonese opera.</td>
<td>It has become a fully equipped multi-purpose venue, can hold fashion shows, musical art performances, cultural and artistic display.</td>
</tr>
<tr>
<td>Font tower</td>
<td>Built in the Ming Dynasty, high 7.6 meters, for the double hexagonal brick structure, the use of green brick, carved with fine scholar ink pattern. In ancient times for the burning of ink to show respect, so called the pyramid.</td>
<td>It reserves as historical site for cultural representative</td>
</tr>
<tr>
<td>Pen-style street</td>
<td>Late Qing Dynasty low-level official building courtyard, the main function of the official text of the official documents for the translation of the text</td>
<td>After the transformation as the entrance of the hotel lobby</td>
</tr>
<tr>
<td>Zhang Hua Li 7/8 Yard</td>
<td>Previous residential yard in the Republic of China</td>
<td>It changes to High-end SPA clubhouse</td>
</tr>
<tr>
<td>Xin Lu</td>
<td>Built in the late Qing Dynasty, before the liberation of its last master named Pu Xinlu, so its name &quot;Xin Lu&quot;, is the classic courtyard of Sichuan, its lower for shops, the upper for living.</td>
<td>It reserves as historical site for cultural representative</td>
</tr>
<tr>
<td>Ma Jiaxiang</td>
<td>About the late completion of the Qing Dynasty, is the region to save a more complete life of the Buddhist temple, there are meditation for Zen Zen worship and meditation for living.</td>
<td>High-end dining place after the introduction</td>
</tr>
</tbody>
</table>

(5) Multiple business type configuration for various consumption demands, as well as comprehensive facilities supply and management, making Taikoo Li square become best choice. It also accomplishes revenue model from selling to leasing, for instance, Fourth quarter 2016
performance report shows that the rental rate increased by 4% over the same period last year to 92%, retail sales rose 78.3%[^18], which is much better than others.

3.3 The four-action framework and strategy canvas

According to Kim and Mauborgne, the four-action framework has been established to reconstruct buyer value elements in order to craft a new curve. Contract with previous CBD in Chengdu, the renewal of Taikoo Li square show its unique investment pattern as previously mentioned. Based on the four-action framework in “Blue ocean strategy” perspective, the value innovation process could be analyzed as Table 3.

Table 3. The four-action framework and strategy canvas

<table>
<thead>
<tr>
<th>Eliminate</th>
<th>Raise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development area-led (profit-led)</td>
<td>Collaboration between companies</td>
</tr>
<tr>
<td>Same modern city planning approach</td>
<td>Experience of public space and access tree</td>
</tr>
<tr>
<td>Demolition development model</td>
<td>Transportation system</td>
</tr>
<tr>
<td>Closed CBD design</td>
<td>Multiple business type configuration</td>
</tr>
<tr>
<td></td>
<td>Operation methods</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reduce</th>
<th>Create</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial function</td>
<td>Local urban culture element excavation</td>
</tr>
<tr>
<td>New construction development</td>
<td>Promotion of business and art activity</td>
</tr>
<tr>
<td>Demand of modern design</td>
<td>Low density and open space planning</td>
</tr>
<tr>
<td>Selling revenue model</td>
<td>Culture Recreation and function exchange</td>
</tr>
</tbody>
</table>

When recognized the new value in urban development process, involution and human seem to the new capital for an urban, become the core competition as well. Experiences learned from developed cities around the world, urban development in mainland China should rethink its unique and core competition. Furthermore, city culture and loyalty that people valued are one of key factors to improve urbanization. Similar as the strategy management in industry, what buyers (customers and citizens) think will lead the planning and decision making process. According to urban planning application perspective, a new concept called “city culture complex” possessing most of foundational function of a modern city, which emphasize unique local culture elements comprising of beyond three kinds of facilities from hotel, office, public space, shopping mall, culture recreation and apartment as well. Besides, local culture recreation and public open space seems to be the most significant factors for strategy making. And multiple and creative operation approach and collaboration between stakeholders contribute to project success and might become the core competition ability for developers.

4. Conclusion

New CBD investment should blend in both local culture and committee value, not individual and segregated buildings group. The private space in city could be redesigned into a public space in order to provide spatial with culture and shared characteristics, and then polycentric stakeholders including the enterprise, government and the community might help to build a new version of real estate investment partnership with urban renewal context, which worth to be implemented in other similar urban renewal development.
References

The Impact of Capital Structure on Financing Efficiency of Infrastructure PPP Projects

Luo, Y.W.1*, Zhou, T.2 and Hou, W.H.3

Abstract: Public Private Partnerships (PPP) can introduce private finance into public infrastructure, which will overcome the limitations of government funds effectively under the monotonous financing channels. However, infrastructure PPP projects are facing many problems because of the characteristics of high investments, multiple project participants and long construction period. Analyzing the availability of PPP projects’ finance and the impact of capital structure on financing efficiency is extremely important for the development of projects. This paper defined the basic concepts in combination with the theory of capital structure and financing efficiency, and focused on what PPP projects’ financing efficiency was. On this basis, this paper carried on the qualitative analysis about the impact of capital structure on financing efficiency. PPP projects’ capital structure mainly contributed to the financing efficiency from four aspects: financing risk, financial sustainability, the tax deduction of interest and financial leverage effect. Then, this paper selected Monte Carlo simulation as the research method and took utility tunnels of Yinchuan as an example to quantify the influence of capital structure on financing efficiency. The results showed that the capital structure was related to transaction efficiency and capital utilization efficiency negatively, correlated with solvency positively. Therefore, this paper argued that PPP project companies should take transaction efficiency, capital utilization efficiency and solvency into account when formulating the project capital structure.

Key words: infrastructure PPP projects, capital structure, financing efficiency, Monte Carlo simulation

1* Luo, Y.W.
Corresponding author, School of Construction Management and Real Estate, Chongqing University, China
E-mail: 18875134953@163.com

2 Zhou, T.
School of Chongqing University, China

3 Hou, W.H.
School of Chongqing University, China
1 Introduction

PPP (Public-Private Partnership) is one of the main ways of social capital’s participation in infrastructure projects, which can solve the problem of insufficient government funds effectively by combining government and the market. However, the financing of the PPP projects is very complicated because of the diversity of the participants, the long-term construction period and the publicity of the products in infrastructure PPP projects. How to play the financing efficiency of PPP projects in order to achieve the optimal allocation of funds is one of the main problems in the development of PPP projects in China. Meanwhile, a reasonable capital structure is a key factor in the success of the project.

According to the modern capital structure theory, financing ways affect the capital structure, and ultimately affect the financing efficiency. However, what is the financing efficiency of infrastructure PPP projects? And what is the relationship between capital structure and financing efficiency? These need to be studied in depth from theory to practice.

Over the past years, there has been many well-known theories in academia. Modigliani and Miller (1958) put forward MM Theory and came to the conclusion that the company's capital structure was irrelevant to company value. Jensen and Meckling (1976) proposed Agency Cost Theory and hold that the capital structure at the lowest cost of agency was the optimal capital structure. Rose (1977) proposed Signalling Theory, she applied the signal transmission to the analysis of capital structure, and found that the information between the internal and external investors was asymmetric. Myers and Majluf (1984) suggested Pecking Order Theory and argued that companies tended to carry out internal financing. Based on theories, scholars focused on studying the optimization of corporate capital structure. Miao J (2005) proposed a model of capital structure equilibrium, and pointed out the relationship between tax deduction of interest, bankruptcy costs and the agency costs should be considered in the decision-making of capital structure. Titman S and Tsyplakov S (2007) studied the bankruptcy costs and agency relationships between shareholders and creditors in companies, and presented a dynamic capital structure model to study the impact of capital structure on debt choices.

In addition, there were few studies about the impact of capital structure on the financing efficiency of PPP projects. Scholars mainly focused on discussing the capital structure of infrastructure PPP projects. Dias, A.et al. (1995) proposed that project companies should bankruptcy cost of debt financing, and established the objective function of ROE and NPV maximization to optimize the capital structure. Bakatjan et al. (2003) took the BOT project of Turkey Electric Power as the research object, and used the linear programming method to establish a capital structure optimization model with the goal of maximizing the investor's internal rate of return. Zhang (2005) argued that capital structure affected the risk-sharing and distribution of benefits of sponsors and lenders. Moreover, he used iterative methods to simulate the risk of PPP projects and calculated the optimal capital structure. YH Kwak et al. (2009) pointed out that a reasonable capital structure is one of the key factors for the success of the PPP project. Yun et al. (2009) established the optimization model of the project capital structure by using the methods of Monte Carlo simulation and GA, and then he used a railway case to verify the model. Sharma D K et al. (2010) summed up the capital structure factors of PPP projects, and he analyzed the influencing factors through a linear
programming method and gained key factors: future earnings of the project, debt reserve ratio, and opportunity cost of public sector investment funds.

Overall, the existing literature on the capital structure research has been mature, but the research mainly stays in the area of capital structure influencing factors and the optimal capital structure, there is little research on the impact of capital structure on financing efficiency of infrastructure PPP projects. Although some scholars realized that there was some correlation between capital structure and financing efficiency, they didn't build a complete system to analyze it. Due to the complexity and particularity of the PPP projects, the reasonable capital structure and financing efficiency will determine the success of the PPP projects. Hence, it is necessary to study the impact of PPP capital structure on financing efficiency and analyze how to formulate capital structure to improve financing efficiency.

Based on the PPP project financing research, this paper will define the concept of PPP project financing efficiency, and analyzes the influence of PPP capital structure on financing efficiency with qualitative and quantitative analysis methods.

2 Research Design

2.1 Concept definitions

2.1.1 Capital Structure of Infrastructure PPP Projects
The capital structure of infrastructure PPP project companies refers to the source and proportion of equity funds and debt funds in the financing process of infrastructure projects.

(1) The source of equity funds and debt funds

The PPP project equity funds is the investment from project investors. Investors enjoy the owner's rights according to the funded ratio. PPP project debt funds mainly come from loans which take project property rights, government guarantees and project management rights as mortgage, and the repayment funds come from the project itself.

(2) The proportion of equity funds and debt funds

The proportion of equity funds and debt funds is another important part of the capital structure. For investors, the equity funds they invest and the risks they take are proportional to the investment income, which means the higher the investment revenue is, the greater the investment risks are. Therefore, investors will develop a reasonable proportion of capital to control the risk so that they can obtain investment revenue as much as possible. For creditors, the greater the proportion of equity capital is, the better the project can resist the risks and the more the amount of money that the creditors are willing to offer. So it's better for creditors when the proportion of equity funds is greater. Therefore, in order to determine the appropriate proportion of equity funds and debt funds, the interests of both investors and creditors should be taken into account.

2.1.2 Financing Efficiency of Infrastructure PPP Projects
The contradiction between the demand of rapid growth of infrastructure and the limited supply capacity of government opened up a space for the development of PPP projects in the infrastructure field. The practice of infrastructure PPP projects embodies a number of advantages: promoting the construction of infrastructure, improving public service efficiency, reducing financial investment pressures and so on. But in the process of operating the PPP mode, the following shortcomings also showed out: Government monopoly phenomenon (franchises system), complex transaction structure which leads to the reduce of financing efficiency and so on. One of the most concerned
problems recently is that how to improve the efficiency of infrastructure PPP project financing to make projects function well. While what is financing efficiency of infrastructure PPP projects is the focus of this paper.

So far, there are no scholars at home or abroad who defined the concept of infrastructure PPP financing efficiency clearly. In addition to the financing efficiency of companies, the investigation on financing efficiency mainly focuses on the area of financing efficiency of projects.

According to the existing researches, this paper argues that as a new type of infrastructure project financing model, the financing efficiency of PPP projects is not only to finance at a cost as low as possible, but also reflects in the effective allocation of funds. Therefore, financing efficiency of the infrastructure PPP projects includes transaction efficiency and allocation efficiency, the composition is shown in the following figure.

Fig.1. The conceptual structure of financing efficiency of infrastructure PPP projects

1) Transaction efficiency of infrastructure PPP project

The transaction efficiency of financing refers to the speed or efficiency of financing activities in a certain period. The financing efficiency of PPP projects is mainly reflected in the level of financing costs. In unit time, the higher the cost of financing is, the lower the efficiency of financing transactions will be. Therefore, the transaction efficiency of financing and financing costs are correlated negatively.

2) Allocation efficiency of infrastructure PPP projects

The efficiency of infrastructure PPP project allocation refers to the capital allocation of the project. Effective capital allocation is a key to the success of financing, which directly affects the financing efficiency of PPP projects. The allocation efficiency of PPP projects can be reflected in both capital utilization efficiency and financing solvency.

1) Capital utilization efficiency of infrastructure PPP projects

Capital utilization efficiency of infrastructure PPP projects is subdivided into: the rate of disbursement and the rate of capital utilization. The rate of disbursement reflects the raising and implementation of investment funds of fixed assets, which affects the financing efficiency by influencing the progress of PPP project development. Higher rate of disbursement indicates the that the implementation of funds is better, and the project financing efficiency is higher. The rate of capital utilization manifests as reasonable use of project financing to avoid capital idle. In a PPP project, higher rate of capital utilization means the funds financed for the project is fully used, the benefits of the unit funds are greater and the waste of capital is less so that the higher the efficiency of the project financing would be. It is critical to improve the efficiency of capital utilization for infrastructure projects which needs high investment and lots of time.
2) Financing solvency of infrastructure PPP projects

The financing repayment solvency of infrastructure PPP projects refers to the debt level of projects. It is an important aspect of financing efficiency and this level reflects the operation of the project and the company’s credit status. It will bring credit risk and affect refinancing if the project company can not repay debt in time. Higher solvency means the project company operates better and have more free cash for repayment so that higher the financing efficiency is.

2.2 Analysis of the Impact of Capital Structure on Financing Efficiency

The impact of capital structure of infrastructure PPP projects is affected by the operation of the PPP project company, which affects the financing efficiency. The influences are mainly in the following four aspects:

(1) The influence of financing risk

Financing risk is one of the main risks faced by infrastructure PPP projects, which runs through the full cycle of the project. Once the project's capital chain is broken and debts can not be repaid, which will affect the progress of PPP projects directly, thus affecting all aspects PPP project of financing efficiency. From the source and composition of funds, the risk brought by the equity financing of PPP projects is lower than what the debt financing brings. Because paying dividends of equity financing is flexible, and there is no periodic financial pressure. Additionally, equity financing can enhance the credit level of PPP project companies, which is conducive to refinancing, so its financing risk is low. In contrast, debt financing brings financial pressure to the project company because of its regular repayment. When there is not enough funds to repay the debt principal and interest in a PPP project company, the company will face bankruptcy risk.

(2) The influence of financial sustainability

The continuity of infrastructure project funds is the guarantee of rate of disbursement. If there is sustained financial support for the project, the possibility of breakage of capital chain and the failure of funds in time will be reduced greatly. The capital stock has a higher financial sustainability than the debt, since the capital stock is permanent and without time limitation, it does not involve the issue of return. Sustained financial support from the shareholders can ensure the rate of disbursement of PPP projects. However, due to the consideration of the credit and profitability of the project company, creditors may control the proportion of debt funds strictly. The project company may be unable to raise funds timely because of restrictions on creditors. Therefore, compared with the debt financing, equity financing can further improve capital utilization efficiency.

(3) The influence of tax deduction of interest

In theory, the cost of equity financing is higher than the cost of debt financing. One of the main reasons is that interest on debt financing can be deducted before income tax. For PPP project companies, the higher proportion of debt financing, the greater effect of interest tax credit. As the dividend that can not be deducted before tax, it does not have the influence of tax deduction compared to interest, which will increase the financing costs of PPP project companies. Therefore, the debt financing cost is lower than equity financing’s. Increasing the proportion of debt financing is conducive to improving the transaction efficiency of PPP project companies.

(4) The influence of financial leverage

Financial leverage refers to the impact of debt financing on the owner’s equity, which is an important factor that affects the efficiency of financing. After the debt financing, the equity capital interest rate of the PPP project company can be expressed as follows:
The equity capital interest rate = (ROI + (ROI – interest rate) × asset liability ratio) × (1 – income tax rate) (1)

From the formula we can see that when the project company ROI > Debt Interest Rate, Equity Capital Interest Rate > ROI, the project company's debt financing will play a positive financial leverage effect. The greater the proportion of debt financing, the more the increase in profit of the project company shareholders. On the contrary, if ROI < Debt Interest Rate, the greater the proportion of debt financing, the more the decrease in profit of the project company shareholders.

It can be seen that arranging the capital structure of PPP project reasonably to make the proportion of debt financing reach an appropriate level is important, which can benefit from the financial leverage effect of debt financing, so that project companies can enhance capital utilization efficiency.

To sum up, different capital structures have different effects on the financing efficiency of PPP projects. These effects mainly can be seen in the following four aspects: financing risk, financial sustainability, the tax deduction of interest and financial leverage effect.

Fig.2. The impact of capital structure on financing efficiency of infrastructure PPP projects

It can be seen from the figure that the capital structure of project companies determines the proportion of equity financing and debt financing, while these two financing methods affect PPP financing efficiency through the four aspects. On the one hand, standing on the PPP project equity financing point of view, due to the impact of financing risks and financial sustainability, equity financing is more favorable to project companies. Appropriate increase in the proportion of equity financing is conducive to reducing the risk of project financing and ensure rate of disbursement, which will also increase the PPP project financing efficiency. On the other hand, from the perspective of PPP project debt financing, debt financing can reduce the financing cost through the tax deduction of interest effect. At the same time, because of the two-way influence of financial leverage, the debt financing affects the allocation efficiency of project companies.

All in all, equity financing and debt financing have different influences on financing efficiency through different paths in infrastructure PPP projects. For example: from the perspective of the financial sustainability, increasing equity financing is conducive to improving capital utilization efficiency; and through the financial leverage effect, appropriate increasing in debt financing can promote capital utilization efficiency. Therefore, this paper suggests that qualitative analysis can explore the impact paths from multiple perspectives, but it can not clarify the specific influence direction and influence degree of equity financing and debt financing on financing efficiency of PPP
projects. Therefore, it is necessary to do quantitative analysis.

2.3 Study Method and Simulation Model

2.3.1 Monte Carlo Simulation

Monte Carlo simulation (also known as random sampling or statistical test) is a method of studying the distribution characteristics by setting stochastic processes, generating random sequences repeatedly, and calculating parameter estimates and statistics.

Monte Carlo simulation is different from the deterministic numerical method, it is used to solve the problem of non-determinism in engineering and economy. With this method, thousands of times of simulation will be run to obtain different data and frequency distributions at a certain probability. Hence, Monte Carlo simulation was used by many scholars to solve problems of uncertainty (Andreas Wibowo et al. 2005; K. C. Iyer 2012).

(1) The accuracy of the Monte Carlo method is high. Through several iterations of simulation, it is easy to get accurate simulation data;

(2) Monte Carlo method can simulate a large number of random data to solve the problem that there is not sufficient data in infrastructure PPP projects;

(3) Through the establishment of the relationship between capital structure and financing efficiency index, Monte Carlo simulation can be used to obtain the correspondence between different index values, which can provide the data basis for analyzing the impact of capital structure on financing efficiency.

2.3.2 Indicators of Capital Structure and Financing Efficiency

This paper chooses the capital ratio of the PPP project (the ratio of the project equity to the total investment) as the research index of the capital structure, and then selects WACC, IRR and DSCR as the research indicators of financing efficiency.

The most representative indicator is the financing cost for the financing transaction efficiency of PPP projects, and the financing cost of the projects can be expressed by the weighted average cost of capital:

\[
WACC = \left[ R_e - R_d \times (1 - T) \right] \times q + R_d \times (1 - T)
\]  

Where \( q \) = capital ratio; \( R_e \) = equity cost; and \( R_d \) = debt cost.

According to the theory, equity cost is generally higher than debt cost in PPP project companies, which means that \( R_e > R_d \). When increasing the capital structure of the PPP project companies, the weighted average cost of capital will be increased. It can be seen that the financing cost is linearly related to the capital structure, so the simulation is not carried out below.

Then it is the discussion about the indicators of PPP projects financing efficiency. This paper chooses both IRR and DSCR to analyze the capital utilization efficiency and financing solvency.

At present, most scholars in China focused on studying corporate financing efficiency in the field of financing efficiency, they usually use the return on net assets or the total asset turnover rate to reflect the capital structure on the impact of financing efficiency. Based on the above analysis and the characteristics of PPP project financing, this paper selects a similar indicator to study the capital utilization efficiency - internal rate of return (IRR). This indicator is generally considered to be the profit rate of the project investment and it can reflects the capital utilization efficiency. IRR is subdivided into IRR of total investment and IRR of equity funds. The former is based on the whole project, assuming all funds are equity funds and there is no issue of debt service, so it has nothing to do with the capital structure; the latter stands on the position of investors, considering
debt financing, so the index is related to the capital structure. Therefore, IRR in this paper is the IRR of equity funds.

The value of IRR is the discount rate when the net present value is equal to zero. The formula is as follows:

\[
\sum_{n=1}^{a} \frac{E_n}{(1 + IRR)^n} = \sum_{m=1}^{b} \frac{FCFE_m}{(1 + IRR)^{m+a}}
\]  

(3)

Where \( a \) = construction period; \( b \) = operation period; \( E_n \) = equity for the nth year; \( FCFE_m \) = free equity cash flow for the nth year; \( n=1,2, \ldots ,a; \) and \( m=1,2 \ldots ,b. \)

Financing solvency of the PPP project refers to the capital adequacy in the operation period. DSCR is a common international index which can be used to evaluate project solvency, this indicator refers to the ratio of the amount of funds for debt service and payable debt in the repayment period. Zhang (2005) argued that DSCR is the main concern indicator of creditors, the higher the DSCR, the greater the free cash flow during the operation period, and the higher the solvency of the PPP project. Therefore, this paper also selects the DSCR as the indicator of PPP projects to study the impact of capital structure on solvency.

The formula for calculating the debt reserve ratio is as follows:

\[
DSCR_k = \frac{EBIT_k + D_k - T_k}{PD_k}
\]  

(4)

Where \( K = 1, 2, 3, \ldots , c; \) \( C = \) repayment period; \( EBIT_k = \) EBIT for the kth year; \( D_k = \) Depreciation for the kth year; \( T_k = \) income tax for the kth year; \( PD_k = \) payable debt for the kth year.

2.3.3 Basic Relationships

In order to establish the function of capital structure and financing efficiency index, it is necessary to combine the parameters of each stage of PPP project. First, during the construction period of PPP projects, the main parameter is total investment, including construction costs and financing costs. The specific formula is as follows:

\[
TI_n = CC_n + FC_n
\]  

(5)

\[
FC_n = \left( \sum_{d=1}^{n} P_d + \sum_{d=1}^{n-1} FC_d \right) \times R_n
\]  

(6)

Where \( TI_n = \) total investment for the nth year; \( CC_n = \) construction costs for the nth year; \( P_d = \) the amount of loans for the dth year; \( FC_n = \) financing costs for the nth year.

At the same time, the amount of total investment is equal to the sum of capital and the amount of loans, and the capital structure is defined as the share of capital in the total investment. Hence, the following formula can be derived:

\[
E_n = q \times TI_n
\]  

(7)

\[
P_n = (1 - q) \times TI_n
\]  

(8)

\( E_n = \) capital for the nth year; \( q = \) capital ratio; \( P_n = \) the amount of loans for the nth year.

Then in operation period of PPP projects, the main parameters are free cash flow to equity and payable debt. Free Cash Flow to Equity refers to the cash flow after the removal of operating expenses, taxes, payable debt, and all capital expenditures. The formula is as follows:

\[
FCFE_m = GR_m - OC_m - T_m - PD_k
\]  

(9)

Where \( GR_m = \) gross revenue for the mth year; \( OC_m = \) operating costs for the mth year; \( T_m = \)
income tax for the mth year.

Assuming that PPP projects take the same amount of repayment each year and repay the principal and interest from the first year of the operation period, the principal and interest can be calculated as follows:

\[ PD_k = \sum_{n=1}^{a} FC_n \times \frac{R \times (1 + R)^c}{(1 + R)^c - 1} \]  

Where \( K = 1, 2, 3, ..., c \); \( PD_k \) = payable debt for the kth year; \( R \) = interest rate.

The annual interest is calculated as follows:

\[ I_k = PD_k \times \left[ 1 - (1 + R)^{-c+k+1} \right] \]

Where \( I_k \) = interest for kth year.

Finally, the functions of capital structure and IRR, DSCR can be obtained by substituting the parameters of the construction period and the operation period into the IRR and DSCR formulas, the function relationship is shown below:

1. The relationship between capital structure and IRR of infrastructure PPP project

\[ \sum_{n=1}^{a} q \times Tl_n \times \frac{1}{(1 + IRR)^{n-1}} = \sum_{m=1}^{b} \frac{1}{(1 + IRR)^{m+a}} \times \left[ GR_m - OC_m - T_m \right] - \sum_{n=1}^{a} FC_n \times \frac{R \times (1 + R)^c}{(1 + R)^c - 1} \]

2. The relationship between capital structure and DSCR of infrastructure PPP project

\[ DSCR_k = \frac{GR_m - OC_m - T_m}{\sum_{n=1}^{a} \left[ \left( \sum_{d=1}^{n} (1 - q) \times Tl_d \right) + \sum_{d=1}^{n-1} FC_d \times R_n \right] \times \frac{R \times (1 + R)^c}{(1 + R)^c - 1}} \]
3 Case Study

3.1 Case Background

The utility tunnels of Yinchuan are located in the south side of Yuantong Road (The reconstructing and extending line of Jingyun Street to the provincial highway S203), Binhe District of Yinchuan, China. The provincial highway S203 expansion line (Yuan Road to the Beijing River Road section) is on the west side. The utility tunnels are "L" type layout with a total length of 8231 meters, of which the east and west sections are 4075 meters long, and the north and south sections are 4156 meters long. The project commenced construction on 28th February 2016 and delivered for use on 30th April 2017.

The major participant of the utility tunnels of Yinchuan PPP project is Yinchuan Binhe District Investment and Development (Group) Co. Ltd. The company brings social investors through public tender, so the project company is co-founded by both of them. The proportion of its investment: 35% of the investment company, 65% of social investors. The total investment of the project company is 689 million yuan, of which the project capital is 314 million yuan and the capital ratio is 45.53%. The cooperation period of the utility tunnels PPP project is 15 years, of which construction period of 1 year. The project adopts the operation mode of "investment, construction operation and maintenance integration + Entrance fees of pipeline companies + government subsidy". After the expiration of the cooperation, the project will be transferred to the Binhe District Administrative Committee or the designated institution. The financing model is shown in Fig.4:

![Fig.3. The PPP model structure of Yinchuan utility tunnels](http://www.xm.xinhuanet.com/2017-04/07/c_1120770033.htm)

The basic financial data of this case includes the amounts of total investment, the proportion of capital, macroeconomic data and project duration data. The data is as follows:

<table>
<thead>
<tr>
<th>Number</th>
<th>Category</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total investment (Million yuan)</td>
<td>68962.18</td>
</tr>
<tr>
<td>2</td>
<td>Capital ratio (%)</td>
<td>45.53%</td>
</tr>
<tr>
<td>3</td>
<td>Macroeconomic data</td>
<td></td>
</tr>
</tbody>
</table>

4 http://www.xm.xinhuanet.com/2017-04/07/c_1120770033.htm
The total investment of Yinchuan utility tunnels is 68962.18 million yuan, and the main sources of funds are capital, loans and entrance fees of pipeline companies.

### Table 2. Construction period data of Yinchuan utility tunnels

<table>
<thead>
<tr>
<th>Number</th>
<th>Category</th>
<th>Construction period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Construction and installation costs</td>
<td>60025.37</td>
</tr>
<tr>
<td>1.1</td>
<td>Preliminary Cost</td>
<td>3720.00</td>
</tr>
<tr>
<td>1.2</td>
<td>Other costs</td>
<td>5216.81</td>
</tr>
<tr>
<td>2</td>
<td>Equity</td>
<td>31400.00</td>
</tr>
<tr>
<td>3</td>
<td>Loan</td>
<td>34122.18</td>
</tr>
<tr>
<td>4</td>
<td>Entrance fees</td>
<td>3440.00</td>
</tr>
</tbody>
</table>

The main income of the PPP project is derived from the operating revenue and government subsidy income. The specific data is shown in the following table:

### Table 3. Operation period data of Yinchuan utility tunnels

<table>
<thead>
<tr>
<th>Number</th>
<th>Category</th>
<th>Operation period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gross revenue</td>
<td>1.1+1.2</td>
</tr>
<tr>
<td>1.1</td>
<td>Operating revenue</td>
<td>317.00</td>
</tr>
<tr>
<td></td>
<td>Operating revenue is 3.17 million at the first year, and the annual growth rate is 10%.</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Government subsidy income</td>
<td>5158.74</td>
</tr>
<tr>
<td>2</td>
<td>Total cost</td>
<td>2.1+2.2+2.3</td>
</tr>
<tr>
<td>2.1</td>
<td>Operating cost</td>
<td>1991.80</td>
</tr>
<tr>
<td>2.2</td>
<td>Interest</td>
<td>214.00</td>
</tr>
<tr>
<td>2.3</td>
<td>Depreciation</td>
<td>1088.18</td>
</tr>
<tr>
<td>2.4</td>
<td>Annual interest rate 5.64%</td>
<td>1.06</td>
</tr>
<tr>
<td>3</td>
<td>Income before tax</td>
<td>1-2</td>
</tr>
<tr>
<td>4</td>
<td>Income tax</td>
<td>3*25%</td>
</tr>
<tr>
<td>5</td>
<td>Net income</td>
<td>3-4</td>
</tr>
<tr>
<td>6</td>
<td>Funds for debt service</td>
<td>5+2.2+2.3</td>
</tr>
<tr>
<td>7</td>
<td>Payable debt</td>
<td>4390.76</td>
</tr>
<tr>
<td>8</td>
<td>FCFE</td>
<td>4142.22</td>
</tr>
<tr>
<td>9</td>
<td>DSCR</td>
<td>248.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.06</td>
</tr>
</tbody>
</table>

This article uses @risk software which is developed by Palisade company for Monte Carlo simulation. In the development model, certain inputs are parameters except capital structure in construction period and operation period. The inputs are as follows:
Table 4. Certain inputs

<table>
<thead>
<tr>
<th>Number</th>
<th>Certain inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gross Revenue $GR_m$</td>
</tr>
<tr>
<td>2</td>
<td>Operating cost $OC_m$</td>
</tr>
<tr>
<td>3</td>
<td>Income tax $T_m$</td>
</tr>
<tr>
<td>4</td>
<td>Total investment $TI_m$</td>
</tr>
<tr>
<td>5</td>
<td>Interest rate $R$</td>
</tr>
<tr>
<td>6</td>
<td>Construction period $a$</td>
</tr>
<tr>
<td>7</td>
<td>The $n$th year in construction period</td>
</tr>
<tr>
<td>8</td>
<td>Operation period $b$</td>
</tr>
<tr>
<td>9</td>
<td>The $m$th year in operation period</td>
</tr>
<tr>
<td>10</td>
<td>Repayment period $c$</td>
</tr>
<tr>
<td>11</td>
<td>The $k$th year in repayment period</td>
</tr>
</tbody>
</table>

The capital structure ($q$) in this paper is capital ratio. According to the State Council of China, the minimum capital ratio of utility tunnels is around 20%. Thus, the distribution of the capital structure is defined as a random distribution between 20% and 100%, and its function is $"= \text{RiskUniform}(20\%, 100\%)$.

Table 5. Uncertain inputs

<table>
<thead>
<tr>
<th>Number</th>
<th>Uncertain entries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Capital Structure ($q$)</td>
</tr>
</tbody>
</table>

Then this paper defines IRR and DSCR as the outputs.

Table 6. Outputs

<table>
<thead>
<tr>
<th>Number</th>
<th>Outputs</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IRR</td>
<td>$\sum_{n=1}^{d} \frac{(1 + IRR)^{m-1}}{(1 + IRR)\times 1 + IRR} - \sum_{m=1}^{d} \frac{1}{(1 + IRR)\times 1 + IRR} \times \left[ GR_m - CR_m - T_m - \sum_{n=1}^{d} FC_m \times R \times \frac{(1 + R)^{n}}{(1 + R)^{n-1}} \right] $</td>
</tr>
<tr>
<td>2</td>
<td>DSCR$_k$</td>
<td>$\sum_{n=1}^{d} \frac{(1 - q) \times TI_d - EF_d + \sum_{d=1}^{n-1} FC_d \times R_n \times R \times \frac{(1 + R)^{n}}{(1 + R)^{n-1}} - 1 }{ (1 + R)^{n}} $</td>
</tr>
</tbody>
</table>

3.2 Simulation Results and Discussions

In this paper, Monte Carlo simulation is performed in 1000 times in iterations to obtain 1000 sets of IRR and DSCR data. The specific data is shown in the following table:

Table 7. Simulated data (1000 times iterations)

<table>
<thead>
<tr>
<th>Number</th>
<th>DSCR</th>
<th>IRR</th>
<th>Capital Structure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.91</td>
<td>8%</td>
<td>70.33%</td>
</tr>
<tr>
<td>2</td>
<td>0.80</td>
<td>16%</td>
<td>28.85%</td>
</tr>
<tr>
<td>3</td>
<td>1.24</td>
<td>10%</td>
<td>54.15%</td>
</tr>
<tr>
<td>4</td>
<td>0.97</td>
<td>12%</td>
<td>41.38%</td>
</tr>
<tr>
<td>5</td>
<td>5.90</td>
<td>7%</td>
<td>90.37%</td>
</tr>
<tr>
<td>----</td>
<td>-------</td>
<td>-----</td>
<td>--------</td>
</tr>
<tr>
<td>6</td>
<td>1.07</td>
<td>11%</td>
<td>46.70%</td>
</tr>
<tr>
<td>7</td>
<td>31.71</td>
<td>6%</td>
<td>98.21%</td>
</tr>
<tr>
<td>8</td>
<td>0.72</td>
<td>19%</td>
<td>20.87%</td>
</tr>
<tr>
<td>9</td>
<td>0.90</td>
<td>13%</td>
<td>36.80%</td>
</tr>
<tr>
<td>10</td>
<td>4.30</td>
<td>7%</td>
<td>86.80%</td>
</tr>
<tr>
<td>11</td>
<td>0.79</td>
<td>16%</td>
<td>28.32%</td>
</tr>
<tr>
<td>12</td>
<td>2.22</td>
<td>8%</td>
<td>74.40%</td>
</tr>
<tr>
<td>13</td>
<td>1.96</td>
<td>8%</td>
<td>71.02%</td>
</tr>
<tr>
<td>14</td>
<td>0.77</td>
<td>17%</td>
<td>26.02%</td>
</tr>
<tr>
<td></td>
<td>......</td>
<td>......</td>
<td>.......</td>
</tr>
<tr>
<td>994</td>
<td>1.22</td>
<td>10%</td>
<td>53.61%</td>
</tr>
<tr>
<td>995</td>
<td>7.67</td>
<td>7%</td>
<td>92.60%</td>
</tr>
<tr>
<td>996</td>
<td>11.61</td>
<td>6%</td>
<td>95.11%</td>
</tr>
<tr>
<td>997</td>
<td>1.47</td>
<td>9%</td>
<td>61.41%</td>
</tr>
<tr>
<td>998</td>
<td>1.32</td>
<td>9%</td>
<td>56.85%</td>
</tr>
<tr>
<td>999</td>
<td>3.42</td>
<td>7%</td>
<td>83.42%</td>
</tr>
<tr>
<td>1000</td>
<td>5.85</td>
<td>7%</td>
<td>90.30%</td>
</tr>
</tbody>
</table>

Based on the simulation data, this paper draws the relationship chart between capital structure and IRR, DSCR.

(1) The relationship chart between capital structure and IRR

![Fig.4. The relationship between capital structure and IRR](image)

As can be seen from the above figure, IRR decreases with the increase of capital structure. The main reason is that the IRR of this paper is the IRR of equity funds. According to the formula of the IRR of equity funds, when \( IRR_{TC} > R \), the greater the capital structure, the smaller the IRR; otherwise, when \( IRR_{TC} < R \), the greater the capital structure, the larger the IRR. Combined with the case, when the capital structure is 100%, that is, the project investment is all self-owned. At this point \( IRR_{TC} = IRR \), and \( IRR_{TC} \) is about 6% in this case. And the known annual interest rate of the project loan which is 5.64% is less than \( IRR_{TC} \) (6%), which conforms to the first case, so the
IRR and the capital structure is correlated negatively. 

\[
IRR = \frac{TC \times IRR - P \times R}{EI} = IRR_{TC} + (IRR_{TC} - R) \times \frac{1 - q}{q} \tag{14}
\]

Where \( IRR_{TC} \) = IRR of total investment; \( IRR_{E} \) = IRR of equity funds; \( R \) = interest rate of project loan.

And from the figure we can also see that there is a non-linear relationship between the capital structure and IRR, this change can be understood as the effects of financial leverage. In the interval \([20\%, 70\%]\), the IRR decreases rapidly with the increase of the capital structure, the average rate of decline of IRR is 24% and the leverage is obvious. So the project company can use this leverage to adjust the proportion of capital structure appropriately, to get the IRR as far as possible in line with investor expectations. However, in the interval \([70\%, 100\%]\), IRR changes gently, the average rate of decline is 6.67%. At this time, the IRR is at a low level, adjusting the capital structure to achieve higher IRR is of little significance. So the proportion of capital structure should not be greater than 70% for investors.

Combined with the case, capital ratio of the PPP project is 45.53%, at this time the IRR is about 11%, which shows that the PPP project can give investors a certain return on investment and its capital allocation is more effective.

In summary, the capital structure is correlated with IRR nonlinearly and negatively. Since the relationship between capital structure and IRR is universal, this conclusion can be extended to other types of PPP projects. This paper argues that for PPP project companies, when the capital ratio is not less than the state's minimum provisions of projects, companies can improve IRR of equity funds and increase the capital utilization efficiency of infrastructure PPP projects by reducing the capital ratio to increase the debt funds.

(2) The relationship chart between capital structure and DSCR

As can be seen from figure 6, the capital structure is related to the DSCR positively, because the larger the capital structure, the smaller the amount of the loan, and the less the pressure on the debt service. Hence, the solvency of PPP project companies will be higher.

At the same time, DSCR changes nonlinearly with the capital structure. The average growth rate of DSCR is only 2.36% in the \([20\%, 70\%]\) range, and when the capital structure is above 70%,
the DSCR begins to grow rapidly. Standing on the creditor's point of view, they expect DSCR to be as high as possible, so the capital structure should be higher than 70%.

Normally, DSCR > 1 indicates that the project is feasible, between 1.3 and 1.5 means that the solvency of projects is good, and higher than 1.5 indicates that the project has a strong solvency. The minimum average DSCR of international financial institutions is 1.50 (Zhang 2005; Koh et al. 1999; Newnan et al. 2004). According to the provisions of the National Bank, the average DSCR is required to be higher than 1.3 during the repayment period. Combining this case, the capital ratio of the PPP project is 45.53% and DSCR is 1.06 at this level, which means the funds are sufficient to meet the requirements for debt repayment of this PPP project. However, we can see that the solvency of the utility tunnels project is weak because of DSCR < 1.3, which is related to the large amount of investment, imperfect charging mechanism and insufficient entrance fee of utility tunnels PPP projects. Thus, it can be seen that the government should standardize the charging mechanism and give some subsidies to ensure the solvency of utility tunnels PPP projects. In conclusion, the capital structure of the PPP project is correlated with the DSCR positively and nonlinearly, and the same conclusion can be applied to other PPP projects due to the universality of the function. For PPP project companies, the higher the level of capital structure, the greater the solvency of PPP projects, indicating that the allocation efficiency is also higher.

To sum up, the capital structure of infrastructure PPP projects has different effects on different aspects of financing efficiency, as shown in the following table:

<table>
<thead>
<tr>
<th>financing efficiency</th>
<th>Indicators of financing efficiency</th>
<th>the impact of capital structure on financing efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>capital structure</td>
<td>transaction efficiency</td>
<td>WACC</td>
</tr>
<tr>
<td></td>
<td>capital utilization efficiency</td>
<td>IRR</td>
</tr>
<tr>
<td></td>
<td>financing solvency</td>
<td>DSCR</td>
</tr>
</tbody>
</table>

It can be seen that the appropriate increase in debt financing can reduce the financing cost and improve the financing efficiency of PPP projects. At the same time PPP project companies can obtain benefits from the effect of financial leverage, and the capital utilization efficiency will be improved. However, the financial pressure on debt service of PPP project companies will be increased because of the financial risk of debt financing, and the solvency of projects will be reduced.

Therefore, when PPP project companies formulate the optimal capital structure, they must combine the reality and measure the relationships between financing costs, investment return and financial risk to maximize financing efficiency of infrastructure PPP projects.
Conclusions

In this paper, the qualitative and quantitative analysis were combined to study the influence of capital structure on financing efficiency. Firstly, combining theories, this paper analyzed the influence mechanism of capital structure on financing efficiency qualitatively, and then selected financing efficiency indicators for quantitative research. Main results of this paper are as follows:

(1) Defined financing efficiency of infrastructure PPP projects and other concepts based on the theoretical analysis. This paper argued that financing efficiency of PPP projects included transaction efficiency and allocation efficiency, and allocation efficiency can be subdivided into capital efficiency and solvency.

(2) Studied the influence mechanism of PPP project capital structure on financing efficiency by combining theories. This paper argued that the PPP project capital structure influences the PPP project transaction efficiency and allocation efficiency respectively in four aspects: financing risk, financial sustainability, the tax deduction of interest and financial leverage effect.

(3) On the basis of qualitative analysis, this paper used Monte Carlo simulation method to analyze the effects of PPP capital structure on financing efficiency quantitatively. Firstly, this paper built functional relationship between the capital structure and the internal rate of return (IRR) and debt solvency coverage rate (DSCR) by defining the parameters in the construction period and the operation period of infrastructure PPP projects. Next @risk software was used to carry out Monte Carlo simulation, and then this paper obtained the changes of financing efficiency index under different levels of capital structure.

The results showed that the capital structure was related to transaction efficiency and capital utilization efficiency negatively, correlated with solvency positively. Therefore, this paper argued that the PPP project company should combine the actual situation when making capital structure decisions and take the project financing costs, investment return and financial risks into consideration to maximize the efficiency of financing as much as possible.

References


Trend of the research on EPC/DB projects, China and overseas

Zhang, R.1*, Li, T.K.2 and Zhao, B.3

Abstract: To address the integration issue in fragmented construction industry, research interests on engineering procurement and construction/design and build(EPC/DB) have resulted in a large amount of publications in English during the last three decades. These researches are mainly from developed areas. In the past two decades, researchers in China has paid attention to EPC/DB. Especially in recent year, there are emerging EPC/DB projects that undertaken by Chinese contractors. Promoting EPC/DB is viewed as one approach to increase the competitiveness for Chinese AEC/O companies by Chinese government. Due to language limitation, there is little awareness of what researches in the other side are doing in EPC/DB area. By comprehensive review EPC/DB literature in English and Chinese, this study compares the research focuses and trends in both sides. It finds out that the common topic that is concerned by both sides are comparing EPC/DB with other modes. In addition, English publications focus on contractor selection in tender stage. Chinese publications give attention to risk management and information technology implementation. How the level of detail (LOD) of design, or the proportion of design in ROF affect project performance is a uniqueness in English publication. For Chinese literature, design management/design-led EPC/DB is the specialty in Chinese literature. Large number of descriptive study in top Chinese journals indicates that the research maturity level in China needs improvement. Improvement includes both research methodology and research focuses. Research gaps in China includes LOD of design in tender document, and design management in joint alliance. This research might help researchers in China to grasp what is the current research progress and what are the potential research directions in EPC/DB area.

Keywords: EPC; DB; Contracts; China; Review.

1* Zhang, R.
Corresponding author, Department of Quantity Survey, School of Construction Management and Real Estate, Chongqing University, China
E-mail: zhang.rong@cqu.edu.cn

2 Li, T.K.
School of Construction Management and Real Estate, Chongqing University, China

3 Zhao, B.
School of Construction Management and Real Estate, Chongqing University, China
1 Introduction
The construction industry is considerably more fragmented than many other industries with a large number of project participants with different specialties [1-3]. In the last few decades the construction industry has made significant efforts to enhance collaboration and integration. From management perspective, innovative contracting mode are emerging, such as engineering procurement and construction/design and build(EPC/DB)[4], partnering[5]. More recently, integrated project delivery approach (IPD) is put forward as an approach to integrates people, systems, business structures and practices[6]. From technic perspective, new ICT technology are developed to reduce fragmentation in construction industry[7], such as Building Information Modelling (BIM) as a coordination tool.

In China, government carried out a policy that promotes EPC/DB mode in construction practice in the year of 2016. Research interests in addressing EPC/DB issues have resulted a large number of publications during the last decade. There are good publications in the language of Chinese that are written by Chinese researchers who access to front line of EPC/DB projects. However, due to language barrier, there is lack of communication between this group of researchers in China and overseas. To build up a communication channel, this paper compares the research focuses and trends in both sides by comprehensive literature review. Researchers might be in a better position to learn from each side, and reveal research gaps worthy of attention and thus, to inspire new research directions for the future research. Section 2 are going to introduce the trend of EPC/DB practice in China. Research methodology are presented in Section 3. Section 4 shows research focuses in China and Overseas, and compares the differences. Section 5 summaries the whole paper.

2 The trend of EPC/DB Practice in China
The number of EPC/DB contractors is increasing in China in the last decade. In the year of 2016, there are 161 contractors that undertake EPC/DB projects. 79 of them undertake EPC/DB projects overseas. The following table shows the contract value of Chinese EPC/DB contractors up to the year of 2016. As for project type, the top three in domestic market are petrochemical, electricity and metallurgy industry; while the top three in oversea market are petrochemical, building material and metallurgy industry.

<table>
<thead>
<tr>
<th>contract source</th>
<th>contract value (billion RMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>contract value that have been signed</td>
</tr>
<tr>
<td>domestic</td>
<td>1168</td>
</tr>
<tr>
<td>oversea</td>
<td>441</td>
</tr>
<tr>
<td>summary</td>
<td>1609</td>
</tr>
</tbody>
</table>

Sources: MHURD 2016

After 20 years booming market in Mainland China, the fix asset investment increase rate in Chinese construction industry began to decline[8]. In addition, the largest proportion of project types in Chinese domestic construction industry has been residential and commercial property. The golden age of real estate and property industry has passed since the year of 2014. Since the
residential and commercial market approaches saturation, the competition for contractors have increased. The overall profit level decreased to 3.48% in 2016 from 3.63% in 2014. In such situation, practitioners in construction industry have to find approach to improve project management, to reduce waste and avoid construction delay. Compared with traditional DBB approach, EPC/DB is superior to traditional systems in involvement of the contractor in the design process, greater price certainty, improved communication and reduced construction time etc. al.[6-8]. Besides traditional contractors, some leading design institutes in China make EPC/DB contractor as their strategy.

The second driver comes from international market. The Central Government has put forward the initiatives of building the Silk Road Economic Belt and the 21st Century Maritime Silk Road, or "One Belt One Road" in short. These economic co-operation corridors, spanning different regions in Asia, Europe and Africa, will promote co-development among countries[9]. Infrastructure development is one of main area to achieve interconnection. Chinese AEC/O firms are encouraged to go aboard to undertake infrastructure projects. It is estimated that the need for infrastructure development project will exceed US $ 22.6 trillion[10]. Building up EPC/DB contracting capability is one way for Chinese AEC/O firms to increase their competitiveness in oversea market.

Ministry of Housing and Urban-Rural Development of the People’s Republic of China (Hereinafter referred to as MHURD), representing Chinese government, carried out a policy to prompt EPC/DB mode in construction industry. The approach is named as “ General Contracting” . The definition given by MHURD is that “ General contracting (Hereinafter referred to as the general contracting enterprise) entrusted by the client, agreed on, the implementation of the project survey, design, procurement, construction, commissioning whole process or a number of stages in accordance with the contract, and take comprehensive responsibility for project quality, safety, duration, cost etc. all”. According to MHURD, promoting EPC/DB in construction industry is an important issue for project delivery revolution in China. It could improve the competitiveness for Chinese contractors.

3 Research Methodology

Literature review is generally considered as a key methodology for examining the development trend of research in particular discipline[11]. The first stage is framework development in order guide literature analysis. the framework is developed based on the principles in project management disciplines. based on project management principle, four questions guide the development of framework:1) which project stage is the research focus? 2) which stakeholder’s perspective is chosen? 3) which project type is investigated? 4) which project management domain is investigated? Based on the four questions, it sets up a four-dimensional space. Each piece of research takes up a position in the four-dimensional space. Figure 1 is a 2D representation of the framework. According to the project stage, it could be categorized into: initiating, tendering, design, construction and operation. As for papers from contractor’s perspective, some papers focus on designer, and some papers focus on constructor. Referring project management body of knowledge[12], research areas are categorized into project planning, project control (quality, cost, schedule, safety, etc.al.), project communication, project risk management and others.
The second stage of research encompasses a thorough literature research considering the "title/keyword/abstract" fields. For English literature, journals targeted includes International Journal of Project Management; Construction Management and Economics; Journal of Management in Engineering; Engineering, Construction and Architectural Management; and Automation in Construction according to Wing [13] and Hosseini et al. [14]. In additional, Building Research and Information is excluded because there is no relevant publication in this journal; Journal of Management in Engineering (JME) is included, because it is a key ASCE journal in construction management field; Databases used for scanning included Scopus, ScienceDirect, ISI Web of Science, Wiley of Library. Literature from the year of 1990 to 2017 are covered. For literature in Chinese, publications are selected from high level journal from three database: CSSCI, CSCD, and Chinese core journal criterion of Peking University.

4 Result

4.1 EPC/DB literature in English

There are 78 related journal papers in the seven targeted journals during the survey period. The author name, number of papers and their affiliations are shown in table 2. The research focuses are presented in table 4.
Table 2 Main authors’ contribution of the publications

<table>
<thead>
<tr>
<th>Author Name</th>
<th>Number of Papers</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xia,B.</td>
<td>10</td>
<td>Queensland University of Technology, Australia</td>
</tr>
<tr>
<td>Molenaar,K.</td>
<td>10</td>
<td>University of Colorado at Boulder, United States</td>
</tr>
<tr>
<td>Chan,A.</td>
<td>8</td>
<td>Hong Kong Polytechnic University.</td>
</tr>
<tr>
<td>Skitmore,M.</td>
<td>5</td>
<td>Queensland University of Technology, Australia</td>
</tr>
<tr>
<td>Gransberg,D.D.</td>
<td>5</td>
<td>Iowa State University, United States</td>
</tr>
<tr>
<td>Arditi,D.</td>
<td>4</td>
<td>Illinois Institute of Technology, United States</td>
</tr>
<tr>
<td>Chen,Q.</td>
<td>4</td>
<td>Statistical Society for Foreign Economic Relations and Trade of Shenzhen, China</td>
</tr>
<tr>
<td>Lee,D.E.</td>
<td>4</td>
<td>Kyungpook National University, South Korea</td>
</tr>
<tr>
<td>Wu,P.</td>
<td>3</td>
<td>Curtin University, Australia</td>
</tr>
<tr>
<td>Zuo,J.</td>
<td>3</td>
<td>University of Adelaide, Australia</td>
</tr>
<tr>
<td>Shrestha,P.P.</td>
<td>3</td>
<td>University of Nevada, United States</td>
</tr>
<tr>
<td>Songer,A.D.</td>
<td>3</td>
<td>University of Colorado at Boulder, United States</td>
</tr>
<tr>
<td>EIAsmar,M.</td>
<td>3</td>
<td>Arizona State University, United States</td>
</tr>
</tbody>
</table>

Regarding level of analysis, 69 of them are at project level, while nine of them focus on company level. As the focus of this paper is EPC/DB project, those nine papers on company level are deleted in the following analysis. The statistical information is shown in table 3 and Figure 4.

Table 3 Journal’s contribution of EPC/DB publications in English

<table>
<thead>
<tr>
<th>Title of Journal</th>
<th>Number of Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journal of Construction Engineering and Management (JCEM)</td>
<td>28</td>
</tr>
<tr>
<td>Journal of Management in Engineering (JME)</td>
<td>22</td>
</tr>
<tr>
<td>International Journal of Project Management (IJPM)</td>
<td>7</td>
</tr>
<tr>
<td>Engineering, Construction and Architectural Management (ECAM)</td>
<td>6</td>
</tr>
<tr>
<td>Construction Management and Economics (CME)</td>
<td>4</td>
</tr>
<tr>
<td>Automation in Construction (AIC)</td>
<td>2</td>
</tr>
</tbody>
</table>

In project initiating stage, 12 papers have focused on contract mode comparison from different perspectives. These perspectives include performance in term of cost, time and/or quality[15-23], causes for construction-phase changes[24], critical risk factors[25], critical cost performance factors[26]. Ten of them compares DB with DBB. Besides that, one paper has developed a process model for public sector design-build planning to improve its understanding and implementation[27].

In tendering stage, contract selection has received the most attention. 17 papers are published in this area. Besides the criteria and procedure to evaluate contractor or contractor’s proposal[28-40], one of them explores selection criteria form request for proposal(RFP)[41]; two of them explore the project goal from RFP[42, 43]; one of them explores owner’s two of them considers the effect of procurement duration[41, 44]. Two papers have investigated contract type selection (i.e., contract payment method)[4, 45]. Three papers have investigated the level of detail (LOD) or the proportion of design to include in request for proposal[46-48].

For project control, there are three papers on schedule management[49-51], one on cost management(cost of quality analysis)[52]. There are two papers on quality management. One paper has concerned with integrating specialty contractor in design stage[53], the other paper has concerned how public sector owners articulated the requirements for design quality management in design/build (DB) projects.[54]. Another paper has investigated on how public owners communicate the sustainability requirements of green design-build projects[55].
Four papers have focused on risk management. One paper has identified design risk factors in design-build projects and conducted an analysis of their impact on project performance[56]. One paper has identified 39 risk factors related to the DB delivery selection process in EPC[57]. One paper has proposed a contingency management model to manage contingency budget in a complex EPC project[58]; and one paper has compared labor cost risk in DB project with that in DBB project[59].

Two papers have investigated project communication. One paper has addressed cross-organizational integration[60]. The other paper has aimed to resolve potential 'downstream' problems early in the project life-cycle based on design function deployment (DFD) - a concurrent engineering design system[61].

As for design management, one paper has reviewed the issues concerning the design liability and contractual provisions for design management between the designer and D/B contractor in contractual arrangement[62]. As for other aspects, four papers have identified success factor for DB project[51, 63-65]; two papers have investigated the difficulties in DB implementation[66, 67]. In addition, one paper has tested hypothetical DB policy alternatives in Korea[68].

<table>
<thead>
<tr>
<th>Table 4 Research focus of EPC/DB publications in English</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research Area</strong></td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Project Initiating</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Tendering</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Project Control</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Project Communication</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Others</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

At the early stage of EPC/DB research, there are quite a few descriptive studies. Eight papers
described the implementation situation of DB project[69-76], with five of them were published before the year of 2000. Six papers have demonstrated industry survey results. All of them have focused on practitioners’ perception/attitude/view toward DB project[77-81]. One of them has revealed performance evaluation from architects on contractor-led DB[79].

4.2 EPC/DB literature in Chinese

There are 76 related EPC/DB related papers in targeted journals. All of the journal papers are published after the year of 2000. According to research framework, the research focuses are listed in table 5 and explained following.

<table>
<thead>
<tr>
<th>Research Area</th>
<th>Research Focus</th>
<th>Number of Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Initiating</td>
<td>Mode Selection</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Contractor Selection</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Bid Strategy of Contractor</td>
<td>2</td>
</tr>
<tr>
<td>Tendering</td>
<td>Quality Control</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Cost Control</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Schedule Control</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Safety Management</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Project Management</td>
<td>10</td>
</tr>
<tr>
<td>Project Control</td>
<td>Risk Management</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Information Management</td>
<td>7</td>
</tr>
<tr>
<td>Others</td>
<td>Design Management</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Purchasing Management</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Contract Management</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Legal Issues</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Supervision</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Market Analysis</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Case Description</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 5 Research focuses of EPC/DB publications in Chinese

In project initiating stage, eight publications have investigated contract mode selection. Two papers have compared EPC/DB with DBB[82, 83]. One paper has compared EPC with EPCM(Engineering, Procurement, Construction and Management), IPMT (Integrated Project Management Team), estimated possible organization behavior and impact on project effectiveness, and suggested project organization structure and human resource arrangement for each mode[84]. Two papers have analyzed the implementation of EPC[85, 86], and one of them has focused on petrochemical industry. One paper has investigated the value chain of EPB and BOT[87]. Another paper has investigated the relationship of EPC and core competence[88]. In addition, one paper has discussed EPC/DB and private investment[89].

As for project control, two papers have investigated quality control in EPC and one of them has focused on material management[90, 91]. Two papers have discussed cost control[92, 93]: one paper has focused on change management, the other one has focused on budget control with an emphasis on material control in design stage. One paper has discussed schedule control from three aspects: design, equipment & main material purchase, and construction[94]. Three papers have investigated health and safety management, and one of them has focused on construction stage[95-97]. Ten papers have discussed EPC/DB broadly and are categorized as “project management”. Five of them have focused on the role of design institutions in EPC/DB projects[98-102]. One paper has discussed project management from the client’s view[103], and another one from general contractor’s perspective[104]. Two papers have discussed the
coordination between project participants and one of them has focused on profit distribution within contractors[105, 106]. One paper has investigated risk distribution between contractor and project management firm in EPC/DB projects according to FIDIC[107]. One paper has evaluated factors that affect EPC/DB project performance [108].

There are ten papers which have investigated risk management from different perspective. They include comprehensive risk management[109], risk type and solution in EPC/DB projects, [110-112], potential risk in EPC contract[113], risk in financial management[114], risk in joint venture[115], risk database and evaluation system[116], risk associated with change management[117] as well as Contractor’s All risks insurance[118].

As for project communication, all of the seven papers have discussed information management in EPC/DB projects. There are three papers on document management, and one of them has focused on construction technology record [119-121]. One paper has showed the systematical design and implementation of information technology on construction site by a case[122]. Three papers have investigated the implementation of information management system[123-125].

Design management has received quite attention. Seven papers have investigated design management with different focuses, including procurement control in power station project [126], problems and solutions in design management[127-129], design management system[130], components in design management and its relationship with partnering and performance[131], the impact of design management on project control[quality, cost, schedule][132]. All projects are either industry projects or infrastructure projects.

Six papers have discussed equipment and material purchasing management. Beside two paper on case study[126, 133], there are one focus on classification scheme[134], one on cost control[135], one on supply chain management[136], and one on procurement procedure standardization[137].Four publications have concerned contract management with different perspectives, including target contract[138] operation process and contract analysis[139], division of contract[140] and conflict management[141].

One paper has discussed the legal environment for EPC implementation in China[142]. Two papers have investigated supervision in EPC projects. One has focused on construction supervision[143], the other has focused on equipment supervision[144]. Two papers have discussed the market of EPC mode: one in civilian building design industry[145] and the other one in industry water treatment[146]. Seven research have described the EPC/DB implementation in selected cases[147-153].

4.3 Comparison

In project initiating stage, both sides of literatures concern the comparison between EPC/DB mode and other mode (i.e., DBB). During comparison, papers from top journal in English are more focused on several dimensions: performance and critical risk factors. In additional, there is lack of attention toward project planning amongst Chinese journal papers.

In tendering stage, the number of English journal papers is much more than that in Chinese Journal papers. Amongst them, quite a number of papers have conducted research through analysis of owner’s request for proposal or contractor’s proposal. The possible reason for the lack of such research in Chinese journal papers is, proposal in Chinese EPC/DB projects have used standard contract in a large extent. Some negotiations between owner and contractor are not recorded in the proposal. Besides that, there is a lack of research on LOD in Chinese journal papers.
Project control has received less attention amongst top English journals than that in top Chinese journals. However, research that are published in top English journals are more focused. Eleven Chinese journal paper have general discussed issues of project management in EPC/DB projects. Most of the authors are practitioners instead of academics. It is suggested that collaboration between practitioners and academics could improve the level of EPC/DB research in China.

Papers in top Chinese journals have given more attention to project communication than papers in top English journals. However, researchers in top Chinese journals have focused on information technology system rather than organization behavior. The focus on information technology is consistent with current information technology strategy in China. It is possible that firms that have undertaken EPC/DB projects are early adopters of information technology strategy in China.

Design management from contractor’s perspective has received more attention amongst top journal papers in Chinese. Contractor-led EPC/DB were most popular for Chinese ECP/DB contractors in the past. As these contactors have little design capability, they usually find a design institute as a sub-contractor. Recently, Chinese government encourages design institute- led EPC/DB contactor. Unlike design institutes in developed areas and nations, most of design institutes are comprehensive ones that consist of all disciplines in construction design (architecture, structure engineering, MEP, etc. al. and even quantity surveying in some of them). Compared with single disciplinary design institution, Chinese large design institution is more likely to transfer to be a design led EPC/DB contractor.

On both sides of research, there are quite a number of descriptive research in early stage. In the side of papers in top English journals, research have been much focused in recent years. In additional, there is a lack of survey on practitioner’s attitude towards EPD/DB projects in China. The large number of descriptive research in top Chinese journals reflects that maturity level of EPC/DB research in China needs improvement.

5 Conclusion

EPC/DB research has received quite attention in top English journals. Chinese government encourages the implementation EPC/DB mode. As a result, there are quite a number of researchers in EPC/DB in the recent decade. Researches in overseas are more focused. Much attention has been given to compare EPC/DB mode with other modes (i.e., DBB) in term of performance, and contractor selection. Request of proposal and proposal documents are common used data sources in overseas. In China, mode comparison, risk management and information technology implementation receive the most attention. Large number of descriptive study in top Chinese journals indicates that the research maturity level in China needs improvement. Improvement includes both research methodology and research focuses. Research gaps in China includes level of detail (LOD) of design in tender document, and design management in joint alliance. Increasing project are constructed using EPC/DB mode, under the background of One Belt One Road and industrialized building. It is anticipated that there will be increasing research on EPC/DB in China.
References


[19]. Shrestha, P.P., J.T. O'Connor and G.E. Gibson Jr., Performance comparison of large
[37]. Molenaar, K.R., A.D. Songer and M. Barash, Pubuc-sector design/build evolution and


[57]. Tran, D.Q. and K.R. Molenaar, Impact of risk on design-build selection for highway design
[77]. Ndekugri, I. and A. Turner, Building procurement by design and build approach. Journal of


[127]. 周晓冬. 对外EPC水泥厂设计管理问题探讨. 国际经济合作. 2010(9): 第70-75页.
[128]. 唐敏. 如何搞好国际EPC工程项目设计管理——以中石化阿尔及利亚沙漠水管道项目设计管理为例. 石油天然气学报. 2010(3).
[135]. 李凯. 降低采购管理成本在EPC总承包项目中的应用. 石油天然气学报. 2010(3).
[152]. 薛康. 长输管道项目的EPC总承包管理模式研究. 石油天然气学报, 2010(3).
The Transition from Unsolicited to Solicited PPP Proposals in BRICS Economies

Igor Martek,1, Asheem Shrestha2* and M Reza Hosseini3

Abstract: BRICS is a term used to describe the countries of Brazil, Russia, India, China, and South Africa. These countries are emergent economies that have in common large populations, extensive resources, and strong economic growth that is expected to see them ultimately take up equal positions among the world's developed nations. The driver of this growth is major infrastructure and capital investment, and in order to finance this investment, public-private-partnerships (PPPs) are commonly employed. PPPs may be solicited by governments, as part of their development strategy, or unsolicited, with investors looking for opportunistic returns. Both approaches carry significant developmental implications, and tracking the degree to which each approach is favoured, provides an indicator of how well an economy is travelling. Data on BRICS PPP solicitation was extracted from the World Bank PPP project database and the analysis was done using data mining. Results reveal that for the five BRICS countries, as a whole, up until the year 2000, proposals were predominantly solicited at a national level. However, from 2001 to 2009, proposals were exclusively unsolicited. From 2010 onwards, proposals reverted to being solicited, but this time at local, state, as well as national levels. Notwithstanding the extensive debate on the current strength of development among BRICS nations, this observation is positive, and adds weight to the view that BRICS economies are evolving healthily.

Keywords: BRICS, Public private partnerships, PPP, Unsolicited proposals.

1 Martek, I.
School of Architecture and Built Environment, Deakin University, Australia

2* Shrestha A.
Corresponding Author, School of Architecture and Built Environment, Deakin University, Australia
E-mail: asheem.shrestha@deakin.edu.au

3 Hosseini, M. R.
School of Architecture and Built Environment, Deakin University, Australia
1 Introduction

Emerging economies are of particular interest in that they compete to outdo each other in economic growth, with developmental economists noting the variations in strategies employed, measuring outcomes, and then attempting to draw conclusions on what macro-economic practices work or don't work. The original definition of an emerging economy was one that had at least 1% of global GDP. In 2001, the American economist Jim O'Neil identified four countries that qualified: Brazil, Russia, India and China, and coined the acronym BRIC to collectively describe them (O'Neil, 2001). While these countries did not at that time have particularly big economies, their vast reserves of resources, combined with relatively large populations, identified them as potential economic giants.

On the 24th December, 2010, South Africa joined the fold, adding the 'S,' and expanding the acronym to BRICS. These five countries share 25% of the world's land, and 40% of the world's population. Goldman Sachs predicted that by 2050, the combined BRICS economies would surpass that of the G6: US, UK, Japan, Germany, France and Italy, overtaking the current developed powers as the future engines of growth (Jacobs & van Rossem, 2014). All that was needed, they said, was that the BRICS had access to sufficiently large inflows of foreign direct investment (FDI); and by 2012, they were already attracting 20% of the world's investment capital (Nistor, 2015).

A number of authors, however, have contested the usefulness of the BRICS categorization (Cheng, Gutierrez, Mahajan, Shachmurove, & Shahrokhi, 2007; Cooper, 2006). The argument goes that along with economic performance, strong nations will also exhibit military as well as political prowess. On this score, the BRICS group show sharply divergent profiles. Russia is exemplary in these respects, China's powers are also on the ascent, while Brazil and South Africa cannot compare. Even in merely economic terms, there are significant differences. China's development is carried by large-scale industrialization, India's depends on import substitution, Brazil has diversified into manufacturing, while Russia's growth remains contingent on its continued transition out of Soviet style military industrialism to market-led consumerism.

Still, since the year 2000, it is shared, strong economic growth that holds the BRICS together. The effects of the 2008 financial crisis triggered persistent declines in most developed economies, yet despite short-term downturns, the BRICS have maintained growth to the present day. Paralleling this growth has been the ability of BRICS economies to attract significant private sector investment and FDI. These investments have been used to pay for needed infrastructure and the capital investments on which developing economies depend. The dominant form of private investment has been in public-private-partnerships (PPPs), where private consortia build and operate government concessions, such as railways, transportation toll-ways, power stations and energy companies, water and sewage treatment plants, telecommunication utilities, and the like.

The 'public' (or government) side of the PPP wants the asset - and somebody else to pay for it - while the 'private' side of the PPP wants a good return on investment. In principle, PPPs make both sides happy. However, the attractiveness of projects are not always symmetrical, nor are the risks, nor even the abilities of the two sides at assessing a projects worth. This asymmetry in
motivation towards PPP projects between the public and private interest can be reflected in how projects are initiated. On the one hand, where projects are initiated by government, they are deemed to be 'solicited.' On the other hand, where projects are initiated by the private sector, they are deemed to be 'unsolicited.'

Evidence suggests that where projects are unsolicited, they may come at a disadvantage to the procuring government; overly expensive, poorly delivered, or simply a sub-optimal allocation of resources (Hodges & Dellacha, 2015). The question then to be asked is whether the attractiveness of BRICS economies to private sector investment comes in the form of unsolicited PPPs; or whether the governments of these countries are proactively directing investment? Has the trend of solicited and unsolicited projects changed over time? Moreover, at what level - national, state or local - is government interceding in the procurement of PPP investment?

2 Research Method

Data for this study was retrieved from the World Bank’s Private Participation in Infrastructure (PPI) database on a range of PPP projects in BRICS from 1990 to 2016. The PPI Database provides information on private participation in infrastructure projects in developing countries, covering different sectors. The database comprises project information highlighting the contractual arrangements, information regarding the government body granting the contracts, information on the main investors and if the projects were unsolicited. To date, this remains the only database that collects comprehensive information on privately financed projects worldwide.

The retrieved data was analyzed using 'Rapidminer Studio 7.5.001.' Rapidminer is an open source analytics program that provides an integrated environment for data mining, including a graphical user interface for visualizing results (Klinkenberg, 2014). The variables considered were country (BRICS), PPP project numbers, procurement format (solicited or unsolicited), and year of procurement. Since all the variables were polynomial, a decision tree model was created.

Decision tree is one of the most widely used techniques in data mining studies, primarily for its simplicity and for the fact that the outcome is easy to grasp and interpret. Decision tree model divides the data in each step into different parts where each part represent one classification included in the dataset. The outcome will be a tree-shaped structure on which nodes represent a test for the value of the particular attribute and each leaf is representing a decision for a particular class. The default values suggested by Klinkenberg (2014) were utilized in performing the analyses (criterion=information gain, maximal depth=20, confidence = 0.25, apply pruning and prepruning).

3 Findings

The outcome of the analysis is illustrated in Figure 1. In the analysis, the data was divided at each step into different categories, with each representing a classification within the original dataset. According to the mechanism of decision tree algorithm, attributes which give the greatest information gain are tested on the top of the tree. As such, it is interesting to see that timeframe, matters more than any other attribute in the dataset in defining whether a contract was solicited or
unsolicited. The second important attribute is the country. Only for Brazil, the level of government awarding the contract mattered in defining the decision while for other countries this attribute plays no significant role.

Over time, the BRICS countries have each developed in their own unique ways, responding to very individual circumstances. Observers have called into question the continuing validity of the BRICS label. Nevertheless, the findings of this study uphold the concept. At the core of the BRICS idea is a shared approach to development, predicated on a shared initial position: underdeveloped, but replete with land, resources, and large workforce. The analysis presented here reveals that private investment in PPPs, the driver of large capital and infrastructure asset development on which developing economies build growth, have unfolded in a remarkably similar way. Specifically, three time periods stand out: pre 2000, the decade 2000 to 2010, and post 2010.

Prior to the year 2000, the BRICS nations procured few PPP projects, and with the exception of Brazil, those that were procured were all unsolicited. This scenario is consistent with the narrative that in the fledgling stage of development, governments were unfamiliar with PPPs and were yet to fashion a strategy for national development through large-scale private investment. Similarly, however, private firms saw opportunities for capital projects in these emerging BRICS nations, and took it upon themselves to exploit the inexperience of government and immature institutional checks to invest where they could. Brazil was more mature in this regard, at this time. Not only did it implement more PPP projects than the other BRICS nations combined, the majority were solicited, and not only at the national level, but also at local levels. This is indicative of Brazil having relatively greater levels of control over its developmental policy. See Figure 2.
The BRICS nations, as a whole, embraced PPPs through the decade 2000 to 2010, where investment remained consistent and steady year on year. See Table 1. While the number of projects in Brazil remained large, there was an absolute decrease compared with the previous decade, from 700 to 422. South Africa, too, appeared to slow, from 76 to 29. Russia, however grew from 8 to 113, while India jumped from 76 to 312 projects, and China soared from 45 to a staggering 598. What is telling at this time is that projects remained overwhelmingly unsolicited, though tending increasingly to be implemented at regional levels. This suggest that this decade is the real springboard of BRICS growth. Investors vie for a plethora of opportunities, but do so by courting government at both national and state levels with their proposals. Government, on the other hand, remains passive, and continues to be led by private interests in overseeing their respective nations’ economic transitions.

This passivity changes from 2010 onwards. In the previous decade, of the 1,474 PPP projects that were implemented across the BRICS countries, only 60 national projects in Brazil, and 3 regional projects in India, were solicited. All the rest were initiated by private enterprise. In this third period, however, the shift is sudden and profound; the majority of PPPs are solicited. In fact, in India, 351 are solicited while 145 are not, and in China only 20 are unsolicited, while a huge 377 are government initiated. 2010 is thus a landmark year. The momentum towards solicited projects begins at that time, is distributed fairly evenly across governmental levels of national, state and local, and is thereafter maintained year on year to the present. Certainly this shift can be explained in terms of governments gaining control of their economic development, formalizing institutions and legislation to regulate their visions, and vetting projects more rigorously to ensure they benefit the public for whom they are procured. But it may also be the case that the fallout of the world financial crisis of the previous year, 2009, may have been a critical catalyst to governments seeking to reassert control over their economies.
4 Discussion and Conclusion

PPP projects proceed when sufficient benefits accrue to both the 'public' and 'private' sides of the transaction. Game theory, however, suggests that, ceteris paribus, the greater balance of benefit will fall to the project initiator (Aziz & Nabavi, 2014). Through this lens it would seem that the governments' within BRICS are gaining the high-ground in PPP negotiations with their private counterparts, adding evidence to the proposition that the BRICS are maturing.

Still, unsolicited projects, too, have documented advantages for all sides. They can identify investments that provide quick fixes, at low risk, with good outcomes. Indeed, in a study by Yun et al., unsolicited projects were found to take far less time to complete. On average, the preparation time for solicited highway projects was shown to be 54 months, while that for unsolicited projects was just two-thirds the time, at 36 months (Yun, Jung, Han, & Park, 2015).

Free-market protagonists argue that it is not the mode of solicitation, per se, that is the problem, but government mismanagement, lack of transparency and stifling of competition (Ruiz-Nunez & Harris, 2016). Market economists point out the dismal historic record governments hold in maximizing utility of the public purse. Where the objections against solicitation can be circumvented, by extending the mandate to identify projects openly into the public area, and allowing competitors to match any unsolicited proposals, competition is in fact enhanced (Zawawi, Kulatunga, & Thayaparan, 2016). These include the 'Bonus system,' 'Swiss challenge system, and the 'Best and final offer system'.

Into the future, should BRICS economies continue to develop smoothly, we can expect greater reliance on solicited PPPs, and where unsolicited projects are initiated, greater use of checks. We can also expect further devolution of PPP procurement to local governmental levels. And finally, as developing economies 'soft-land' as fully developed economies, we can expect reducing need for PPP projects overall. Indeed, in the future, the BRICS acronym may itself need amending to absorb new emerging economies, such as Argentina or Iran.
One of the limitation of this study is its dependence on the data from the World Bank database. There have been some concerns regarding the completeness of the data, especially in regards to Chinese PPPs. However, since no other database exist, that compiles information on PPP projects worldwide; this specific source of information is used. Future studies may focus on specific regional data to come up with results that are more accurate.

References


Smart Cities: An analysis of Accepted Behaviors for Implementing BMS Technology in Pakistan Using TAM

Maqsoom A.¹* and Rehman J.²

Abstract: The world is progressing towards the smart city concepts by implementing new technologies in different attributes of their cities to save their assets. The benefits of smart cities include efficient buildings, reliable transport systems, improved healthcare, up to date education and other important systems. Buildings in any city are considered to be the basic block of the entire city, if the building get smart then the way towards the smart city would be easy. This study focuses on the behaviors of managers, responsible for operation of high rises and other multistory conventional buildings, with the help of which they are ready to convert the conventional buildings into smart buildings by introducing building management system (BMS) in Pakistan. Technology Acceptance Model (TAM) has been used to assess the Attitude (A) by analyzing four latent factors namely subjective norms (SN), organization support (OS), compatibility (C) and technology complexity (TC). 54 usable questionnaires out of 110 were analyzed through SPSS software. The results indicate that subjective norms (SN) is the most critical latent factor for implementation of BMS technology with highest average MIR value, followed by compatibility (C) and technology complexity (TC) having almost equal average MIR values, whereas organization support (OS) came out to be less critical and ranked at lowest position. The findings may be served as guidelines for improvements in handling and using building management systems in cities of Pakistan and other developing countries.

Keywords: Building Management Systems, Technology Acceptance Model, Energy Conservation in Buildings, Building Automation Systems, Smart Buildings.

¹ Ahsen Maqsoom
Assistant Professor, Department of Civil Engineering, COMSATS Institute of Information and Technology, Pakistan. E-mail: ahsen.aot@gmail.com

² Jameel ur Rehman
Graduate Student, Center for Advanced Research and Engineering (CARE), Islamabad, Pakistan
E-mail: jameelurrehman@yahoo.com
1 Introduction

In every nation around the world, distinctive areas expend energy to complete their coveted exercises for different purposes. Among them, three segments are said to be on top in their energy demands and utilization. Business division falls in top three and typically consumes significant measure of nation's energy. In created nations, structures in business part use around 15-20% of aggregate energy delivered. However in Pakistan this figure is around 7.5%, positioning third higher [1]. Lodging and hotel, educational institutions, healthcare facilities, retail offices and office structures utilize the lion's share of this energy. The energy is for the most part utilized for lighting, hardware and for HVAC (cooling and warming). Making those structures more productive may help proprietors to save their energy utilization.

It has been seen that lately, Pakistan is presently in center by investors for development of high rise structures including chains of international hotels, shopping centers, private offices and corporate workplaces. By expansion of every high rise, energy demand raises and put an influence to whatever is left of the nation's load distribution. Pakistan is confronting intense deficiency of power and these developments are constantly rising energy demands. However there are no up-coming impressive ventures to adapt this circumstance in near future. Results might be most exceedingly terrible if right strides would not be taken around there. This review centers at one conceivable way out to spare energy in this area. Energy efficiency is the topic which is being discussed presently in all sectors of life throughout the globe. Energy efficiency is very critical for companies for running and maintaining their processes sustainable. With proper control and managing its usage, organizations can reduce their energy consumption costs and can move towards green buildings. To gain this level, many Asian countries have adopted or announced the newer policies for implementing programs regarding energy efficiency or conservation. In these programs, various points focus on energy management in large buildings [2]. For making buildings smart and intelligent, there are systems that are installed in buildings and are generally termed as Building Management Systems (BMS) or Building Automation Systems (BAS). BMS is generally installed in various facilities for conservation of energy and it has been shown through several literatures that implementation of these systems help to reduce their consumption of energies significantly when compared to normal or conventional ways of doing energy reduction without using BMS [3-5]. In Pakistan, this technology is fresher when contrasted with other created nations. It has been observed that not many associations have introduced this system. Technology Acceptance Model (TAM) has been utilized as a part of different literatures for investigating behavioral aims of client's and it is known for much of the time connected and demonstrated model in such manner.

This study reviews on business segment particularly to use BMS for energy conservation. It is trusted that discoveries of this review fills in as rules for BMS clients and specialist organizations to comprehend the required practices with respect to administrative points of view. This study is fundamentally focused on investigating the latent factors of Technology Acceptance Model (TAM) for utilizing Building Management System (BMS) in Pakistan. This research tries to discover those acknowledged practices which depend on the viewpoints of managers in this field.

2 Literature Review

2.1 Building Management System

Building management system is also referred as Building Automation System (BAS). The fundamental guideline of BAS is to automate each system and to deal with each asset of the building [6]. This framework can give checking and control over different frameworks keeping in mind the end goal to get business and operational proficiency. There are many reviews which proposed that automation systems put extraordinary effect on energy conservation in structures. Structures that have these systems expend less energy when contrasted with structures without these systems. A study in Warsaw for office and private structures recommends that by actualizing building automation systems in lighting it is conceivable to utilize energy and power productively and can have financial savings that prompts bring down energy utilization and decrease in support costs [7]. Structures utilize a few assets, if BMS introduced structures can be coordinated with city asset administration frameworks then gigantic measure of city's assets could be spared [8]. The BMS applications use less energy by 25% and labor by half. This review took the instance of an airport terminal, the load of the HVAC system takes up around 40% of the aggregate energy of that office and the heap on the
lighting system takes up around 35%. We can observe that both systems consume a significant energy of the airport terminal [9].

2.2 Technology Acceptance Model

In 1989, Davis F.D. proposed a model called Technology Acceptance Model. This model talks about the human practices with respect to acceptance or adoption of modern technologies keeping in mind that end goal is to get benefits. Basic TAM is presented below in figure 1:

![Technology Acceptance Model](image)

This model is open on the left side which implies there might be outside components that could be influential to TAM. After the distribution of Davis study, numerous analysts utilized this model for examination of users’ points of view towards acceptance of more up to date advances and discovered this model substantial for results. TAM has been utilized to explore the practices of clients in different fields and found a solid structure for understanding the idea of technology acceptance everywhere throughout the world. In an exploration study, it was concluded that TAM discovered the future of health IT and proposed with suitable components of TAM could be utilized as a part of future to have future advances in health division [10]. Another research in Spain, tried the consequences of TAM with considering the external factors of trust and individual qualities (time consciousness and environmental concern) for e-government services adoption [11]. In Tunisian review, research was completed if the fantasy website acknowledged or not, results showed that technology complexity factor leaded to higher perceived ease of use [12]. Another study in Lebanon was completed to explore the expectations of utilizing balance score card and Information System in public sector organizations, the review likewise utilized TAM for its testing model [12, 13]. As it was observed that Technology Acceptance Model (TAM) has been using widely around the world to determine the acceptance of behaviors in different countries for adoption of new technologies and amazingly found this model valid for almost all cases.

2.3 Theoretical Framework

In current study four external factors were selected for TAM 1 besides existing factors of the model according to the culture of Pakistan and tested for their effectiveness. The four factors are: Subjective Norms (SN), Organizational Support (OS), Compatibility (C) and Technological Complexity (TC). These factors are assumed to be very important for acceptance of new technologies in commercial sector of Pakistan and have been used in various literatures in the past [14]. These were tested according to the model presented below (Fig 2):

![Research Model](image)
3 Method
The objective of this study is to explore some specific behaviors which are essential for acceptance of a specific technology called building management systems (BMS). This has been achieved by conducting behavior analysis of functional managers which are currently using this system. In this study, positivistic approach has been followed i.e., taking information for one time only and preparing results from that information. A questionnaire has been developed to conduct the data collection part. The proposed model offers five constructs (SN, OS, C, TC and A) for testing. These constructs have been measured through questions that were prepared after extensive look in literature and previous studies related to BMS and TAM. Each construct was further divided into five items to be asked by the participants. In result, there are twenty five questions in the final questionnaire that will measure the proposed model of technology acceptance. Each question has 5-point Likert scale as 1 for strongly disagree, 2 for disagree, 3 for neutral, 4 for agree and 5 for strongly agree. Questionnaire consists of two sections, first one is about the respondents’ general information and the second section is about the model. All participants of this study observed the same questionnaire.

The questionnaire asked about the external factors which were Compatibility (C), Technology Complexity (TC), Subjective Norms (SN) and Organizational Support (OS) and Attitude (A) of the managers for the implementation of BMS. BMS technology is not being used extensively in Pakistan so far and there are very less companies and buildings that have installed Building Management Systems, therefore the total population for this study is not too much. Efforts were made to find out for all those companies which are using BMS system and with the reference contacts nearly all buildings have been identified which are using this system in Rawalpindi/Islamabad. The questionnaire was also sent to Lahore and Karachi for filling but the response rate was very low because it was sent through e-mail service. In Rawalpindi / Islamabad, the questionnaire was sent to approximately 70% of the subject population while snowball sampling technique was used for Lahore and Karachi area. 54 usable responses were received out of 110 sent questionnaires to the main cities of Pakistan namely Islamabad, Rawalpindi, Lahore and Karachi on which analysis was carried out. The reliability and validity of questionnaire was analyzed and descriptive analysis was performed with the help of Statistical Package for the Social Sciences (SPSS).

4 Findings
This section of the paper presents the results regarding the suggestive variables as per the theoretical model. The first phase of analysis is related to the subjective norms for attitude. The results for the subjective norms are presented below in Table 3. Descriptive statistics have been found for all items and results are shown in the tabular form. Tables mention the standard deviation (S.D), minimum and maximum choices marked, mean of choices, ranks and the remarks for the corresponding means. The remarks for the corresponding means are elaborated based on the scale: 4.5-5.0 = very important, 3.5-4.49 = important, 2.5-3.49 = moderately important, 1.5-2.49 = less important, and less than 1.49 = unimportant (Kirby and Lebude, 1998; Abdul-Aziz and Wong, 2010).

4.1 Subjective Norms for Attitude

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>S. D</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>People who are important to me, think I should use BMS</td>
<td>54</td>
<td>.752</td>
<td>3</td>
<td>5</td>
<td>4.33</td>
<td>1</td>
<td>Important</td>
</tr>
<tr>
<td>People who influence me, encourage me to use BMS</td>
<td>54</td>
<td>.738</td>
<td>3</td>
<td>5</td>
<td>4.28</td>
<td>2</td>
<td>Important</td>
</tr>
<tr>
<td>People close to me, tell me about BMS benefits</td>
<td>54</td>
<td>.572</td>
<td>3</td>
<td>5</td>
<td>4.11</td>
<td>3</td>
<td>Important</td>
</tr>
<tr>
<td>People familiar to me, influence my intention to use BMS</td>
<td>54</td>
<td>.793</td>
<td>2</td>
<td>5</td>
<td>3.78</td>
<td>4</td>
<td>Important</td>
</tr>
<tr>
<td>People close to me, help me to use BMS</td>
<td>54</td>
<td>.656</td>
<td>3</td>
<td>5</td>
<td>3.72</td>
<td>5</td>
<td>Important</td>
</tr>
</tbody>
</table>

Subjective norms can be defined as the people close to one think collectively to do or not to do specific behavior by that person. In this relationship we can take the subjective norms as people think to use or not use
BMS technology by the person. The items asked about how subjective norms affect the behavior of the people. First question explores the thinking about the people close/important to the respondent for using this technology, in fact it concerns with the importance of using the technology in question. It is very common in Pakistan that people weight to others’ opinion very much specially in practical sector where they are generally dependent or linked with each other on business lines. Therefore, it is very common to think about using the same technology which is already in use by them. It is observed clearly by the mean value of this question that people are very much agreed about the item.

It is obvious from the table that all items or variables are laying in “important” category which means that means of the variables are between 3.5 to 4.49 ranges. The top item in terms of mean is “important people think to use BMS”, this is basically the culture of Pakistan in which people’s opinions matter a lot to their closed community. Similarly, variables fall in 2nd and 3rd ranks have values of mean above 4 which means they both have good impacts to the people. The remaining two variables have values below 4 but still in the range of important category. So, overall subjective norms influence the attitudes of working managers. Standard deviations of all items fall between .5 and .8, which also shows that most people have similar opinions regarding subjective norms.

### 4.2 Organization Support for Attitude

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>S. D</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>My management has positive intention to use BMS</td>
<td>54</td>
<td>.664</td>
<td>3</td>
<td>5</td>
<td>3.89</td>
<td>1</td>
<td>Important</td>
</tr>
<tr>
<td>My management is eager to know about BMS</td>
<td>54</td>
<td>.711</td>
<td>3</td>
<td>5</td>
<td>3.85</td>
<td>2</td>
<td>Important</td>
</tr>
<tr>
<td>My management supports me to use BMS</td>
<td>54</td>
<td>.906</td>
<td>1</td>
<td>5</td>
<td>3.83</td>
<td>3</td>
<td>Important</td>
</tr>
<tr>
<td>My management knows the benefits of BMS</td>
<td>54</td>
<td>.834</td>
<td>2</td>
<td>5</td>
<td>3.61</td>
<td>4</td>
<td>Important</td>
</tr>
<tr>
<td>My management understands the value of BMS</td>
<td>54</td>
<td>.899</td>
<td>1</td>
<td>5</td>
<td>3.39</td>
<td>5</td>
<td>Moderately Important</td>
</tr>
</tbody>
</table>

In today’s business environment owners and top management have more powers than before and eventually got more decision authorities. There are very few organizations in the corporate world that include their employees in making critical decisions rather 99% organizations make their important decisions through top management only. This fact put important factor on accepting new technologies in organizations. Technology acceptance model is used to determine the right behaviors to incorporate new technologies in any organization, so the factor of top management or organization support has high importance in exploring true behaviors of managers.

To have information about new and existing technologies is very easy nowadays for any person or organizations. The thing is how a person or organization perceives it. If the information have got more profits and fewer expenses then it’s very useful for organizations. The questions was asked that if the respondents’ organization knows it and have positive intention for this BMS, if yes then it means that the organization have already got knowledge and feels positive for it.

In this section, it is discussed how organization support impacts on attitude of managers. There are five items regarding OS to PU and findings show that four items have means value from 3.5 to 3.9 which shows that they are important while the fifth item has the mean value less than 3.49, which indicates that it is moderately important. This shows an overall inclination of organizations that they generally support less for using BMS according to working managers. During interviews, managers share their opinions about organization support that their owners or board of governors do not take initiatives for this technology and we (the managers) have to convince them for using it. This is because this technology has very high initial cost and owners want quick results after investing such type of costs. The benefits of this technology generally appear quickly yet return on investment starts after 1 to 1.3 years. The ROI takes place in terms of less utility bills compared to the bills before using this technology. Secondly, standard deviations of all items are less than 1 which represents good values.
So, if management even knows the benefits and positive points of any technology, it will be reluctant initially but subjective norms can do the thing if someone uses it wisely. Additionally, top management can rely on one or two persons only in their lower hierarchy for operations of their businesses. If those persons can convince the top management then it would be very easy to use it.

4.3 Compatibility for Attitude

Table 3. Descriptive Statistics of all Items towards Implementing BMS

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>S. D</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe BMS is useful for me</td>
<td>54</td>
<td>.816</td>
<td>3</td>
<td>5</td>
<td>4.11</td>
<td>1</td>
<td>Important</td>
</tr>
<tr>
<td>In my opinion BMS system is perfectly matched to my work</td>
<td>54</td>
<td>.787</td>
<td>3</td>
<td>5</td>
<td>4.06</td>
<td>2</td>
<td>Important</td>
</tr>
<tr>
<td>BMS is very suitable for my work</td>
<td>54</td>
<td>.712</td>
<td>2</td>
<td>5</td>
<td>3.94</td>
<td>3</td>
<td>Important</td>
</tr>
<tr>
<td>Using BMS fits into my work style</td>
<td>54</td>
<td>.744</td>
<td>3</td>
<td>5</td>
<td>3.89</td>
<td>4</td>
<td>Important</td>
</tr>
<tr>
<td>BMS is compatible with all aspects of my work</td>
<td>54</td>
<td>.718</td>
<td>2</td>
<td>5</td>
<td>3.78</td>
<td>5</td>
<td>Important</td>
</tr>
</tbody>
</table>

The compatibilities of new systems are highly important in organizations because new expenses are required in case of system non-compatibility. Some organizations don’t want to install the systems that are not compatible with their existing systems in order to avoid further expenses in addition to new technology costs even if the results would go far better after installing the said technology. This scenario brings the factor of system compatibility with more strength. Big organizations might ignore the compatibility costs but small and medium enterprises always consider for less expenses.

This section discusses the compatibility issues with attitude of working managers. As it is obvious from the table that all the values are important as they fall in this category. However first two items have mean values greater than 4 while the remaining three items have the values less than 4. This tells that how compatibility shows the impacts on its usefulness. The responses of first two questions indicate that compatibility of BMS technology has a good impact on managers in this field as they made their choices towards more acceptances. They think that this technology has usefulness and this usefulness could make the managers more influential and suitable in their jobs. According to responses the BMS technology has already shown its compatibility in commercial sector, the only thing remaining is how to convince the top management and the owners for using it. The values of standard deviation show that the items are well understood and this is indicated by the magnitudes of standard deviation that are less than 0.9.

The variables asked here is to measure typically the managers’ attitude due to its compatibility for the benefit of their own jobs. It has been seen that managers around the industries have shown greater usefulness for using this technology. One thing is clear from these responses that at least working managers are convinced to use BMS in their respective organizations. If suitable offer and benefits are shown to them, it would be very easy for them not only to accept it but to tell others using subjective norms influences. So, this technology has no issues regarding its compatibility with the current systems or situations.

4.4 Technology Complexity for Attitude

Table 4. Descriptive Statistics of all Items towards Implementing BMS

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>S. D</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel no difficulty in understanding the system architecture</td>
<td>54</td>
<td>.664</td>
<td>3</td>
<td>5</td>
<td>4.11</td>
<td>1</td>
<td>Important</td>
</tr>
<tr>
<td>I feel no difficulty in system technicalities</td>
<td>54</td>
<td>.752</td>
<td>3</td>
<td>5</td>
<td>4.00</td>
<td>2</td>
<td>Important</td>
</tr>
<tr>
<td>System help is easily available</td>
<td>54</td>
<td>.979</td>
<td>1</td>
<td>5</td>
<td>3.94</td>
<td>3</td>
<td>Important</td>
</tr>
</tbody>
</table>
The complexity of any technology has great importance in accepting it by the market. Generally, systems developed with difficult technologies are not easy to use and specified training for dedicated persons are required by the vendor or manufacturers. Afterwards, retaining of trained personnel is again a big deal for organizations. Therefore, small organization normally pick technologies with easy working due to above mentioned fact however large organization seldom take risks by adopting the difficult technologies and put a lot of money on it for multiple issues. So, new technologies must be easy to use and handle to create the impression of easy and adoptable. In all the items these issues were addressed. The behavior of attitude can be easily measured by the complexity of the technology.

In this section, it is observed that what impact of technology complexity can be measured on attitude. This relationship is actually measuring the complexity of BMS technology and its ease of use perceived by working managers. In the table, first two variables measure the difficulty in understanding the system architecture and the difficulty in system technicalities. Interestingly, respondents have given their opinions as they don’t feel difficulties with these two aspects. The mean value of system architecture is 4.11 and of system technicalities is 4.0.

The remaining three variables lie above 3.8 range. The variable with third rank indicates that help of BMS technology is easily available and its mean value is 3.94. Variable with fourth rank indicates that workers don’t need the manuals every time for working; it means that system operation is easy and easy to remember. Respondents have given the mean value of 3.89. Variable in the last has its mean value 3.83 and its importance indicates that respondents show that there is no difficulty in system softwares. They are easy to use and handle or they are user friendly in other words. So overall it can be perceived that respondents believe that BMS technology is not complex and it’s easy to use in any organization. The values of standard deviation are less than 1 except for one item. This indicates that the questions were well understood by respondents.

### Table 5. Descriptive Statistics of all Items towards Implementing BMS

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>S. D</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using BMS is a good idea</td>
<td>54</td>
<td>.763</td>
<td>2</td>
<td>5</td>
<td>4.39</td>
<td>1</td>
<td>Important</td>
</tr>
<tr>
<td>BMS is beneficial to my organization</td>
<td>54</td>
<td>.738</td>
<td>2</td>
<td>5</td>
<td>4.28</td>
<td>2</td>
<td>Important</td>
</tr>
<tr>
<td>BMS can improve my work experience</td>
<td>54</td>
<td>.861</td>
<td>2</td>
<td>5</td>
<td>4.22</td>
<td>3</td>
<td>Important</td>
</tr>
<tr>
<td>I have a positive perception for using BMS</td>
<td>54</td>
<td>.744</td>
<td>3</td>
<td>5</td>
<td>3.89</td>
<td>4</td>
<td>Important</td>
</tr>
<tr>
<td>Using BMS is a wise thought</td>
<td>54</td>
<td>.718</td>
<td>2</td>
<td>5</td>
<td>3.78</td>
<td>5</td>
<td>Important</td>
</tr>
<tr>
<td>Valid N (list wise)</td>
<td>54</td>
<td></td>
<td></td>
<td></td>
<td>3.78</td>
<td>5</td>
<td>Important</td>
</tr>
</tbody>
</table>

First question was asked about the goodness of idea for using BMS technology. The mean value came out to be 4.39 which indicates strong agreement for this item with value of standard deviation of .763 which is again a good sign of item understanding. For making choice for agreement of this question, managers have to be very clear about this specific technology and the mean value suggests that respondents are well aware of BMS technology and its potential benefits.

In technology acceptance model, attitude is the last behavior before actual system use and model suggests that if attitude get developed of any person then his/her attitude would be very likely to trigger to perform the task.
by accepting the new technologies and start using for the benefits. As table shows that all variables have mean values in “important” category. First in rank has the mean value 4.39 and the fifth rank possesses 3.78. Three items have mean values above 4 while remaining two variables have below 4. In this relationship, respondents actually have chosen the values for their attitude for using BMS technology. As we can see first item is related to have the perception for good a bad, interestingly, it has the highest value of 4.39 which clearly indicates that working managers have agreed its usefulness. Similarly, second item talks about the benefits of respective organization, we see that managers from different fields have chosen the mean value of 4.28, which is quite high. They believe that BMS technology has many benefits for their organization if used properly. They also have shown in third item that this technology will definitely improve their work experience in the current market.

In last two items, managers suggest that after using this technology they have a very positive perception about it and they are willing to use it in future and can recommend others. Especially in last item, they have chosen the mean value of 3.78 which indicates that according to them using BMS technology in their organization is a wise thought which may be beneficial for them.

5 Conclusion

As per the deductions of this study, an inclined rate of construction works is observed on the national scale that do demand a sustainable environment to keep on developing. Especially, if an exponential increase in the development sector on larger scale, is deemed to be observed. In terms of statistical evaluations it we determinable that the “Subjective Norms” that do impact the Technological Acceptance Model practices, which further determine the utilization of Building Management System. Followed to which is the “Compatibility” that is rated second when it comes to determine how suitable is the utilization of TAM that further suggests the application of BMS. On the third, comes the “Technological Complexity” that must be evaluated in terms of its contribution towards the TAM (Figure 3). Since, not all technological advances are considered crucial in attaining the efficiency. So opting for the right technological advances with the comprehendible level of complexity is the rightful choice. Lastly, it is the “Organizational Support” that is a considerable factor in determining the implication of the TAM over implementing the BMS.

Regardless of the prioritization, it is recommend for practical application to consider all the mentioned factors i.e. (SN, C, TC & OS) when utilizing the building management systems, in the development associated applications.

References


Manru, G., S. Wei, and X. Lijun. *Engineering design of intelligent building management system (IBMS)*. in *Computer and Communication Technologies in Agriculture Engineering (CCTAE), 2010 International Conference On*. 2010. IEEE.


Labor Productivity in Construction Industry: Impact of External Psychosocial Stressors

Ahsen Maqsoom¹*, Mazhar Ali Shah², Abdul Mughees², Faisal Khan², Muhammad Zeeshan Khan³

Abstract

Firms are facing several challenges due to dynamic nature of environment. However, researchers remain divided whether ‘workplace stress’ is caused by workplace experiences or other external factors. It is commonly accepted that regardless of the cause, employee experiencing stress will demonstrate decreased performance at the workplace. The objective of this paper is to analyze the economy, country environment, infrastructure and work environment related psychosocial factors that influence the labor productivity. Data has been collected through on-site surveys by getting survey questionnaire filled by 163 middle management and lower management staff working at various construction projects. Infrastructure and economy related psychosocial stressors are the most critical factors influencing the labor productivity. It is recognized that the labor productivity is dependent on the low salary, delay in salary, job insecurity, change in government, changing in policies and good health condition of employees.

Keywords: Labor productivity, psychosocial stressors, work environment, country environment

¹* Ahsen Maqsoom
Assistant Professor, Department of Civil Engineering, COMSATS Institute of Information and Technology, Pakistan. E-mail: ahsen.ait@gmail.com

² Mazhar Ali Shah, Abdul Mughees, Faisal Khan
Graduate Student, Department of Civil Engineering, COMSATS Institute of Information and Technology, Pakistan. E-mail: a.mugheesciit@gmail.com

³ Muhammad Zeeshan Khan
Lecturer, Department of Civil Engineering, COMSATS Institute of Information and Technology, Pakistan. E-mail: muhammad.zeeshan64@gmail.com
1 Introduction

Labor productivity in the workplace is a clear objective of an organization. In order to improve the labor productivity, there is need to reduce the stresses at the workplace. Reports and scientific literature shows that psychosocial risks are a growing challenge related to worker safety and productivity [1]. Work related stress is believed to be a major cost to organizations and countries in a wider sense, as it affects productivity, notably through absenteeism and presenteeism (EU-OSHA, 2012).

The previous scientific literature on effect of psychosocial factors reveals that psychosocial stressors cause’s health problems in employees associated with cardiovascular disease, muscular skeletal disorders, and some immune-related disorders. Also, tough work conditions, especially job stress, is associated with adverse behavioral changes and it has adverse effect on the productive work behavior of employee [2, 3]. In reviewing the scientific literature, several authors have consistently found evidence that psychosocial factors in the workplace may play a role in well-being and psychological distress of employees. However, the impact of psychosocial workplace factors on labor productivity has not been reviewed. This is regrettable because poor productivity of labor has a major impact on project performance in terms of timely completion and cost overrun.

In Pakistan, the construction industry is facing a lot of problems regarding psychosocial and organizational factors which influence employees’ productivity and also project performance. As the employee is the basic unit of organization, if he does not perform well, the whole progress definitely gets into un-satisfactory phase. Most of the projects in Pakistan suffer the failure due to poor labor performance [4]. Although these psychosocial parameters are difficult to remove but they can be reduced to the significant scale.

The objective of this paper is to investigate the effect of external psychosocial stressors on labor productivity in construction industry of Pakistan. The psychosocial stressors examined in this study are country environment; economy; infrastructure and work environment related stressors. The findings of this study will contribute to the previous literature related to psychosocial issues, where there is scarcity of literature relating to construction sector.

2 Literature Review

Some of the theoretical models regarding stress have included the country environment as a key stressor influencing the employee productivity [5]. For the success of project, it must have a good management and knowledge of the impact of country environmental related stressors. [6] identified some country environment related factors that constitutes the environment of project as political, legal, institutional, cultural, sociological, technological resources, economic, financial, and physical infrastructure. He listed these environmental factors as stress causing factors. This factor is the product of government policies and their decisions that directly influence on projects. The issues include the changing policies and hence the budget. Government can also use their power to initiate or stop the project on political, social, and economic grounds. Thus political stability, national unity and leadership are very crucial in the development process [7].

Economy related factors have the highest level of stress induced into the worker’s mind. This is the most critical and basic factor for stress and indeed for the worker because it is their basic need for the survival and for satisfaction. The highest level of stress is caused by low wages of workers. In some cases the employees’ wages are being delayed or not enough and not improving with time due to bad economy of country, hence a worrying factor for worker. Thus minimum wage produces stress on the worker giving him no reason to remain fair to his job [8]. An employee is in stress if he is having insecurity about his job. He is worried that either he will be transferred or left un-employed. The job insecurity to which workers are subjected is linked to the perception of role conflict and ambiguity [9].

Infrastructure related psychosocial factors effects in huge scale the worker productivity [10]. In construction, labor productivity is impacted very broadly by the change and compression in schedule. [11] examined the effect of shortening the estimated duration on workers during project and identified that planned or unplanned schedule compression causes losses in labor performance. [12] also found similar results from his study, that the economic consequences of schedule acceleration to the contractor relative to labor productivity are quite severe. Some researchers suggest optimum weather conditions for a high productivity levels [13]. [14]
observed in their study that significant losses of 65% in productivity were due to rainfall and cold temperatures.

Work environment plays a key role in developing employees’ attitudes and behaviors. Motivation is also dependent upon work environment and other processes. Immense competition and continuous increase in cost of production is leading organizations toward downsizing, layoffs and restructuring as a result employees have to do a lot of work as compared to before as additional workload is added to their responsibilities [15]. Also a shift towards service economy has increased work flexibility which has caused increased work pressure and workload [16]. Some researchers found links between employee health and aspects of the physical environment at work such as indoor air quality, ergonomic furniture and lighting. In many studies, it is found that the office workers are not comfortable in open plan configuration and prefer private enclosed workspace [17].

3 Research Method

Keeping in view the research questions above a structured questionnaire was developed considering the factors as identified in the proceeding discourse on economy, infrastructure, country environment and work environment related psychosocial factors. In order to ensure validity of the questionnaire, a combination of items developed and used by previous researchers was adopted. Further, the questionnaire was pretested with the Head of Construction Association of Pakistan and construction contracting firms in Pakistan.

Questionnaire was divided into three parts. The first part includes eleven questions related to the general background of firms. Nine questions were asked related to the labor productivity and project performance which made the second part of the questionnaire. The third part of the questionnaire included 4 questions related to the psychosocial factors influencing the labor productivity. First question was related to the country environment related psychosocial stressors which included 6 items, second question was related to the economy related stressors which included 6 items, third question was related to the infrastructure stressors which included 7 items and last question was related to work environment related stressors which included 8 items.

The response rate of in this study is 74.5% as total 220 questionnaire were sent to the construction contracting firms who have operated overseas and out of which 164 complete responses were returned. The data so collected was then analyzed using (SPSS) statistical package for social science. With respect to internal consistency of the survey instrument, each factors cronbach alpha was greater than 0.7, corroborating the reliability of the items. Later, the responses were extrapolated based on the scale: 4.5-5.0=very important, 3.5-4.49=important, 2.5-3.49=moderately important, 1.5-2.49=less important, and less than 1.49=unimportant.

4 Research Findings

The first phase on analysis is related to the country environment related psychosocial stressors influencing the labor productivity. These stressors were taken from earlier researches on country environment related factors causing the stress in employees. The results for this phase are presented in Table 1 below.

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wars and natural disasters add to the hardship of the worker reducing their work efficiency</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.86</td>
<td>.949</td>
<td>1</td>
<td>Imp</td>
</tr>
<tr>
<td>Change in government usually rattles the work progress</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.82</td>
<td>.855</td>
<td>2</td>
<td>Imp</td>
</tr>
<tr>
<td>Social norms and employee lifestyle affects the way employee think about the project</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.79</td>
<td>.928</td>
<td>3</td>
<td>Imp</td>
</tr>
<tr>
<td>Economy and political state of the region influences the work progress</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.75</td>
<td>.945</td>
<td>4</td>
<td>Imp</td>
</tr>
</tbody>
</table>
Employees are mostly concerned with the change in policies that can be beneficial or adverse for them

Change in taxation laws, licensing and insurance laws creates problem for the employees

All variables in the country environment related psychosocial factors are considered important by the respondents. “Wars and natural disasters add to the hardship of the worker reducing their work efficiency” is ranked 1st among the other variables in country environmental related factors with MIR value 3.86 and SD value 0.949. Every organization try to complete their project in time but various conditions such as flood, earthquake, wars, government change etc causes the time overrun in projects. Due to natural disaster the efficiency of worker decreases and ultimately affects the project performance and quality.

“Change in government usually rattles the work progress” and “Employees are most concerned with the change in policies that can be beneficial or adverse for them” are ranked 2nd and 5th among the other variables with MIR values 3.82 and 3.61 and SD values 0.855 and 0.945. Change in government or its policies is important factor which delay the project. Government can also use their power to initiate or stop the project on political, social, and economic grounds. Thus political stability, national unity and leadership are very crucial in the development process of project and it harms the productivity of labor.

“Social norms and employee lifestyle affects the way employee thinks about the project” and “Economy and political state of the region influences the work progress” are important factors and ranked 3rd and 4th among the other variables with MIR values 3.79 and 3.75 and SD values 0.928 and 0.945. Being country related environmental stressors; these factors can influence physiological processes, producing negative impacts, limit employee motivation and their performance and limits their social interaction. Lastly, “Change in taxation laws, licensing and insurance laws creates problem for the employees” is ranked 6th among the other variables with MIR value 3.55 and SD value 0.833. The results of the study show that these laws are strictly followed by Pakistani construction industry as this variable is considered important but ranked last among other variables.

The second phase of the results is related to economy related psychosocial stressors (Table 2). “Low wage/salary of employee effect that progress of project”, “the delay in salary employees has a negative effect on project progress” and “in the case of financial crisis employees feel uncomfortable in their job” are important factors and ranked 1st, 2nd and 5th among the other variables in economy related psychosocial factors with MIR values 4.08, 4.06 and 3.83 and SD values 0.896, 0.734 and 0.750. According to Brown et al. (1982), the effect of minimum wages in employment has negative effect although fairly small in their study. Low salary/wages is important factor for the employees because if salary of employee is less and sometime delayed, then employee will not take an interest in project and will feel uncomfortable. The employee will face burden from family expenditure and it will have negative effect on his performance.

Table 2. Economy Related Psychosocial Stressors

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low wages/salary of employee affect the progress of project</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>4.08</td>
<td>.896</td>
<td>1</td>
<td>Imp</td>
</tr>
<tr>
<td>The delay in salaries of employees has a negative effect on project progress</td>
<td>163</td>
<td>2</td>
<td>5</td>
<td>4.06</td>
<td>.734</td>
<td>2</td>
<td>Imp</td>
</tr>
<tr>
<td>Financial stability of the firm keeps the employee satisfied with the job</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>4.01</td>
<td>.871</td>
<td>3</td>
<td>Imp</td>
</tr>
<tr>
<td>Job insecurity causes the reduction in the performance of worker</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.85</td>
<td>.764</td>
<td>4</td>
<td>Imp</td>
</tr>
<tr>
<td>In case of financial crisis employees feel</td>
<td>163</td>
<td>2</td>
<td>5</td>
<td>3.83</td>
<td>.750</td>
<td>5</td>
<td>Imp</td>
</tr>
</tbody>
</table>
uncomfortable in their job

Economic stability of the country is a crucial factor for the motivation of employees

Financial stability of firm keeps the employee satisfied with the job” is the important factor and ranked 3rd among the other variables with MIR value 4.01 and SD value 0.871. If the employee salary is stable, he will show interest in job. He will feel relax or comfortable and will work at job with full effort. “Job insecurity causes the reduction in the performance of worker” is the important factor and ranked 4th among the other variables with MIR value 3.85 and SD value 0.764. According to Montgomery et al. (1996), the job insecurity to which workers are subjected is linked to the perception of role conflict and ambiguity. Studies have shown that job insecurity links with the decreasing psychological health, leading to distress and burnout. If employee job is insecure then the employee will face difficulties and face depression. As a result, it will affect the worker productivity.

“Economic stability of the country is a crucial factor for the motivation of employee” is also ranked 5th among the other variable in economy related psychosocial factors with MIR value 3.83 and SD value 0.966. If the country has good economic stability than the employees will be motivated due to better conditions in the country and they will take interest in the job and vice versa.

The third phase of the results is related to infrastructure related psychosocial stressors (Table 3). “Sudden compression in schedule puts extra burden on employees” is the important factor and ranked 1st among the other variables in infrastructure related psychosocial factors with MIR value 4.40 and SD value 0.510. Sudden and unpleasant compression in project schedule can disturb the uniformity of employees and due to this employees may have less interest in development of project. Employees can face difficulties in handling the work due to compression in schedule, so the efficiency of work greatly reduces.

Table 3. Infrastructure Related Psychosocial Stressors

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sudden compression in schedule puts extra burden on employees</td>
<td>162</td>
<td>2</td>
<td>5</td>
<td>4.40</td>
<td>.510</td>
<td>1</td>
<td>Imp</td>
</tr>
<tr>
<td>Good health condition of employees drives their performance</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>4.20</td>
<td>.815</td>
<td>2</td>
<td>Imp</td>
</tr>
<tr>
<td>Performance level of different aged employees is different</td>
<td>163</td>
<td>2</td>
<td>5</td>
<td>4.04</td>
<td>.753</td>
<td>3</td>
<td>Imp</td>
</tr>
<tr>
<td>Discontinuity in work schedule due to equipment and material based problem demoralizes the worker</td>
<td>162</td>
<td>1</td>
<td>5</td>
<td>3.95</td>
<td>.833</td>
<td>4</td>
<td>Imp</td>
</tr>
<tr>
<td>The arrangement of tools and equipment in unorganized manner affects the progress badly</td>
<td>162</td>
<td>2</td>
<td>5</td>
<td>3.88</td>
<td>.866</td>
<td>5</td>
<td>Imp</td>
</tr>
<tr>
<td>Design error if occurs at some point creates confusion and sense of un-surety in worker</td>
<td>162</td>
<td>2</td>
<td>5</td>
<td>3.86</td>
<td>.923</td>
<td>6</td>
<td>Imp</td>
</tr>
<tr>
<td>Sudden illness of worker causes stoppage of work</td>
<td>162</td>
<td>2</td>
<td>5</td>
<td>3.62</td>
<td>.959</td>
<td>7</td>
<td>Imp</td>
</tr>
</tbody>
</table>

“Good Health condition of employees drives their performance” and “sudden illness of worker causes stoppage of work” are ranked 2nd and 7th among the other variables in infrastructure related psychosocial factors with MIR values 4.20 and 3.62 and SD values 0.815 and 0.959. If the employees are healthy then the project work will continue uniformly and with fast pace. Whereas if the employees are sick or having health problems, it will slow their productivity and cause delay in project work. “Performance level of different aged employees is different” is ranked 3rd among the other variables with MIR value 4.04 and SD value 0.753. Performance is directly proportional to the age of employees. Young employees can show good results and

529
work in the finalizing of project rapidly and reliably. On the other hand aged employees are unable to produce the work at faster speed.

“Discontinuity in work schedule due to equipment and material based problem demoralizes the worker” and “the arrangement of tools and equipment in unorganized manner affects the progress badly” are ranked 4th and 5th among the other variables with MIR values 3.95 and 3.88 and SD values 0.833 and 0.866. Uniformity is one of the most important factors in the finishing of project on time. If the discontinuity occurs in work schedule, then it will affect the project work and demoralize the worker, which ultimately affects the worker’s interest in work. Thomas (2000) also found similar results from his study, that the economic consequences of schedule acceleration to the contractor relative to labor productivity are quite severe.

“Design error if occurs at some point creates confusion and sense of un-surety in worker” is the important factor and ranked 6th among the other variables with MIR value 3.86 and SD value 0.923. Design is most important part of a construction project. If some problem occurs in design at some certain point, it will waste time and make discontinuity in the work. Without proper designing it is impossible to work efficiently, it develops the disintegration and un-sure sense in the worker.

The fourth phase of the results is related to work environment related psychosocial stressors (Table 4). “Long working hours without any sufficient rest reduces the efficiency of employees” and “Insufficient pay for the overtime reduces worker’s performance” are ranked 1st and 2nd among the other variables in the work environment related psychosocial stressors with MIR values 4.16 and 4.11 and SD values 0.846 and 0.861. Work environment plays a key role in developing employee’s attitude and behavior. Spector (1997) also observed that ignoring the working environment within the organization effect on the performance of its employees. According to him, the workers do not work properly if they are having work burden and less rest. Long working hours without any sufficient rest demotivates the employee and is harmful for the worker health as well as his productivity. If the firm pays less wages or insufficient pay to the employees for the overtime, it will reduce the worker performance which directly affects the project success.

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
<th>Rank</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long working hours without any sufficient rest reduces the efficiency of employees</td>
<td>163</td>
<td>2</td>
<td>5</td>
<td>4.16</td>
<td>.846</td>
<td>1</td>
<td>Imp</td>
</tr>
<tr>
<td>Insufficient pay for the overtime reduces worker’s performance</td>
<td>163</td>
<td>2</td>
<td>6</td>
<td>4.11</td>
<td>.861</td>
<td>2</td>
<td>Imp</td>
</tr>
<tr>
<td>Un-accessibility to the different tools and equipment required for the job slows down the work rate</td>
<td>163</td>
<td>2</td>
<td>32</td>
<td>4.02</td>
<td>2.365</td>
<td>3</td>
<td>Imp</td>
</tr>
<tr>
<td>Employee feels devolved in case of having no authority for decision required on sites</td>
<td>163</td>
<td>2</td>
<td>5</td>
<td>4.00</td>
<td>.816</td>
<td>4</td>
<td>Imp</td>
</tr>
<tr>
<td>Availability of basis facilities at work area increase the comport level of workers</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.90</td>
<td>.848</td>
<td>5</td>
<td>Imp</td>
</tr>
<tr>
<td>Ease of access to the work location by cheap means adds to the satisfaction of worker</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.87</td>
<td>.862</td>
<td>6</td>
<td>Imp</td>
</tr>
<tr>
<td>In-appropriate lighting causes laziness, dullness in the workers</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.40</td>
<td>1.046</td>
<td>7</td>
<td>Mod Imp</td>
</tr>
<tr>
<td>A worker gets bored by doing the same job everyday</td>
<td>163</td>
<td>1</td>
<td>5</td>
<td>3.40</td>
<td>1.069</td>
<td>7</td>
<td>Mod Imp</td>
</tr>
</tbody>
</table>

“Un-accessibility to the different tools and equipment required for the job slows down the work rate” and “Ease of access to the work location by cheap means adds to the satisfaction of worker” are ranked 3rd and 6th among the other variables in work environment with MIR values 4.02 and 3.87 and SD values 2.365 and 0.862). These factors are very common and can be faced in almost every construction project. For better
construction site, organization needs to hire management group to make a nice plan. The management group can handle different equipment and tools at the time of construction, if they did not manage properly employee causes stress which affects the project performance.

“Employee feels devolved in case of having no authority for decision required on sites” and “Availability of basic facilities at work area increase the comport level of workers” are important factors and ranked 4th and 5th among the others variables with MIR values 4.0 and 3.90 and SD values 0.816 and 0.848. In an organization, performance depends upon the employee’s condition which includes employee health, authorities, facilities etc. In construction projects, availability of facilities and having authority for the decision making increases the encouragement of employees, hence positively affecting the employee productivity and project performance.

“In-appropriate lighting causes laziness, dullness in the workers” and “A worker gets bored by doing the same job everyday” are moderately important stressors and ranked 7th among the other variables in work environment related psychosocial stressors with MIR value 3.40 and SD values 1.046 and 1.069. Construction workers need a proper light supply for carrying out their work in an effective way. Insufficient supply of light causes problem to the worker and induces stresses which ultimately results in non-completion of work in time. It seems from the results of the study that employees in Pakistani construction industry usually get different tasks from the management which keeps them motivated and are having proper light arrangements at the construction projects; hence these two variables have comparatively less impact on the labor productivity.

5 Conclusions

This research investigated the external psychosocial stressors influencing the labor productivity in construction industry of Pakistan. Based on results of the study, overall picture of the external psychosocial stressors influencing the labor productivity is shown in figure 1. Among the psychosocial stressors, infrastructure related psychosocial stressors are found to be the most critical with average MIR value 3.96 followed by the economy related psychosocial stressors with average MIR value 3.90. On the other hand, country environment related psychosocial stressors are found to be less critical comparatively with average MIR value of 3.73.

![Figure 1. Average MIR Values of the Psychosocial Stressors](image)

Among the variables, it is recognized that labor productivity is influenced by the sudden compression in schedule and health condition of employees (infrastructure related), low wages/salary and delay in salaries (economy related), long working hours and insufficient pay for the overtime (work environment related) and wars and natural disasters and change in government (country environment related) stressors.

This research is limited to the construction sector and Pakistani economy only. However, the future studies can be conducted on other sectors and developing economies for the better understanding. The authors of this research call for future studies to be conducted which measures the variance in the psychosocial factors vis-à-vis age and industry experience of employees.
References


Impact of Crew Composition on Productivity and Unit Labour Cost in Construction Projects – A Case Study

Gupta, M.1*, Hasan, A.2, Jain, A.K.3 and Jha, K.N.4

Abstract: The construction projects are usually labour-intensive. Consequently, construction workers become an important resource who drive productivity through effective use of materials and equipment. Although considerable research has been conducted in the area of construction labour productivity, very few studies have examined the impact of crew composition on productivity and unit labour cost. The present study was undertaken to examine the impact of crew composition on both labour productivity and unit labour cost in shuttering activities in a construction project. A total of 20 sub-contractors working on a construction site were evaluated in terms of the number of workers engaged, productivity rates, and unit labour cost incurred during the shuttering job. A correlation between these three attributes for each sub-contractor provided some useful insights into the impact of unbalanced crew composition on labour productivity and total project cost.

Keywords: Crew composition, Labour productivity, Unit labour rate, Shuttering, Formwork

1* Gupta, M.
Corresponding author, M.Tech. Student, Department of Civil Engineering, IIT Delhi, India.
Email: mayank1673@gmail.com

2 Hasan, A.
PhD Candidate, School of Natural and Built Environments, University of South Australia, Australia.
Email: abid.hasan@mymail.unisa.edu.au

3 Jain, A.K.
Professor, Department of Civil Engineering, IIT Delhi, India.
Email: akjain@civil.iitd.ac.in

4 Jha, K.N.
Associate Professor, Department of Civil Engineering, IIT Delhi, India.
Email: knjha@civil.iitd.ac.in
1 Introduction

Project scheduling is based on realistic projection of total man-hours and it is one of the key parameters in the successful completion of construction projects [1]. A crew on a construction site refers to a group of workers engaged in a particular activity such as concreting, shuttering (formwork), and fabrication. In a typical large-sized construction project in developing countries such as India, a large number of workers are employed through different sub-contractors to do the same activity. Each of these sub-contractors has a different crew composition based on the number, skill, efficiency and experience of the workers for performing that activity. As a result, labour productivity of different crews differ considerably due to notable differences in the nature of job, and personal and professional traits of the workers.

While some of the crews exhibit higher productivity, others may cause delays in the completion of the assigned jobs due to low productivity rates. An imbalanced crew takes more time to complete an activity due to lower productivity as compared to a balanced crew. This difference in productivity rates may affect both cost and schedule of the entire project. One of the possible solutions to maintain similar productivity rates is to achieve a balance between different classes of workers engaged in a particular activity. The crew composition will depend upon the nature, size, and quantum of the activity along with the required level of expertise and skill.

The poor performance of the crews was found to be a major cause of turnover and absenteeism amongst construction workers [2] which impedes the progress of the entire project. Due to an imbalanced crew composition, the sub-contractors need to put more efforts towards monitoring their work and applying corrective measures to ensure timely completion of the assigned work. This highlights the need of a balanced composition of the crew to achieve better performances. However, on several occasions, the sub-contractors engage a large number of workers to meet the tight deadlines of the project but they generally overlook the importance of organising the workers into balanced crews. A balanced crew should include the workers possessing different skills that are needed to perform a particular job. The oversized crews could be sub-divided into smaller crews to make them more manageable and productive. Moreover, the age and experiences of the crew members have a significant impact on the efficiency of the crew [3]. The proper size and composition of the crew also prevent overcrowding, interference, and unproductive work on construction sites and thereby, boost the morale and productivity of the workers [4]. Since majority of construction activities are undertaken at the crew level, the performance of the crew affects the productivity in construction operations. Hence, it is necessary that the optimum crew composition is maintained for timely completion of an activity.

2 Research Objectives

It is not necessary that each of the sub-contractors engage all different classes of workers in a right proportion. This leads to remarkable differences in the productivity rates achieved by them while performing the same activity in a construction project. The problem of imbalanced crew is more dominant in labour-contracts where the main contractor incur more financial loss than his sub-contractors because the payments are made to the subcontractors on the basis of head-counts rather than item-rate work due to the contractual obligations. However, in case of lump-sum contracts,
item-rate contracts, and cost-plus contracts, the payment to the workers is made by the subcontractors and thereby, the sub-contractors suffer more due to low productivity rates. Therefore, there is a clear scope for improving the productivity through better crew compositions in construction projects. The main objectives of this paper is to examine the impacts of crew composition on productivity rates and unit labour cost in a construction project.

3 Data Collection and Analysis

The data pertaining to the shuttering activity at a steel plant construction site in the state of Orissa, India was collected for this study. The quantity of the work executed by different sub-contractors was taken out from the daily progress reports (DPR) maintained by the planning department of the main contractor. These reports track the quantum of work executed by different sub-contractors in a structured manner on a daily basis. The basic labour wages were also obtained from the planning department. The data regarding the man-days (MD) worked and overtime (OT) hours were collected from the labour reports maintained by the finance department of the main contractor. The crew composition was then worked out by taking the inputs from the site supervisors. Table 1 shows the data on the number of MD and OT of the four different categories of crew workers of twenty different sub-contractors along with the quantity of shuttering completed by the crew in one month.

Table 1. Man-days and overtime performed by four different classes of workers

<table>
<thead>
<tr>
<th>Sub-contractor</th>
<th>Carpenter</th>
<th>Assistant-carpen</th>
<th>Helper</th>
<th>Foreman</th>
<th>Shuttering (in m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MD OT (h)</td>
<td>MD OT (h)</td>
<td>MD OT (h)</td>
<td>MD OT (h)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>96 311</td>
<td>50 159</td>
<td>244 767</td>
<td>30 95</td>
<td>591.59</td>
</tr>
<tr>
<td>2</td>
<td>118 284</td>
<td>0 0</td>
<td>182 445</td>
<td>0 0</td>
<td>355.49</td>
</tr>
<tr>
<td>3</td>
<td>168 451</td>
<td>0 0</td>
<td>307 800</td>
<td>0 0</td>
<td>594.31</td>
</tr>
<tr>
<td>4</td>
<td>53 167</td>
<td>0 0</td>
<td>199 624</td>
<td>32 103</td>
<td>456.30</td>
</tr>
<tr>
<td>5</td>
<td>162 570</td>
<td>0 0</td>
<td>370 1289</td>
<td>0 0</td>
<td>387.67</td>
</tr>
<tr>
<td>6</td>
<td>58 161</td>
<td>0 0</td>
<td>161 447</td>
<td>26 71</td>
<td>373.73</td>
</tr>
<tr>
<td>7</td>
<td>141 587</td>
<td>69 251</td>
<td>187 935</td>
<td>0 0</td>
<td>427.65</td>
</tr>
<tr>
<td>8</td>
<td>38 89</td>
<td>2 4</td>
<td>95 225</td>
<td>0 0</td>
<td>165.60</td>
</tr>
<tr>
<td>9</td>
<td>73 209</td>
<td>0 0</td>
<td>168 469</td>
<td>0 0</td>
<td>309.82</td>
</tr>
<tr>
<td>10</td>
<td>36 72</td>
<td>0 0</td>
<td>61 124</td>
<td>0 0</td>
<td>82.85</td>
</tr>
<tr>
<td>11</td>
<td>31 76</td>
<td>0 0</td>
<td>135 287</td>
<td>0 0</td>
<td>101.44</td>
</tr>
<tr>
<td>12</td>
<td>90 91</td>
<td>56 58</td>
<td>426 445</td>
<td>0 0</td>
<td>125.56</td>
</tr>
<tr>
<td>13</td>
<td>63 158</td>
<td>0 0</td>
<td>88 264</td>
<td>0 0</td>
<td>222.29</td>
</tr>
<tr>
<td>14</td>
<td>83 96</td>
<td>3 0</td>
<td>131 168</td>
<td>0 0</td>
<td>224.22</td>
</tr>
<tr>
<td>15</td>
<td>141 461</td>
<td>31 97</td>
<td>133 437</td>
<td>21 76</td>
<td>601.79</td>
</tr>
<tr>
<td>16</td>
<td>17 30</td>
<td>0 0</td>
<td>89 162</td>
<td>12 22</td>
<td>82.96</td>
</tr>
<tr>
<td>17</td>
<td>18 35</td>
<td>0 0</td>
<td>137 261</td>
<td>0 0</td>
<td>95.00</td>
</tr>
<tr>
<td>18</td>
<td>22 51</td>
<td>0 0</td>
<td>12 30</td>
<td>0 0</td>
<td>25.20</td>
</tr>
<tr>
<td>19</td>
<td>28 76</td>
<td>0 0</td>
<td>92 218</td>
<td>0 0</td>
<td>125.20</td>
</tr>
<tr>
<td>20</td>
<td>86 273</td>
<td>0 0</td>
<td>149 463</td>
<td>0 0</td>
<td>217.62</td>
</tr>
</tbody>
</table>

Table 1 contains information on the amount of time spent by the four different class of the workers...
involved in the shuttering activity: carpenter, assistant-carpenter, helper, and the foreman. The time spent was segregated in terms of normal MD and OT. Here, MD represents the normal eight-hour work duration of a construction worker while the extra hours over and above MD are considered as OT.

The labour wages, skill level, and brief description of the job for different classes of workers involved in the shuttering activity have been presented in Table 2.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Class/Category of worker</th>
<th>Skill level</th>
<th>MD wages (in INR)</th>
<th>Brief job description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Foreman</td>
<td>Highly-skilled</td>
<td>600</td>
<td>Supervision of the job; Job execution as per drawing and specification; Job planning and mobilization of workers; Job progress</td>
</tr>
<tr>
<td>2</td>
<td>Carpenter</td>
<td>Skilled</td>
<td>550</td>
<td>Shutter making; Fixing; Alignment; Plumbing; De-shuttering</td>
</tr>
<tr>
<td>3</td>
<td>Assistant carpenter</td>
<td>Semi-skilled</td>
<td>500</td>
<td>Assistance to the Carpenter</td>
</tr>
<tr>
<td>4</td>
<td>Helper</td>
<td>Unskilled</td>
<td>490</td>
<td>Shifting materials; Application of shuttering oil on boards; Cleaning</td>
</tr>
</tbody>
</table>

As can be seen from Table 1, only few sub-contractors had employed the workers from all the four different classes of the workers in the crew while most of them had either assistant carpenter or foreman or both of them missing from their crews. Consequently, the work of semi-skilled assistant carpenter had to be compensated by the other workers in the crew. However, the compensated work of would take more time if it is performed by a helper. On the other hand, if it is performed by a carpenter, the time of a skilled worker would be lost while doing a low-skilled task. Therefore, an imbalanced approach in recruiting the workers from different classes can affect the labour productivity in a negative manner.

The total time taken by the carpenter, assistant carpenter, helpers and the foreman were calculated by using Equation 1.

\[
\text{Total time (MD)} = \text{number of MD} + \frac{\text{OT}}{8} \quad (1)
\]

The productivity of each crew was then calculated using Equation 2.

\[
\text{Shuttering productivity} = \frac{\text{Shuttering quantity (m}^2\text{)}}{\text{TotalTime (MD)}} \quad (2)
\]

From the daily wages amount as shown in Table 2, the amount paid to each category of the workers can be easily calculated by multiplying it with the total MD of that particular category. The summation of the amounts paid to all the four categories of workers will give the total cost to be borne by the sub-contractor. The unit labour cost of shuttering was calculated by using the following equation.

\[
\text{Unit labour cost of shuttering} = \frac{\text{Total cost (INR)}}{\text{Shuttering quantity (m}^2\text{)}} \quad (3)
\]

4 Correlation between Crew Composition, Unit Labour Cost, and Productivity
Table 3 shows the total cost incurred, cost incurred per square metre of shuttering (unit labour cost), and productivity rates for the crews of all twenty sub-contractors.

<table>
<thead>
<tr>
<th>Sub-contractor</th>
<th>Carpenter (MD)</th>
<th>Assistant carpenter (MD)</th>
<th>Helper (MD)</th>
<th>Foreman (MD)</th>
<th>Total (MD)</th>
<th>Total cost (INR)</th>
<th>Unit labour cost (INR)</th>
<th>Productivity (m²/MD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>135</td>
<td>69.88</td>
<td>339.88</td>
<td>41.88</td>
<td>587</td>
<td>591.59</td>
<td>300783</td>
<td>1.05</td>
</tr>
<tr>
<td>2</td>
<td>154</td>
<td>0</td>
<td>237.63</td>
<td>0</td>
<td>391</td>
<td>355.49</td>
<td>200861</td>
<td>1.01</td>
</tr>
<tr>
<td>3</td>
<td>224</td>
<td>0</td>
<td>407</td>
<td>0</td>
<td>631</td>
<td>594.31</td>
<td>322836</td>
<td>1.05</td>
</tr>
<tr>
<td>4</td>
<td>74</td>
<td>0</td>
<td>277</td>
<td>44.88</td>
<td>396</td>
<td>456.30</td>
<td>203286</td>
<td>1.22</td>
</tr>
<tr>
<td>5</td>
<td>233</td>
<td>0</td>
<td>531.13</td>
<td>0</td>
<td>764</td>
<td>387.67</td>
<td>388539</td>
<td>0.51</td>
</tr>
<tr>
<td>6</td>
<td>78</td>
<td>0</td>
<td>216.88</td>
<td>34.88</td>
<td>330</td>
<td>373.73</td>
<td>170163</td>
<td>1.20</td>
</tr>
<tr>
<td>7</td>
<td>214</td>
<td>100.38</td>
<td>303.88</td>
<td>0</td>
<td>619</td>
<td>427.65</td>
<td>316993</td>
<td>0.86</td>
</tr>
<tr>
<td>8</td>
<td>49</td>
<td>2.5</td>
<td>123.13</td>
<td>0</td>
<td>175</td>
<td>165.60</td>
<td>88600</td>
<td>0.95</td>
</tr>
<tr>
<td>9</td>
<td>99</td>
<td>0</td>
<td>226.63</td>
<td>0</td>
<td>326</td>
<td>309.82</td>
<td>165565</td>
<td>0.95</td>
</tr>
<tr>
<td>10</td>
<td>45</td>
<td>0</td>
<td>76.5</td>
<td>0</td>
<td>122</td>
<td>82.85</td>
<td>62235</td>
<td>0.76</td>
</tr>
<tr>
<td>11</td>
<td>41</td>
<td>0</td>
<td>170.88</td>
<td>0</td>
<td>211</td>
<td>101.44</td>
<td>106004</td>
<td>0.48</td>
</tr>
<tr>
<td>12</td>
<td>101</td>
<td>63.25</td>
<td>481.63</td>
<td>0</td>
<td>646</td>
<td>125.56</td>
<td>323378</td>
<td>0.28</td>
</tr>
<tr>
<td>13</td>
<td>83</td>
<td>0</td>
<td>121</td>
<td>0</td>
<td>204</td>
<td>222.29</td>
<td>104803</td>
<td>1.09</td>
</tr>
<tr>
<td>14</td>
<td>95</td>
<td>3</td>
<td>152</td>
<td>0</td>
<td>250</td>
<td>224.22</td>
<td>128230</td>
<td>0.90</td>
</tr>
<tr>
<td>15</td>
<td>199</td>
<td>43.12</td>
<td>187.63</td>
<td>30.5</td>
<td>460</td>
<td>601.79</td>
<td>241043</td>
<td>1.35</td>
</tr>
<tr>
<td>16</td>
<td>21</td>
<td>0</td>
<td>109.25</td>
<td>14.75</td>
<td>145</td>
<td>82.96</td>
<td>73795</td>
<td>0.67</td>
</tr>
<tr>
<td>17</td>
<td>22</td>
<td>0</td>
<td>169.63</td>
<td>0</td>
<td>192</td>
<td>95.00</td>
<td>95423</td>
<td>0.62</td>
</tr>
<tr>
<td>18</td>
<td>28</td>
<td>0</td>
<td>15.75</td>
<td>0</td>
<td>44</td>
<td>25.20</td>
<td>23324</td>
<td>0.82</td>
</tr>
<tr>
<td>19</td>
<td>38</td>
<td>0</td>
<td>119.25</td>
<td>0</td>
<td>157</td>
<td>125.20</td>
<td>79058</td>
<td>0.80</td>
</tr>
<tr>
<td>20</td>
<td>120</td>
<td>0</td>
<td>206.88</td>
<td>0</td>
<td>327</td>
<td>217.62</td>
<td>167438</td>
<td>0.67</td>
</tr>
</tbody>
</table>

It can be seen that the productivity values of the crews of different sub-contractors for shuttering varied considerably from 0.28 m²/MD to 1.35 m²/MD on the same construction site performing the same activity under same set of conditions. Additionally, only seven sub-contractors had obtained a productivity rate above 1.0 m²/MD. Out of these seven sub-contractors, only two had recruited the
workers from all four different categories. The other four sub-contractors had imbalanced crews but still managed to achieve the productivity rates comparable to that of sub-contractors with balanced crews. However, it should not be concluded that the imbalanced crews could also give equally higher productivity rates until examining the cost incurred per square metre of shuttering because the higher productivity rates could be the result of higher costs incurred due to larger man days spent by the skilled workers to compensate the unavailability of other semi-skilled or unskilled workers. Another point that needs to be considered is that out of twenty sub-contractors, only five engaged foreman to supervise the workers. The productivity rates for four of these five sub-contractors were greater than 1.0 m²/MD which show that the foreman holds a significant place in the crew composition for achieving a higher productivity rate. Previous researchers have also emphasised the role of supervisor in ensuring high productivity, good quality of work, and less idle time of resources [5-7].

Figure 1 shows the crew composition in terms of man-days along with the values of productivity and unit labour cost. It can be easily interpreted from the graph that some of the sub-contractors incurred higher unit cost even when their productivity rate was comparatively low. For example, the sub-contractor number 12 had suffered the maximum cost towards shuttering while achieving the least productivity. Some other sub-contractors incurred costs which are three to four times more than that of the sub-contractor with the least cost. This shows the cost implications of the crew composition for the unit labour cost and total cost of a construction activity.

![Figure 1 Comparison between crew composition, productivity rates, and unit labour cost](image)

**5 Conclusions**
This study analysed the productivity rates and unit cost of various sub-contractors engaged in the shuttering work on a construction site to examine the impact of crew composition on labour productivity. It was found that the unbalanced crew composition has adverse effects on both unit costs and construction productivity. This leads to undesired project outcomes in terms of schedule and cost targets in construction projects. The balanced crews were found to have significantly higher productivity rates compared to the unbalanced crews. The problem of unbalanced crew could be addressed by segregating the under-utilized workers of the different sub-contractors and re-grouping them to form more balanced crews. However, the terms of payments must be discussed initially between the different sub-contractors.

It was further noticed that the foreman as a highly skilled worker played an important role in ensuring higher labour productivity rates due to their role in better management of material, improved site planning, and effective labour supervision. It is evident from the data that most of the crews with higher productivity had employed a foreman in their team. Although the daily wage of a foreman is the highest amongst various categories of the workers, the increase in productivity rates justifies their role in a balanced crew.

The study also showed that it is possible to achieve higher productivity through the unbalanced crews. However, the unit labour cost of the activity will be relatively higher which will eventually increase the total cost of the project. Therefore, it is important to form a crew with a suitable representation from all different categories of workers with appropriate levels of skill to achieve high productivity rates in a cost effective manner. Periodic monitoring and timely analysis of productivity rates and unit costs of different crews can help in comparing their performances and taking corrective actions to improve productivity. Further research on more data should be conducted to propose a crew composition model for achieving optimum productivity rates.

References


Influence of Type of Activator on Fracture Properties of Geopolymer

Nematollahi, B.\textsuperscript{1}\textsuperscript{*} and Sanjayan, J.\textsuperscript{2}

Abstract: This paper reports the results of experimental research on fracture properties (fracture energy and fracture toughness) of geopolymer paste with various type of activators. Four different activator combinations including two sodium-based (Na-based) and one potassium-based (K-based) liquid activators and one calcium-based (Ca-based) solid activator were used to prepare the low calcium fly ash-based geopolymer paste. Fresh and hardened properties of the mixtures including workability, density, compressive strength, elastic modulus, fracture energy and fracture toughness were experimentally measured. The results indicated that the type of activator had a significant effect on the fracture properties of the fly ash-based geopolymer paste. Among the activators investigated, the Na-based activator combination composed of sodium hydroxide and sodium silicate solutions exhibited the highest compressive strength, elastic modulus, fracture energy and fracture toughness. The different fracture properties of the mixtures is attributed to their different geopolymer microstructures, owing to their different type of activators.

Keywords: geopolymer; fly ash; type of activator; fracture energy; fracture toughness.

\textsuperscript{1}\textsuperscript{*} Nematollahi, B.
Corresponding author, Center for Sustainable Infrastructure, Swinburne University of Technology, Australia
E-mail: bnematollahi@swin.edu.au

\textsuperscript{2} Sanjayan, J.
Center for Sustainable Infrastructure, Swinburne University of Technology, Australia
1 Introduction

Geopolymer is an alternative cement-less binder to ordinary Portland cement (OPC). The term geopolymer was initially introduced by Davidovits [1]. Geopolymer is synthesized from materials of geological origin (e.g. metakaolin) or industrial by-products such as fly ash and slag that are rich in silica and alumina with high alkaline activators. Previous studies reported that production of fly ash-based geopolymer requires approximately 60% less energy and has at least 80% less CO₂ emissions compared to manufacture of OPC [2, 3]. The mechanical and material properties of the concrete are remarkably similar whether it has geopolymer or OPC origins. This is very encouraging aspect of the geopolymer concrete which then becomes available to replace conventional OPC concrete in many applications [4]. Previous studies reported that the load-carrying capacity of reinforced geopolymer concrete structural members is similar to that of OPC concrete [5], thereby it is believed that geopolymer concrete is suitable for structural applications.

In terms of design and safety assessment of concrete structures, it is known that fracture properties of concrete need to be considered in structural design [6]. For instance, brittleness of concrete governs the limits on minimum flexural and shear reinforcement [7]. Therefore, it is necessary to investigate the fracture properties of geopolymer concrete in order to ensure the safety of structures built with such material. However, the fracture properties of geopolymer concrete have received less attention. Pan et al. [8] investigated the fracture properties of fly ash-based geopolymer paste and concrete. The effects of different ratios of sodium silicate to sodium hydroxide solutions and different curing time on the fracture energy and brittleness of fly ash-based geopolymer were evaluated in their study. They concluded that for a given strength level, fly ash-based geopolymer paste and concrete have a higher brittleness than the equivalent OPC paste and concrete. This is due to lower fracture energy and elastic modulus, but higher tensile strength of geopolymer paste and concrete than those of OPC paste and concrete [8].

Previous studies revealed that the type of alkaline activator plays an important role in the geopolymerisation process and has significant effect on the mechanical strength of geopolymer [9]. It is therefore believed that the type of activator affects the fracture properties of geopolymer. However, the effect of type of activator on the fracture properties of geopolymer has not yet been investigated. Thus, the objective of this study is to evaluate the effects of four different activator combinations including two sodium-based (Na-based), one potassium-based (K-based) and one calcium-based (Ca-based) activator combinations on the fracture properties of a heat cured fly ash-based geopolymer paste.

2 Experimental Procedures

2.1 Materials and mix proportions

The low calcium fly ash (class F) used in this study was supplied from Gladstone power station in Queensland, Australia. Table 1 presents the chemical composition and loss on ignition (LOI) of the fly ash determined by X-ray Fluorescence (XRF). As presented in Table 2, four different activator combinations including two Na-based and one K-based activator combinations in the form of solution and one Ca-based activator combination in the form of powder were used in this study. The D Grade Na₂SiO₃ solution has a specific gravity of 1.53 and a modulus ratio (Mₛ) equal...
to 2.0 (where $M_s=\text{SiO}_2/\text{Na}_2\text{O}$, $\text{Na}_2\text{O}=14.7\%$ and $\text{SiO}_2=29.4\%$). However, the GD Grade $\text{Na}_2\text{SiO}_3$ powder has $M_s=2.0$ (where $\text{Na}_2\text{O}=27.0\%$ and $\text{SiO}_2=54.0\%$). The KASIL 2040 Grade $\text{K}_2\text{SiO}_3$ solution has a specific gravity of 1.40 and $M_s=2.0$ (where $M_s=\text{SiO}_2/\text{K}_2\text{O}$, $\text{K}_2\text{O}=13.3\%$ and $\text{SiO}_2=26.7\%$).

Table 1. Chemical composition of fly ash

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Component (wt. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Al}_2\text{O}_3$</td>
<td>25.56</td>
</tr>
<tr>
<td>$\text{SiO}_2$</td>
<td>51.11</td>
</tr>
<tr>
<td>$\text{CaO}$</td>
<td>4.3</td>
</tr>
<tr>
<td>$\text{Fe}_2\text{O}_3$</td>
<td>12.48</td>
</tr>
<tr>
<td>$\text{K}_2\text{O}$</td>
<td>0.7</td>
</tr>
<tr>
<td>$\text{MgO}$</td>
<td>1.45</td>
</tr>
<tr>
<td>$\text{Na}_2\text{O}$</td>
<td>0.77</td>
</tr>
<tr>
<td>$\text{P}_2\text{O}_5$</td>
<td>0.885</td>
</tr>
<tr>
<td>$\text{TiO}_2$</td>
<td>1.32</td>
</tr>
<tr>
<td>$\text{MnO}$</td>
<td>0.15</td>
</tr>
<tr>
<td>$\text{SO}_3$</td>
<td>0.24</td>
</tr>
<tr>
<td>LOI</td>
<td>0.57</td>
</tr>
</tbody>
</table>

Table 2: Specifications of the activators used in this study

<table>
<thead>
<tr>
<th>Activator ID</th>
<th>Activator form</th>
<th>Activator composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na-based-1</td>
<td>Solution</td>
<td>8.0 M NaOH solution (28.6% w/w) and D Grade $\text{Na}_2\text{SiO}_3$ solution (71.4% w/w) with a $\text{SiO}_2/\text{Na}_2\text{O}$ ratio of 2.0</td>
</tr>
<tr>
<td>Na-based-2</td>
<td>Solution</td>
<td>Only 8.0 M NaOH solution (100% w/w)</td>
</tr>
<tr>
<td>K-based</td>
<td>Solution</td>
<td>8.0 M KOH solution (28.6% w/w) and KASIL 2236 Grade $\text{K}_2\text{SiO}_3$ solution (71.4% w/w) with a $\text{SiO}_2/\text{K}_2\text{O}$ ratio of 2.23</td>
</tr>
<tr>
<td>Ca-based</td>
<td>Powder</td>
<td>Ca(OH)$_2$ powder (88.3% w/w) and GD Grade $\text{Na}_2\text{SiO}_3$ powder (11.7% w/w) with a $\text{SiO}_2/\text{Na}_2\text{O}$ ratio of 2.0</td>
</tr>
</tbody>
</table>

Table 3 presents the details of the mix proportions used in this study. Previous studies revealed that water content plays an important role on the properties of geopolymer binders [10]. Therefore, in this study in order to compare the effect of different activators, the water to geopolymer solids ratio (W/GP solids) of all mixtures as defined by Hardjito et al. [10] was kept constant equal to 0.20. For a given geopolymer binder, the total mass of water in the mixture is taken as the sum of the mass of water in each of the activator solutions and the mass of extra water, if any, added to the mixture. The mass of geopolymer solids is the sum of the mass of fly ash and the mass of activator solids used to make each of the activator solutions.

2.2 Mixing, curing and testing of specimens

All mixtures were prepared in a Hobart mixer. To prepare the first 3 mixtures (i.e. Na-based-1-GP, Na-based-2-GP and K-based GP), the alkaline activators in the form of solution as well as extra water in Na-based-1-GP were added to fly ash and mixed for about 4 min. Whereas in the case of Ca-based-GP, the alkaline activator in the form of powder was added to fly ash and dry mixed for approximately 3 min. Water was then gradually added to the mix and the mixing was continued for another 3 min. Subsequently, a Polycarboxylate Ether (PCE)-based superplasticizer was added
to the mix and the mixing was continued for almost 6 min. After the ingredients of each mix were thoroughly mixed to achieve a consistent fresh flowable state (visually assessed), the workability of each mix was measured to evaluate the effect of type of activator on the flowability of the mix. The fresh geopolymer pastes were then cast into different molds and compacted using a vibrating table.

Table 3: Mix proportions of the fly ash-based geopolymer mixtures

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>Fly ash</th>
<th>Activator</th>
<th>Water</th>
<th>SP6</th>
<th>W/GP solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na-based-1-GP</td>
<td>1</td>
<td>0.35¹</td>
<td>0.014³</td>
<td>0.00</td>
<td>0.20</td>
</tr>
<tr>
<td>Na-based-2-GP</td>
<td>1</td>
<td>0.29²</td>
<td>0.00</td>
<td>0.00</td>
<td>0.20</td>
</tr>
<tr>
<td>K-based-GP</td>
<td>1</td>
<td>0.35³</td>
<td>0.00</td>
<td>0.00</td>
<td>0.20</td>
</tr>
<tr>
<td>Ca-based-GP</td>
<td>1</td>
<td>0.093⁴</td>
<td>0.22</td>
<td>0.01</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Note: All numbers are mass ratios of fly ash weight except W/GP solids.

1 Composed of Na-based-1 activator combination.
2 Composed of Na-based-2 activator combination.
3 Composed of K-based activator combination.
4 Composed of Ca-based activator combination.
5 Extra water added to the Na-based-1 activator solution.
6 PCE-based superplasticizer.

Heat curing was adopted in this study. For heat curing, all molds were sealed to minimize moisture loss and placed in the oven at 60°C for 24 hours. At the end of heat curing period, the specimens were removed from the oven and kept undisturbed until being cool and then removed from the molds and left in the laboratory at ambient temperature (23°C ± 3°C) until the day of testing. Previous studies reported that age does not have considerable effect on strength of fly ash-based geopolymers after the completion of the heating curing period. Three-day compressive strength of fly ash-based geopolymer is considered to be equivalent to a typical OPC strength development after 28-days of ambient temperature curing [10,11]. Therefore, in this study all specimens were tested 3 days after casting.

Mini slump test also known as spread-flow test was conducted to determine flowability of the fresh geopolymer paste. Details of the mini-slump test can be found in [12]. Compressive strength of each mix was measured according to ASTM C109 [13]. In this regard, for each mix at least three 50 mm cube specimens were cast and compacted using a vibrating table. The cube specimens for compressive strength tests were weighed on the testing day to determine the hardened density of each mix. Three-point bending tests on single edge notched beam specimens were conducted to determine the fracture properties (including elastic modulus (E), fracture energy (Gf) and fracture toughness (KIC)) of each mix. Three-point bending tests with a fixed span to depth (l/d) ratio of four and an initial notch depth to beam depth (a/d) ratio of 0.5 were conducted under displacement control at the rate of 0.18 mm/min using MTS testing machine. An LVDT was used to measure the deflection of the mid-span. Resulting load versus deflection data were recorded. The Gf of each mix was calculated according to RILEM [14] using fictitious crack model. The E and KIC of each mix were calculated according to the effective crack model (ECM) developed by Karihaloo and Nallathambi [15]. Further details of the three-point bending test and the formulas for calculating the Gf, E and KIC can be found in Pan et al. [8] and Nematollahi et al. [16,17,18].
3 Results and Discussions

The workability of each mix in terms of the relative slump value is presented in Table 4. It should be noted that the reported relative slump values are based on the mini-slump test without the 25 times tamping of the flow table. As can be seen, the type of activator had a significant effect on the workability of the mix. According to Wallevik [19], slump is influenced by the yield stress of the paste. Therefore, it can be said that the underlying reason for different workability of the mixes lies in their different yield stresses, owing to their different type of activators. It should be noted that although Na-based-2-GP exhibited the lowest relative slump value among all mixes, visual observations revealed that all mixes exhibited adequate workability as being vibrated using a vibrating table due to their thixotropic properties. Therefore, there was no problem in terms of casting and compaction of the specimens.

Table 4: Properties of geopolymer mixes

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>Relative slump value</th>
<th>Density (kg/m³)</th>
<th>Compressive strength (MPa)</th>
<th>Elastic modulus (GPa)</th>
<th>Fracture energy (J/m²)</th>
<th>Fracture toughness (MPa.m⁰.⁵)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na-based-1-GP</td>
<td>6.9</td>
<td>1859</td>
<td>54.6</td>
<td>8.5</td>
<td>19.2</td>
<td>0.436</td>
</tr>
<tr>
<td>Na-based-2-GP</td>
<td>0.6</td>
<td>1894</td>
<td>25.4</td>
<td>5.7</td>
<td>13.7</td>
<td>0.312</td>
</tr>
<tr>
<td>K-based-GP</td>
<td>11.0</td>
<td>1845</td>
<td>32.3</td>
<td>5.2</td>
<td>12.0</td>
<td>0.237</td>
</tr>
<tr>
<td>Ca-based-GP</td>
<td>13.1</td>
<td>1827</td>
<td>8.8</td>
<td>1.8</td>
<td>7.7</td>
<td>0.086</td>
</tr>
</tbody>
</table>

The hardened density of each mix is also presented in Table 4. As can be seen, the density of all mixes was comparable. In other words, the type of activator did not have a significant effect on the density of mix.

The compressive strength of each mix is also presented in Table 4. As can be seen, the type of activator had a significant effect on the compressive strength of the geopolymer mix. Na-based-1-GP and Ca-based-GP exhibited the highest and the lowest compressive strength, respectively. The compressive strength of Na-based-2-GP, K-based-GP and Ca-based-GP were 53.5%, 40.8%, and 83.9% lower, respectively than that of Na-based-1-GP. Fernández-Jiménez and Palomo [9] reported that in fly ash-based geopolymer, the main reaction product formed, regardless of the type of activator, is an alkaline aluminosilicate gel with low-ordered crystalline structure. However, the microstructure as well as the Si/Al and the Na/Al ratios of the aluminosilicate gel depend on the type of the activator used. It is thereby hypothesized that the geopolymer microstructure of fly ash-based mixes are different, due to their different type of activator, which resulted in their different compressive strength. In other words, it can be said that the most prominent reason for different compressive strength of fly ash-based mixes lies in their different geopolymer microstructure, due to their different type of activator.

The elastic modulus (E) of each mix is also presented in Table 4. It should be pointed out that in this study the elastic modulus of each mixture was not measured experimentally using cylindrical specimens in compression, instead they were derived indirectly based on ECM [15] from the linear portion of the load-deflection curve of the notched beam specimen in three-point bending tests. The derived E values thereby should only be considered as relative values enabling us to compare the elastic modulus of each mixture. Na-based-1-GP exhibited the highest matrix elastic modulus. This is consistent with compressive strength results reported in Table 4, where
Na-based-1-GP exhibited the highest compressive strength among all mixes. The elastic modulus of Na-based-2-GP, K-based-GP and Ca-based-GP were 32.9%, 38.8% and 78.8%, respectively lower than that of Na-based-1-GP, which correspond to their lower compressive strengths, as reported in Table 4.

The fracture energy (GF) and fracture toughness (KIC) of each mix are also presented in Table 4. As can be seen, Na-based-1-GP exhibited the highest KIC among all mixes. The KIC of Na-based-GP-2, K-based-GP and Ca-based-GP were 28.4%, 45.6% and 80.3%, respectively lower than that of Na-based-1-GP. According to Pan et al. [8], the fracture toughness of concrete is generally influenced by the microstructure of the paste and the size, texture and angularity of the coarse aggregates. Thus, it can be inferred that the different fracture toughness of the mixtures is attributed to different microstructure of the geopolymer pastes, because no aggregate was used in the mixtures investigated in this study. As mentioned earlier, Fernández-Jiménez and Palomo [9] demonstrated that the microstructure as well as the Si/Al and the Na/Al ratios of the aluminosilicate gel depend on the type of the activator used. Therefore, it is hypothesized that the microstructure of geopolymer pastes are different due to their different type of activator.

As can be seen in Table 4, Na-based-1-GP also exhibited the highest GF among all mixes. The GF of Na-based-GP-2, K-based-GP and Ca-based-GP were 28.6%, 37.5% and 59.9%, respectively lower than that of Na-based-1-GP. Similar to the above discussion, it can be said that different microstructure of the geopolymer pastes is responsible for different fracture energy of the mixtures investigated in this study.

4 Conclusion

The influence of four types of activators on the fracture toughness and fracture energy of fly ash-based geopolymer paste was investigated in this study. The Na-based-1 activator was composed of 8.0 M NaOH solution (28.6% w/w) and Na2SiO3 solution (71.4% w/w) with a SiO2/Na2O ratio of 2.0. The Na-based-2 activator was composed of only 8.0 M NaOH solution. The K-based activator was composed of 8.0 M KOH solution (28.6% w/w) and K2SiO3 solution (71.4% w/w) with a SiO2/K2O ratio of 2.23. The Ca-based activator was composed of Ca(OH)2 powder (88.3% w/w) and Na2SiO3 powder (11.7% w/w) with a SiO2/Na2O ratio of 2.0. Based on the experimental study conducted, the following conclusions are drawn:

(1) Among the activators investigated, the Na-based-1 activator resulted in the highest fracture energy and fracture toughness of the geopolymer paste. The most prominent reason for the different fracture properties of the mixtures lies in their different geopolymer microstructures. It is known that in fly ash-based geopolymer, type of activator affects the microstructure as well as the Si/Al and the Na/Al ratios of the aluminosilicate gel.

(2) The fracture energy and fracture toughness of geopolymer paste made by the Na-based-2 activator were 28.4% and 28.6%, respectively lower than those of the paste made by the Na-based-1 activator. The compressive strength and elastic modulus of the paste made by the Na-based-2 activator were also 53.5% and 32.9%, respectively lower than those of the paste made by the Na-based-1 activator. This is due to the fact that addition of soluble silicate to NaOH solution increases the rate of geopolymerisation reaction. It can be concluded that in fly ash-based geopolymer, the addition of Na2SiO3 solution to the NaOH solution is highly beneficial as it results in higher mechanical properties gain of the geopolymer and lower cost of the activator.
(3) The fracture energy and fracture toughness of the geopolymer paste made by the K-based activator were 37.5% and 45.6%, respectively lower than those of the paste made by the Na-based-1 activator. The compressive strength and elastic modulus of the paste made by the K-based activator were also 40.8% and 38.8%, respectively lower than those of the paste made by the Na-based-1 activator. It can be concluded that in fly ash-based geopolymer, the use of Na-based-1 activator is highly beneficial in terms of higher mechanical properties gain and lower cost compared to the K-based activator.

References

International, 43(8), 5999-6007.


Investigating Safety Communication of Migrant Workers in Construction Industry

Lyu, S.N., Hon, K.H. and Chan, P.C.

Abstract: Many migrant workers have been employed in the construction industry in both developed and developing countries, and their workplace safety and health has been a pressing global concern. Statistics show that they were more vulnerable to occupational injuries than their local counterparts, their safety and health thus deserves special attention. Effective workplace safety communication is a vital part of safety management, however, studies on safety communication for migrant workers in the context of construction are limited. This paper presents the framework and initial findings of the ongoing empirical study in both Hong Kong and Australian construction industry, which aims to fill the research gaps in safety communication of migrant construction workers. Findings of the study will contribute to the improvement of safety communication of migrant workers, which could lead to their decrease of occupational near-miss, injuries, or fatalities, and improvement of safety climate and safety behaviors.

Keywords: Construction industry, Migrant workers, Safety communication, Safety and health

1* Lyu, S.N. Corresponding author, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China; School of Civil Engineering and Built Environment, Queensland University of Technology (QUT), Australia
E-mail: sainan.lyu@hdr.qut.edu.au

2 Hon, K.H. School of Civil Engineering and Built Environment, Queensland University of Technology (QUT), Australia

3 Chan, P.C. Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong, China
1 Introduction

The increasing employment of migrant workers has formed a distinctive feature of the construction industry in many countries or areas, such as Polish and Baltic employees in Europe, Nepalese and Indian employees in Qatar, Indian employees in Dubai and Singapore, Hispanic employees in the US, and Nepalese and Pakistani employees in Hong Kong. According to the latest statistics, the percentage of migrant workers in the total construction workforce has reached to 8% in the UK (Rienzo, 2016), 30% in Spain (Meardi, Martin, & Riera, 2012), 28.9% in the US (U.S. Bureau of Labor Statistics, 2016), 69% in Malaysia (Abdul-Rahman, Wang, Wood, & Low, 2012), and 64% in Singapore (Ministry of Manpower Singapore, 2016a, 2016b). The number of migrant workers in the construction industry is expected to increase further to mitigate the growing demand for a construction workforce. However, many studies demonstrate that migrant construction workers are more vulnerable to accidents and injuries than their local counterparts (Cigularov et al. 2013; Dong and Platner 2004; Dong et al. 2010; Goodrum and Dai 2005; Loosemore and Lee 2002; Roelofs et al. 2011; Trajkovski and Loosemore 2006; Tutt et al. 2011). In light of that, safety and health of migrant employees deserves more investigation.

Effective workplace safety communication is a vital part of safety management, however, comprehensive studies on safety communication for migrant workers in the context of construction are limited. Although the significance of safety communication for safety performance has been highlighted by previous studies, little empirical research has been conducted to investigate the connection between communication and safety performance. In addition, an effective safety communication structure is of great importance to distribute safety information to the migrant workers on construction site. However, there is few studies on unveiling and improving the safety communication structures for migrant construction workers. Thus, this ongoing study aims to investigate and improve safety communication of migrant construction workers. Four corresponding objectives include: identifying the key factors of safety communication for migrant workers (objective 1), investigating the influence of safety communication on safety performance (objective 2), evaluating existing safety communication structure (objective 3), and establishing the effective safety communication structure for migrant workers (objective 4).

This paper presents the framework and initial findings of this ongoing empirical study in both Hong Kong and Australian construction industry. Four main categories and 32 subcategories of safety communication factors have been identified based on literature review and semi-structured interviews. The identified safety communication factors will help to diagnose the deficiencies existing in safety communication management, which could improve the effectiveness of safety communication of migrant workers in construction industry and their safety performance.

2 Safety communication in the workplace

The impact of safety communication on safety climate, safety behaviors and safety outcome has been examined by many previous researchers. The positive influence of safety communication on safety climate has been found. For instance, Kines et al. (2010) conducted empirical research on the impact of leader-based verbal safety communication on safety climate onsite. Their results reveal that training the foremen to convey safety to their workers through daily verbal communication could contribute to the increase of the workers’ safety climate. Liao et al. (2014) explored the influence of safety communication on safety climate, through a questionnaire survey on four subcontractors in Mainland of China. Their findings revealed higher communication density and degree centrality, and lower betweenness centrality could contribute to better safety climate. The strategy related communication was also provided to improve safety climate, such as more frequent communication between safety leaders and workers when organizational centrality is higher, establishing more communication channels among employees.

The findings of some researchers have demonstrated that effective safety communication could contribute to the decrease of occupational near-misses, injuries, or fatalities. Zohar (1980) argued that positive interaction among workers and between workers and their supervisors was one characteristic of the groups with better safety outcome. Bentley and Haslam (2001) further pointed out the safety communication between manager and employees was one of the top five safety practices of managers that distinguished high and low accident rate postal delivery offices.

Research has also indicated that there was significant association between safety...
communication and safety behaviors. For example, according to the studies of Mattila et al. (1994) and Niskanen (1994), the more competent supervisors showed a supportive style of leadership, and provided effective advices to employees on safety issues. In line with conclusion drawn from these researchers, Zohar and Luria (2003) found that supervisors’ safety-related verbal exchanges could contribute to the improvement of employees’ safety behaviors. The employees’ safety behaviors improved with the increase in interactions between safety supervisors and employees. Cigalarov et al. (2010) conducted an empirical research on construction workers in United States and the research outcome revealed that safety communication was a significant predictor of safety behaviors as well as the work-related pain. Liao et al. (2014) investigated how safety communication influenced worker behaviors from the cognitive perspective. They found that the quality of communication played more important role in improving safety performance than the frequency of safety communication. Team leaders demonstrating how to perform safety behaviors to workers would decrease the number of workers who experience cognitive failure. This will further reduce unsafe behavior.

3 Research Methods

The research framework of this ongoing study is presented in Figure 1. Both qualitative and quantitative data collection methods will be employed in this study. Qualitative research method will be applied to obtain an enhanced understanding of safety communication problems, and safety communication strategies because safety information targeting for this group is insufficient. The quantitative research methods in the form of questionnaire survey will be applied. Various quantitative methods for data analysis are also adopted, including factor analysis (FA), structural equation modelling (SEM), social network analysis (SNA), and logistic regression analysis.

3.1 Research methods for objective 1 and 2

In order to achieve Objective 1 and 2, literature on communication theory, and safety communication in construction has been reviewed. The potential factors affecting safety communication and indicators of effectiveness of safety communication have been summarized. Structured interviews have been conducted to supplement the factors identified through literature review.

Based on the findings of literature and interviews, questionnaire 1 has been designed and will be distributed to local construction workers, migrant construction workers, and management in both Hong Kong and Australia, as the questionnaire is effective in collecting quantitative data in a standardized manner and the results are more generalizable (Oppenheim 2000). The questionnaire survey 1 consists of five parts: a self-explanatory letter that introduces the survey, the personal attributes of the respondents, effectiveness of safety communication, safety communication factors, and safety performance. The questionnaire in migrant workers’ native languages were prepared because the language used and context of the questions must be familiar to the respondents. The
English version of questionnaire was firstly translated into their native languages by translation company and the translation was verified by two native construction research students. This questionnaire survey will be administered to both local and migrant frontline workers. This questionnaire is being distributed at Hong Kong and Australian construction sites, where a great number of migrant workers have been employed. Contractors and sub-contractors have been invited to participate in this survey.

The data collected from questionnaire survey 1 will be analyzed by SPSS 21.0 software (Norušis 2012). FA in terms of exploratory factor analysis and confirmatory factor analysis will be adopted to identify the critical factors influencing safety communication (Objective 1). The comparison of safety communication of migrant workers and local workers will be made. Also, the differences among perceptions on safety communication factors from the perspectives of migrant workers and management, will be analyzed. SEM will be applied to investigate the relationship between safety communication and safety performance of migrant workers (Objective 2).

### 3.2 Research methods for objective 3 and 4

To achieve Objective 3, and 4, questionnaire 2 has designed to build the main safety communication structure of migrant workers based on literature review on SNA in construction. Questionnaire has been applied most frequently for collecting sociometric network data (Scott 2012). Questionnaire survey 2 consists of three parts: demographic information (Section A), safety communication structure (Section B), and safety performance (Section C). The questionnaire will be distributed to migrant construction teams in both Hong Kong and Australia. For the respondents in Hong Kong, questionnaire has been translated into their native languages. It is anticipated that the English version will be suffice for migrant works in Australia.

After obtaining data through a questionnaire survey, the validity of the data will be also analyzed. The data collected from Section B will be analyzed with the help of software UCINET. Safety sociagram will be firstly drawn by software Netdraw to visualize the relations within the network. Overall and individual social network characteristics will be calculated, such as density of the network, and centrality of the actors. Finally, the relationship between demographic variables and characteristics of network, and relationship between characteristics of network and safety performance will be analyzed by regression analysis.

### 4 Initial Findings

Objective 1 of this ongoing empirical study has been achieved. This section describes the researching finding of objective 1. To identify factors affecting safety communication of migrant workers, studies on communication theory, safety communication in construction, safety communication of migrant workers have been reviewed. The safety communication factors having similar meanings were renamed and classified together. Four major categories and 32 subcategories of safety communication factors of migrant construction workers were initially summarized, as shown in Table 1. “Cultural and ethnical background of migrant workers,” “language, technical terms and dialect used by safety staff,” “degree of power or status differences between migrant workers and site safety staff,” “appropriateness of communication channel,” and “selection of modes of safety communication” were the most frequently mentioned factors in the selected literature.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Subcategories of safety communication factors</th>
<th>Literature</th>
<th>Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker related factor</td>
<td>Educational level of migrant workers</td>
<td>F, N</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Cultural and ethnical background of workers</td>
<td>F, H, N, S</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Religious background of workers</td>
<td>F, N</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Length of work experience in construction</td>
<td>F</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Gender differences</td>
<td>F, H</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Selective listening of workers</td>
<td>F, I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Language ability of workers</td>
<td>G, R</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Personality type of communicators</td>
<td>N</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Ages of construction workers</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drinking habits of workers</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stress and emotion of workers</td>
<td>B, K, N</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Safety communication factors of migrant workers drawn on literature and interviews
Amount of feedback from workers to their co-workers and site safety staff: F, I

Language, technical terms and dialect used by safety staff: F, M, N, P, T

Communication style of leader: N, Q

Appropriation of pictorial safety materials: O

Appropriation of time when safety information is provided: O

Construction workers’ trust in site safety staff and co-workers: C

Accuracy and adequacy of safety information provided by safety management: E

Degree of power or status differences between construction workers and site safety staff: B, F, H, I

Relationship between site safety staff and workers: C, D

Appropriateness of communication channel adopted to convey safety information: I, N, P, T

Selection of modes of safety communication: I, N, O, T

Frequency and content of formal presentation from upper management: T

Frequency and content of written communication: T

Frequency and content of safety training: C, T, L

Frequency and content of toolbox talks: T

Usage of communication techniques: O

Culture of organization and project: O, N, U

Complexity of team task: J, N

Time pressure for completion of the project: B, M, N

Composition of construction team members: N, O

Physical environment at construction site such as noisy equipment and room layout: N, H, L

Note: A: Gibson et al. (1994); B: Metts et al. (1994); C: Graen and Uhl-Bien (1995); D: Wayne et al. (1997); E: Skyttner 1998; F: Preece and Stocking (1999); G: Loosemore and Muslmani, (1999); H: Huczynski and Buchanan (2001); I: Dickens (2002); J: Roberts et al. (2002); K: Loosomere and et al. (2003); L: Tam et al. (2003); M: Wong et al. (2004); N: Dainty et al., (2007); O: Emmitt and Gorse (2009); P: Lunenburg, 2010; Q: Kines et al. (2010); R: Phua et al., (2011); S: Hare et al. (2012); T: Alsamadani et al. 2013; U: Hurn and Tomalin (2013).

A total of 15 face-to-face semi-structured interviews were conducted with professionals in Hong Kong construction industry, to enhance the results of literature review. In Hong Kong, Nepalese and Pakistani workers made up the most proportion of migrant construction workers. The contractors were firstly targeted as they tended to have more hands-on work experience with migrant construction workers. Other stakeholders (i.e., government and private developers) were also interviewed. The semi-structured interview was adopted as it could provide a high degree of flexibility (Ochieng and Price, 2010). The positions of the interviewees were mainly director, safety and health manager, safety officer and ganger. Four questions were asked during the semi-structured interviews (i.e., What are the key factors of safety communication for migrant workers? What are key success factors of effective safety communication of migrant workers? What are major safety communication problems of migrant workers? What measures should be taken to improve safety communication of migrant workers?). All interview dialogues were recorded and transcribed with the permission of participants. The transcriptions were analyzed with the help of software NVivo 10. 16 distinct categories of safety communication factors were determined, as shown in Table 1.

The most frequently mentioned safety communication factor by interviewees was the language ability of migrant workers (N=14). Many migrant workers are not fluent in either English or Cantonese (local language used in Hong Kong). “They are encouraged to learn key safety terms in Cantonese so that safety communication can be more smooth and direct”, as pointed out by one interviewee. Language, technical terms and dialect used by safety staff (N=6) was the second most frequently stated safety communication factor. Since the local management could not understand the migrant native languages, they mainly rely on the migrant gangers or team leaders to act as the communication bridge. Two interviewees expressed that, “if you get the right Nepalese foreman or supervisor, you can get the best workers. It is important to make sure supervisory people can communicate with the workers”, “with the help of the ganger, the communication between the migrant workers and local workers will be no problem. The ganger would explain the required information to the migrant that he leads.” Although the importance of language ability of safety staff was empathized, these suitable frontline level safety staff are lack in Hong Kong, especially...
trilingual staff. Application of pictorial safety materials (N=6) was the third most frequently mentioned safety communication factor. The usage of some pictorial posters, diagrams, photos and icons, will help migrant construction workers to understand the safety related information, as highlighted by interviewees.

Conclusions

This paper presents the framework and initial findings of the ongoing empirical study conducted in both Hong Kong and Australia. This study attempts to improve the safety communication of migrant workers, who are more vulnerable to accidents and injuries than local employees. Four specific objectives and corresponding research methods to achieve the aim of the study were proposed and elaborated. In addition, literatures on safety communication in construction have been reviewed, and 15 structured interviews have been conducted. According to the communication theory, a total of four main categories of safety communication factors have been identified based on literature review and interviews. These safety communication factors are related to workers, safety management, communication channel and media, and construction context. The next stage of this study is to explore the key safety communication factors of migrant workers and connections of safety communication and safety performance using a questionnaire survey. The effective safety communication structure to convey safety communication to migrant workers will also investigated. Findings of the study will contribute to the improvement of safety communication of migrant workers, which could lead to their decrease of occupational near-miss, injuries, or fatalities, and improvement of safety climate and safety behaviors.

Acknowledgements

The work described in this paper was jointly supported by grants from the Hong Kong Central Policy Unit and the Hong Kong Polytechnic University. The paper forms part of the Hong Kong Polytechnic University funded project entitled “Managing construction safety for ethnic minorities in Hong Kong”, (Project No. 1-ZV9E) and Public Policy Research project entitled “Improving safety communication of ethnic minority workers”, (Project No. K-QZ1F) from which other deliverables are produced with different objectives/scope but sharing a common background and methodology. The authors acknowledge and thank all the respondents who participated in this research and remain nameless without them this research would not have been possible.

References


Dual Process of Consumption and Investment Motives in Residential Market Indonesia

Njo, A.¹*, Made Narsa, I.², and Irwanto, A.³

Abstract: The thinking of dual process between conscious processes and unconscious processes generate a different decision. Thinking consciously produces rational decisions. However, a person's cognitive limitations makes him simplify complex scenarios then makes heuristics decision. This research aims to evaluate the relationship patterns of decision-making and dual motives on house purchases, time for buyer, and family life cycle in Indonesia. The data is collecting by distributing questionnaires to home buyers. The analysis shows that buyers have consumption motives in buying a house and they behave rational, while investors behave heuristics. Time for Buyers are not significant to decision model. Family Life Cycle is significant to decision model.

Keywords: Dual Process, Dual Motives, Time for Buyer, Family Life Cycle

---

¹* Njo, A.
Corresponding author, Economic Faculty, Petra Christian University, Indonesia
E-mail: anas@petra.ac.id

² Made Narsa, I.
Economic and Business Faculty, Airlangga University, Indonesia

³ Irwanto, A.
Economic and Business Faculty, Airlangga University, Indonesia
1 Introduction

Individual can make a decision using logic or heuristic thinking. The logic is associated with reasoning, whereas, heuristic is associated with intuition [1]. This condition happens because dual process way of thinking, which consists of conscious process and unconscious process, results in rational decision or irrational decision. Investors’ behavior changes from rational to irrational. It is not at the same time. Their knowledge growth gradually during searching process, then investors should decide in making decision naturally due to their environment [2]. Therefore, one’s behavior that is considered as rational cannot be equated to other individual’s behavior as everyone has his or her own rationality degree [3].

House has two functions which are consumption and investment [4]. The growth of an individual’s worth net will affect consumption motive and investment motive when deciding to purchase a house. Dual motives model is used to measure housing demand in America [5], France [6], and Spain [7], but this model cannot explain the reason for the purchase of a house. Inconsistency results show weakness of model. Contradiction in dual motives researches previous makes it a necessary to be analyzed in real estate market in Indonesia.

Demographic factors of age, education, income [5][6] and behavior in making decision are stimuli purchase decision. First-home buyers (FHB) need a house for living, but they have financial problem because their income is relatively low. The income and loan amount which is approved affect house price that can be bought. Therefore, consideration of choosing a house related to one’s financial decision is made rationally [8][9]. However, Burns shows when investors are looking for a house and specific location, investors involve emotional and sentimental factor [10]. Their need of a house depend on stages in family life cycle. This research will examine about dual motives factor that is inconclusive which has not yet observed a dual process in oneself when making decision. Therefore, this research confirms involvement of dual process in behavioral model of decision-makers related to dual motives in purchasing house.

2 Dual Process vs Dual Motive in Real Estate

An investor does heuristic because of limited time in searching information and outcome effort so heuristic decision causes trade-off; the loss of accuracy due to the pace and savings cognition [11]. In 1996, Cognitive Experiential Self Theory (CEST) is changed to Rational Experiential Inventory (REI) [12]. REI-40 is designed to asses preferences information processing. First measurements of dual process in REI-40 were Rational Ability which is an individual’s thinking ability using logic and analytics, and Rational Engagement which is the individual involvement in decision-making on pleasure of analytical thinking using logic. Second, Experiential Ability which is an ability that is possessed by an individual based on intuition and feeling, and Experiential Engagement which is an individual involvement in decision-making based on his or her feeling and intuition. Rational thinking is symbolized as slow, discussion or consultative, following rules, especially verbally and consciously. Intuition is symbolized as pre conscious, closely related to affective, quick, operational automatically and holistically. Memories and feelings of an individual affect the process and behavioral tendencies subsequently. If an individual recalls positive feeling, he or she will automatically think and have the tendency to reproduce feelings [13].
Real estate investment is a commitment on individual’s fund with purposes to maintain and improve asset and get benefit. Benefits that are expected by real estate investors are income which consists of active income (salary, bonus, commission); passive income (rental income, dividend); and portfolio income (interest income, stock dividend, capital gain, royalty) [14]. Home-buyers have different purposes because of investment booster or consumption booster [15]. Investors are sellers of property who want portfolio in some properties and do not have to stay in every of those properties [16]. Investment decision or consumption involves trade-off process when deciding a location. Individuals or families with high income choose desired location with better quality of public places and facilities. Otherwise, Individuals or families with lower income choose less-desired location based on the level of their wealth and nowadays “compatibility” condition.

Empirically, characteristics of social economy (size of household, age of each members of the household, education, income) also affect preferences and choices of location on individuals or families [17]. Marriage and children are main factors that drive someone to buy the first house, therefore, people have the tendency to choose a residence that is not an investment opportunities area. Younger families have stronger relationship between house’s price and consumption needs than older families. Younger families bound the needs of minimal house size because it is related to financial needs and the loan to be provided. Furthermore, buyers’ experience changes in house needs because of high income, price of the house, capability to pay debt, interest rate, and inflation [18].

H1 : When an individual buys a house with consumption motive, his or her decision model tends to be rational compare to an individual with investment motive.

H2 : An individual who buys a house for the first time, his or her decision model tend to be rational compare to an individual who buys a second house and subsequent.

H3 : When a younger families buy a house, their decision model tend to be rational compare to older families.

3 Methodology

This study uses primary data by questionnaires to home buyers who have done transactions in 2013-2016. Respondents are domiciled in Surabaya, but the location of the purchased property is located in all areas in Indonesia. Sample search is done incidentally at the housing exhibition, the developers’ office, the property broker's office, and the online way through Google forms. The psychology questionnaire uses REI 40 as a measure of buyer rationality. Before distributing the questionnaire, REI 40 is translated into Bahasa Indonesia by involving linguists and psychologists who provide inputs, so the questionnaire can be understood easily by the respondents. Questionnaire obtained 254 respondents, and further data that can be processed are 231 data. The data is tested for its validity and reliability. The data analysis using ANOVA contained in SPSS program.
Table 1. Research Variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Keterangan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Motives</td>
<td>1 = Consumption; 0 = Investment</td>
</tr>
<tr>
<td>Time For Buyer</td>
<td>1 = First Home Buyer; 0 = Not First Home Buyer</td>
</tr>
<tr>
<td>Family Life Cycle</td>
<td>1 = Younger Family (less than 10 years marriage); 0 = Older Family (more than 10 years marriage)</td>
</tr>
<tr>
<td>Dual Process</td>
<td>20 item Rational; 20 item Experiential, with likert scale: 1 = very not true; 2 = not true; 3 = true enough; 4 = true; 5 = very true</td>
</tr>
</tbody>
</table>

Table 2 shows descriptive data respondents who have consumption and investment motive separated by Time For Buyer (TFB), Family Life Cycle (FLC), dual process, age, and income. The majority of respondents is non-FHB, dominated by younger families, married below 10 years, has a rational decision-making model. Buyers are dominated by 31-40 years old people, have an income of 10-25 million Rupiahs.

Table 2. Respondents’ Demographic Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Consumption</th>
<th>Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time For Buyer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First-Home Buyer</td>
<td>42</td>
<td>13</td>
</tr>
<tr>
<td>Non-First-Home Buyer</td>
<td>88</td>
<td>88</td>
</tr>
<tr>
<td>Family Life Cycle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Younger Family</td>
<td>97</td>
<td>51</td>
</tr>
<tr>
<td>Older Family</td>
<td>33</td>
<td>50</td>
</tr>
<tr>
<td>Dual Process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rational</td>
<td>120</td>
<td>86</td>
</tr>
<tr>
<td>Heuristic</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

Measuring the level of rationality of home buyer using REI 40 which separates the question items into Rational and Experiential. Both group were searched for their average score, then used in ANOVA analysis. The test of decision-making model of dual motives, Time for Buyer (TFB) and Family Life Cycle (FLC) are listed in Table 3. Homogeneity test is performed before ANOVA test on variable of dual motives, TFB, and FLC. Levene statistical motive of ownership (L=2.685, p-value = .103) and TFB (L=.212, p-value=.646) show that the data have the same variance (homogeneous). However, Levene statistical of FLC (L=11.079, p-value=.001) shows that the data has not the same variance. The result of F test on the motive of ownership (F=3.408; p-value=.066) show there is statistically significant differences in decision-making model on consumption motive (M=2.7190) and investment motive (M=2.6041). Therefore, an individual with consumption motive has a decision model that tends to be rational compared to an individual with investment motive. The result of F test on the TFB (F=.611; p-value=.435) show there is not statistically significant differences in decision-making model on first home buyer and not first home buyer. The result of Welch test on FLC (W=12.127, p-value=.001) show there is statistically significant differences in decision-making model on younger family (M=2.7534) and older family (M=2.5177). A younger family has a decision model that tends to be rational compared to older family.
Table 3. ANOVA Findings for Dual Motives, TFB and FLC in Decision-Making Model
Panel A: Table ANOVA

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>Hypothesis</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between groups</td>
<td>.751</td>
<td>1</td>
<td>.751</td>
<td>H₁</td>
<td>3.408</td>
<td>.066</td>
</tr>
<tr>
<td>Within groups</td>
<td>50.458</td>
<td>229</td>
<td>.220</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TFB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between groups</td>
<td>.136</td>
<td>1</td>
<td>.136</td>
<td>H₂</td>
<td>.611</td>
<td>.435</td>
</tr>
<tr>
<td>Within groups</td>
<td>51.073</td>
<td>229</td>
<td>.223</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between groups</td>
<td>2.955</td>
<td>1</td>
<td>2.955</td>
<td>H₃</td>
<td>14.024</td>
<td>.000</td>
</tr>
<tr>
<td>Within groups</td>
<td>48.254</td>
<td>229</td>
<td>.211</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Categories</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision</td>
<td>Dual Motives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>Consumption</td>
<td>2.7190</td>
<td>.44616</td>
<td>130</td>
</tr>
<tr>
<td></td>
<td>Investment</td>
<td>2.6041</td>
<td>.49779</td>
<td>101</td>
</tr>
<tr>
<td>TFB</td>
<td>FHB</td>
<td>2.7122</td>
<td>.45374</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Not FHB</td>
<td>2.6552</td>
<td>.47782</td>
<td>176</td>
</tr>
<tr>
<td>FLC</td>
<td>Younger family</td>
<td>2.7534</td>
<td>.41102</td>
<td>148</td>
</tr>
<tr>
<td></td>
<td>Older family</td>
<td>2.5177</td>
<td>.53443</td>
<td>83</td>
</tr>
</tbody>
</table>

4 Discussion

Memory and feelings of an individual affect process and behavior tendency further. Experience system has a positive or negative effects in rational system. A person reacts an incident emotionally, the order of reaction will automatically directed to experience system and instantly looking for a memory bank that related to incident. That process is proven in individuals who buy a house. Buyers choose a house with many considerations to be a residence that provides comfort [19]. Those many considerations are processed in a longer time by collecting many information from parents or relatives, friends, or newspaper, brochure, or internet. Buyers’ experience in searching process for a desired house in a time will affect their experience in another time. Buyers will consider their financial ability such as availability and capability in paying. Numbers of consideration will make buyers tend to use rational system in making decision.

From investors’ point of view, purchasing a house or apartment is portfolio allocation. Investors have purposes to get additional income from rent, to get capital gain when the house is sold, and to prefer property as their investment product instead of other products. Time needed for investors to make decision is shorter; through property broker, house exhibition, and products launching. This media creates interaction between investors and developers or mediators, so that investors’ position will be influenced and pushed to make quick decision with bait; direct profit. The influence of spouse, children, friends, even oneself really affects in making decision if it is dominated by emotional factor. Resulting in driving investors to use experience system or intuition in purchasing house, because problem-solving is made quickly and has the tendency to ignore the information especially in a situation with high complexity level, uncertainty, and time-pressure [1][20].
Newly married FHB or married but not yet have children need to own a house as a place to build new families and to live comfortably. FHB have a desire to build an independent household without depending on parents, so that FHB try to find information and take consideration about the first-purchased-house. However, dual process of FHB cannot be differentiated significantly to not FHB. Information processing process in FHB and not FHB uses rational system and experience system at the same time and they interact to one another [12] [18]. A younger families with marriage age less than 10 years tend to be rational in making purchasing-decision compare to older family. The amount of income will affect family in accumulating wealth. That condition illustrates a family’s ability to decide purchasing a house. If you are still an obstacle, then purchasing-decision through many consideration is not yet decided. On the other hand, good financial condition will ease the family in making purchasing-decision faster. Knowledge improvement and investment experience allow older families to make better investment decision by studying the risks more accurately and having better understanding in risk and return relationship in real estate market which is considered more stable compare to stock market [21][22]. However, emotional factor that binds older families related to environment location and condition in their surroundings, social condition, and personal relationship with the neighbours, will direct older families act irrational to fulfil their want. Repetitive experiences in purchasing houses also drive older families to use intuition in making decision [19].

4 Conclusion

Dual motives and family life cycle show the differences in making purchasing-decision model, whereas first home buyers have no differences in making purchasing-decision. Research on decision-making behavior is important to be developed to create an efficient real estate market. Subject’s involvement in real estate market such as developers, can focus in deciding developing strategy and selling residential house product and better, more efficient apartment. Further research can be developed by going deep into demographic background and family life cycle structure of families related to dual process. A house shows a family’s wealth and saving in retirement, so that demand will always take place. Dynamical needs occur according to shift in family cycle.

References


Technique-Economics Analysis of Tower Crane Selection in Construction of Precast Concrete Structures in China

Wang, K.1, Fu, Y.2*, Guo, J.J.3 and Peng, Z.Y.4

Abstract: During the process of building industrialization in China, precast concrete structures, a sample from the technology of industrialized building, has been adopted increasingly and it increased the demand of construction equipment on site. Tower crane is one of the major indispensable construction hoist in every construction project. More attention should be paid to the location and type of tower crane, which, when poorly considered, will incur extra site costs and delay the entire project. In this paper, the factors affecting performances of tower crane including hoisting weight, coverage and lifting speed were studied for establishing logical framework of crane selections. The framework, based on a quantitative model of value engineering was built to evaluate the technique-economics analysis through indexes of hoisting operation and selection in assembly construction. The model aims to estimate construction volume within unit cost and cycle time containing long-distance navigation, maneuvering, loading and unloading. This research will make a contribution to meeting the challenges of strictly scheduled and assembly constructions in recent China.

Keywords: Precast concrete structure; Tower crane; Technique-economics; Value engineering.

Acknowledgments
This study is supported by the Fundamental Research Funds for the Central Universities (Project No.106112016CDJXY030002).

1Wang, K.
School of Construction Management and Real Estate, Chongqing University, China
E-mail: realwk1122@gmail.com

2*Fu, Y.
Corresponding author, School of Construction Management and Real Estate, Chongqing University, China.
Research Center of Construction Industrialization and Innovation, Chongqing University, Chongqing 400045, China.
E-mail: fuyan1981@foxmail.com

3Guo, J.J.
School of Construction Management and Real Estate, Chongqing University, China
E-mail: jingjing.guo@cqu.edu.cn

4Peng, Z.Y.
School of Civil Engineering, Chongqing University, China.
E-mail: cz_pengzhenyu@gmail.com
1 Introduction

The construction machinery is a major cost component in prefabrication. Tower crane is the highest price type among these construction equipment types\cite{1}. Especially in the construction of high-rise buildings, tower cranes are supposed to lift many components\cite{2}. In addition, tower crane type and location selection are the key factors to influence the construction cost and production efficiency\cite{3}.

Many of today’s contractors mainly rely on their experience to carry out the type of tower crane and location\cite{2}. Zhang et al. have optimized the location of the tower crane group\cite{4}. Researchers later analyze the scheme of crane in several aspects including consummating the method of calculating the lifting time, introducing optimization algorithm and using indicator to evaluate the scheme of crane. However, the equation calculating the jib rotation proposed by zhang et al. missed a minus which would lead an error on the total time and this equation was cited by most of the researchers later. In addition, the equations to combine the movement of trolley and jib rotation, the movement of vertical and horizontal did not consider the sequential order. This also made the time model imprecise and depart from practice.

Moreover, the previous researchers mainly studied the single-objective optimization of hoisting time or costs. But the shortening the time will lead to the increase of rental costs, and the lower cost may lead to the decrease of efficiency. Therefore, this research aims to modify the time model proposed by previous researchers, and came up with an index of value based on value engineering. Thus, the disciplines will be extracted out and evaluated into a general model for similar construction projects.

2 Literature Review

Method of calculating the lifting time

The method of calculating the lifting time is mainly based on the equations proposed by Zhang et al. in 1999\cite{4}. He summarized the equations to calculate the total travel time of a crane to deliver the component from supply location to the demand point. Huang et al.\cite{9} later introduced a parameter to represent the location specific effects within a construction site. Mohammed et al.\cite{6} separate the loaded time and unloaded time to more comprehensively calculate the total time. In 2016, Zahra et al.\cite{2} further introduced another parameter to decide the capacity of the crane to lift a particular component.

Optimization algorithm of calculation

There are many studies that were optimized by different algorithms. Javier Irizarry et al. improved the method by using BIM and GIS, so that the tower crane can be optimized from the perspective of 3D visualization\cite{5}. Tam et al.\cite{3}, Mohammed Adel Abdelmegid\cite{6} and Mohamed Marzouk\cite{7} proposed the genetic algorithms to optimize the tower crane location, and the distances between the supply demand points. Mohamed Al-Hussein et al. proposed an optimization algorithm to avoid the collision in construction site\cite{8}. Huang et al. used Mixed Integer Linear Programming to reduce the operating costs of tower cranes\cite{9}. Lien et al. further suggested that Particle bee algorithm can be used to solve the problem of locations\cite{10}. Wang et al. used BIM technology and firefly algorithm to study the automatic arrangement of the tower crane\cite{11}. Tam et al. studied the total time cost by using artificial neural network and genetic algorithm to optimize the supply location\cite{12}.

Indicator of evaluating the lifting scheme
To optimize the lifting scheme, scholars proposed several kinds of indicators. The indicators proposed by these researchers mainly related to the time, cost, conflicts and locations. Zhang et al. optimized the location for group of tower groups by minimizing the conflicts between cranes and location [4]. Huang et al. refined the hoisting time of the tower crane by considering the influence of the tower crane operators and the time for each lifting process [9]. Based on these researches, Zara et al. discussed with the relationship between the location optimization and the costs [2].

In this paper, we further improve the method of calculating the lifting scheme. In addition, a new indicator of value was introduced in this paper to appraise the scheme.

3 Methodology

As shown in Figure 1. The methodology introduced the optimization of the hoisting scheme from the location, total time and the value.

![Figure 1. Framework of methodology](image)

### 3.1 Selection of location

#### 3.1.1 Model assumptions

The following assumptions are considered in developing the model:

a. The location and load of the demand points have already been set during the design stage.

b. The constraints such as the landforms, roads, surrounding obstructions are not considered.

c. The impacts caused by the shape and volume of the demand point are not considered.

#### 3.1.2 Potential crane location

The framework shown in Figure 2 is the method of working out the possible crane locations. Assuming D1 and D2 are the demand points of the same type of component (such as the wall), D3 is a demand point of another type of component (such as the column), and M1=M2>M3; R1, R2, R3 are the radiusses ($\rho_{D,\text{max}}^K$) of the maximum area to ensure the crane to lift the load of the corresponding point. The further the jib is, the lower the capacity of the crane, which leads to $R_1=R_2<R_3$. The crane has to be positioned in the overlapping region to deliver the all components from supply point to output. 

---

Is there any point of intersection with attachment route? 

```
N
```

```
Y
```

Calculate the value of crane selection $V_i(T_{t_1}, C^k)$ of each possible crane location

```
m = \max\{V_i, V_{i-1}\}
```

Output $V(T_{t_1}, C^k) = m$

---

Unavailable

---

565
the demand point.

3.1.3 Potential supply location

By using the same method discussed in the previous part, every potential crane location can have its potential supply area, as shown in Figure 3.

3.2 Calculation of total time

In general, the hoisting process introduced above can be separated into two main modes: (i) Load mode; (ii) Unload mode [6]. When delivering the prefabricated component, the movement of the crane can be divided into two paths: The horizontal movement and the vertical lift movement. The horizontal movement for transporting the component from the supply point \( S(x_s, y_s, z_s) \) to the demand point \( D(x_d, y_d, z_d) \) is divided into the linear motion of the trolley and the rotation of the jib, as shown in Figure 4. Eqs. (1) - (3) calculate the travel distances between the supply and demand points.

\[
\rho_d^g = \sqrt{(x_d - x_k)^2 + (y_d - y_k)^2} \quad (1)
\]

\[
\rho_s^g = \sqrt{(x_s - x_k)^2 + (y_s - y_k)^2} \quad (2)
\]

\[
\rho_r^g = \sqrt{(x_s - x_d)^2 + (y_s - y_d)^2} \quad (3)
\]

Then the needed time of the trolley sliding and the jib rotation during the horizontal movement could be calculated in Eqs. (4) and (5), respectively.

\[
T_\omega = \frac{1}{v_\omega} \arccos \left( \frac{(\rho_d^g)^2 - (\rho_s^g)^2 - (\rho_r^g)^2}{-2 \rho_d^g \rho_s^g} \right) \quad (4)
\]

\[
T_r = \frac{|\rho_d^g - \rho_s^g|}{v_r} \quad (5)
\]
0 ≤ arccos (θ) ≤ π

Where \( T_ω \) = time for trolley movement; \( T_r \) = time for jib rotation; \( v_ω \) = slewing speed of jib (rad/min); and \( v_r \) = radial speed of trolley (m/min).

Eq. (1) – (5) are directly cited from the research of Zhang et al. [4]. The following calculation are further improved their methods. In the practical situation, the movement of the trolley sliding and the jib rotation can run in parallel. Therefore, Eqs. (4) and (5) can be combined to calculate the time of horizontal movement, as shown in Eqs. (6). The parameter \( α \) indicates whether the movement is simultaneous or not, showing the degree of coordination between the movement of trolley and the jib rotation. The parameter \( α \) should be assigned to the value between 0 and 1, where 0 and 1 stand for full simultaneous movement and full consecutive movement [2]. The parameter \( β_r \) and \( β_ω \) represent the first movement of the trolley or the jib rotation, when 0 and 1 represent the later movement and the first movement, respectively. The corresponding time could be referred to Eq. (6).

\[
T_h = [β_r T_r + β_ω T_ω] + \max\{(1 - α)[β_r T_r + β_ω T_ω], β_r T_r + β_ω T_ω\} \quad (6)
\]

When \( α=1\), \( β_r=1\), \( β_ω=1\), or \( α=0\), \( β_r=1\), \( β_ω=0\), or \( α=0\), \( β_r=0\), \( β_ω=1\), the results of Eq. (6) are same as the results of that of Zhang [4].

As shown in Figure 5, the vertical movement can be separated into two parts. One is the vertical lift movement, and the other is the vertical descent movement. In the practical conditions, there should be a safe height \( h_0 \) above the demand point (Eq. (7) shows the time \( T_{v1} \) for horizontal movement from a supply point to a demand point). Therefore, compared to the former researches, the time \( T_{v2} \) for descent movement given in Eq. (8) should be added.

\[
T_{v1} = \frac{|x_d - x_s| + h_0}{v_h} \quad (7)
\]

\[
T_{v2} = \frac{h_0}{v_h} \quad (8)
\]

Where \( v_h \) = hoisting speed of hook (m/min)

The calculation of total travel time to deliver a component \( T_{i,j}^\alpha(x_s, y_s) \) is given in Eq. (9). In the same consideration, the horizontal movement and the vertical lift movement can be manipulated simultaneously, hence to add the parameter \( γ \) to define the degree of coordination between the horizontal and vertical movement. In addition, the parameter \( μ_k \) refers to the degree of difficulty in different potential crane location K for the operator to manipulate ranging from 0.1 to 10.0, which is diverse when towards different demand and supply points.
This paper uses Eqs. (1) - (9) to define the total travel time of a single potential crane location. Besides, considering that there would be unloading time and waiting time in the whole process of hoisting, the total time of a hoisting scheme could be defined as Eq. (10).

\[ T_{t_n} = \sum_{i=1}^{I} \sum_{j=1}^{J} T_{ij}^{0} + T^{u} + T^{w} \]  

### 3.3 Decision objective based on value engineering

With regard to optimization of hoisting scheme, the analysis could proceed from time, cost and value towards different targets. This paper is based on the theory of value engineering, calculating the efficiency and value \( V(T_{t_n}, C_{t}^{k}) \) of the hoisting scheme to evaluate it. The value refers to the lifted load in per unit time and cost. As shown in Eq. (11), then the best value scheme could be selected.

\[
V(T_{t_n}, C_{t}^{k}) = \frac{F}{E^{k}} = \frac{\sum_{i=1}^{I} \sum_{j=1}^{J} V_{ijl}}{T_{tn} \cdot C_{t}^{k}} = \frac{\sum_{i=1}^{I} \sum_{j=1}^{J} V_{ijl}}{T_{tn} \cdot C_{t}^{k}} = \frac{M}{T_{tn} \cdot C_{0}}
\]

\[ F = \sum_{i=1}^{I} \sum_{j=1}^{J} V_{ijl} \]

\[ C_{t}^{k} = T_{tn} \cdot C_{0} \]  

Where \( F \) refers to the function of the scheme, \( C_{t}^{k} \) refers to the total cost of the hoisting scheme, \( V_{ijl} \) refers to volume of each prefabricated component, \( C_{0} \) refers to the monthly rental cost, \( M \) refers to the total weight of prefabricated components.

### 4 Case Study

To make the crane selection more specific and well-managed, this section will analyze a building with thirteen floors in Chongqing, China. The chosen tower cranes are the most commonly-used types in China, QTZ63, QTZ80 and QTZ125, where the numbers after “QTZ” refer to the max load moment (unit: kN·m) of that type of tower. These cranes are fixed at the periphery of the building with attachment facilities. The distance of attachment \( d \) is 4m, as shown in figure.6.

In this case, every demand point has a matched concentric circles for successfully allocated the crane. The intersection of all the circles is determined to be the target position of tower crane. Another constraint is the linear route of attachment which further narrows the space into a segment. At the four aspects of this building, the possible crane location could be described as particle distribution with horizontal coordinates. In this case, the spot of supply point is supposed to be transport vehicle stops and the parameter \( d_{2} \) indicating the distance between supply point and crane location, could be assume as 8m. Next step is the calculation about total hoisting time \( T_{t_n} \), overall costs of cranes and the introduced index \( V(T_{t_n}, C_{t}^{k}) \), value of crane selection. The calculating process can be achieved by Python programming.

The maximum weight for crane to lift is limited by the jib length and the jib length increases along with the type promotion. Their possible locations are irregular, as shown in Figure 6. At different aspects, the shortest hoisting time appears in the middle with respect to the surface of the regular rectangle building.
Figure 6. The relation between types and possible crane location

When the type enlarges, the total hoisting time and value of crane selection will act reversely, while the overall cost is increasing, as shown in Figure 7. The shortening of total hoisting time is due to the mechanical property, especially lifting speed $V_h$. The regular rule for value of crane selection is depending on the total hoisting time and overall cost, which can be seen in the Eq.11.

Figure 7. The relation between types and three variables

The results based on the scheme and index of value this paper has proposed, comparing with single-objective optimization, indicate that the best choice of tower crane in this case is QTZ63. However, from the perspective of cost-saving, the best choice is QTZ63 too. The best time-saving option is QTZ125, which cost most and at a low level of value.

5 Discussion

According to the results of this case, we can hardly identify the deference of value-based from time-saving and cost-saving based patterns. This does not mean that the decision itself is unreasonable or wrong because the data we adapted from market is temporary and particular. In this case, it is necessary to discuss the applicability of this index and find out the differences by comparing the results of decision with other two decision objectives.

Initially, concerning about the most possible state of market, all the discussions consist in the
following circumstance: \( C^{63}_0 < C^{80}_0 < C^{125}_0 \). Then, an important premised concern about the rule of value is that it varies with rental cost if only the variables have been calculated and settled except rental prize. The different conditions and corresponding results when rental prizes gaps shrink have been illustrated in figure.8. Once the rental prizes of QTZ80 and QTZ125 are within specific range, the value-based decisions will vary from the cost-saving results. For instance, the first state ((1), Fig.8) which stands for the case this paper has studied, recommends QTZ 63 consistent with the cost-saving decision. The second state ((2), Fig.8) suggests QTZ80 when the rental cost of QTZ80 decreases and consists in the range of \( 1.015C^{63}_0 \) to \( 1.03C^{63}_0 \) but other types remain the same, while the most cost-saving choice is still QTZ63. The third state ((3), Fig.8) based on the second one prefers QTZ125 after its rental prize has been degraded into a range of \( 1.088C^{63}_0 \) to \( 1.183C^{63}_0 \), whereas the best choice for saving cost is QTZ63. These conditions all support that it is possible for QTZ80 and QTZ125 to attain a better value than QTZ63 by narrowing the gap of rent prize between them. Besides, after being narrowed, the gap of rent prize and value depends on the mass of different projects according to Eq.11. The more workload, the bigger the gap is, which means the difference between the two ways of selection is about to be more noticeable.

![Figure 8. Different decision resulting from two different objectives, value and cost](image)

6 Conclusion

According to the evaluation, the plane model for selecting tower cranes is much more scientifically feasible than the traditional one based on the experience without considering about the efficiency and optimization. In the meanwhile, this research has modified the process of calculating the total hoisting time based on former researches. In addition, a new index has been proposed for selecting cranes introducing another thought of using money from the province where they are needed most. Besides, on the basis of the case this paper has studied, the comparison among three objects has been conducted and consequently different results did emerge.

Finally, it becomes noticeable that once the possible provided types of cranes are settled, the main concern turns out to be the rental prize, in which case this paper provided a fast track for making decision.
References


Investigating project performance measurements based on the complexity level of IT-enabled projects

Odusanya, S.¹*, Elmualim, A.², Ochoa J.J.³ and Chileshe, N.⁴

Abstract: The success of Information Technology (IT) implementation projects and in particular IT-enabled projects has long been a concern for the project management fraternity. This paper reviews literature in order to describe the need to measure the performance of IT-enabled projects based on the complexity level of IT-enabled projects. These IT-enabled projects deliver organisational changes and they are impacted by socio-cultural, organisational, process and technology challenges while implementing IT systems. Complexity comes in several forms and it leads to risks within the project environment. Project management often places a lot of emphasis on ensuring that a project delivers its deliverables according to a defined performance measure but it is less focused on ensuring that the correct performance measures are in place. Project managers are blamed for failures that are caused by environmental factors. In fact, IT projects are often abandoned due to human related, political and organisational issues.

This paper presents the proposal for investigating how project performance can be measured based on the complexity level of IT-enabled project. It presents the research problem which highlights the fact that project management can be viewed as scientific in terms of how success is measured. It also points out that project managers are blamed for project failures that they have little or no control over as these failures may have occurred due to environmental factors. It presents literature on the various measurements of success and the types of complexities that exist within a project environment. It concludes that project managers need a better understanding of complex projects and their adaptive environment to effectively manage projects. The aim being to improve project management practice by measuring project performance based on the complexity level of the IT-enabled project.

Keywords: IT Projects; IT-enabled Projects; Project Management; Complexity.

---

¹ Odusanya, S.
Corresponding author, School of Natural and Built Environments, University of South Australia, Australia
E-mail: sylvia.odusanya@mymail.unisa.edu.au

² Elmualim, A.
School of Natural and Built Environments, University of South Australia, Australia
E-mail: abbas.elmualim@unisa.edu.au

³ Ochoa J.J.
School of Natural and Built Environments, University of South Australia, Australia
E-mail: jorge.ochoapaniagua@unisa.edu.au

⁴ Chileshe, N.
School of Natural and Built Environments, University of South Australia, Australia
E-mail: Nicholas.Chileshe@unisa.edu.au
1 Introduction

World Bank, 2003 cited by Affisco and Soliman, (2006) stated that ‘Information technology leads to better delivery of government services to citizens, improved interactions with business and industry, citizen empowerment through access to information, or more efficient government management’.

IT-enabled projects are IT projects that are used to deliver IT systems that support business and service transformation leading to organisational changes (Brouwer, 2011). Business transformation is therefore a radical change to business processes or model. Radical change leads to re-thinking the business model of an organisation and improving processes. This will lead to changes in the business processes, organisational structure and culture (Besson and Rowe, 2012). IT-enabled projects are implemented to ensure that an organisation remains competitive in its market place due to the advantages of implementing these projects (Jugdev and Thomas, 2002). Transformation takes an organisation from its “as is” to the “to be” state with radical changes in the structure of the organisation, culture and business processes as part of the introduction of a new IT system as shown in Figure 1 (Weerakkody et al., 2011). In the UK and Netherland, public agencies transformation change has led to a reduction in administrative burden which in turn has led to service improvements (Layne and Lee, 2001; Weerakkody et al., 2011).

Figure 1. Overview of Transformation (Weerakkody et al., 2011)

According to Weerakkody et al. (2011), public agencies in the Netherlands and the UK have faced challenges like resistance to change while undergoing transformation. These challenges can be overcome by getting employees involved in the change. Transformation is broad as it involves changing the structure and culture of organisations (Besson and Rowe, 2012). There is a need to understand the various challenges such as socio-cultural, organisational, process and technology challenges that are faced during transformation (Layne and Lee, 2001; Weerakkody et al., 2011). Approximately 70% of the government transformation initiatives did not deliver their initial transformation objectives due to lack of ability for the government to change business processes (Weerakkody et al., 2011).
2 Research Problem

The 2009 version of the CHAOS report produced showed that only 32 percent of IT projects (this includes IT-enabled projects) are successfully delivered. The Standish report classified IT projects into three types: Successful, Challenged and Failed. Successful projects were completed within budget and on time with original functions and features (Eveleens and Verhoef, 2010). Challenged projects were completed with fewer features and function along with over the time estimate and over budget. Failed projects were simply cancelled before completion (Eveleens and Verhoef, 2010; Pearce, 2003). Table 1 list some Victorian government projects that did not deliver to their original estimate.

Table 1. Victoria government projects that did not deliver to original estimate (Brouwer, 2011)

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Initial Budget</th>
<th>Extra amount required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myki</td>
<td>$999 million</td>
<td>$350 million</td>
</tr>
<tr>
<td>HealthSMART</td>
<td>$323 million</td>
<td>$243 million</td>
</tr>
<tr>
<td>CRIS</td>
<td>$22 million</td>
<td>$70 million</td>
</tr>
<tr>
<td>Link</td>
<td>$59 million</td>
<td>$187 million</td>
</tr>
</tbody>
</table>

The review of the existing literature on the research topic has shown that very little research has been undertaken to investigate the impact complexity has on the performance measurement of IT-enabled projects. The approach to project management has been very scientific with the use of schedules and cost estimated that has led to some assumption of control. But to a large extent project managers have no control of the environment that projects take place in. Also the environment to an extent impacts project execution and delivery cannot be controlled (Weaver, 2007). Project management often assumes that the scope of the project has been clearly defined and the focus is to ensure that things get done right. It is not focused on ‘whether the right things are being done, why the project should proceed or what performance criteria would be appropriate’ (Atkinson et al., 2006). The survey study completed by Wateridge, (1998) concluded that project managers focus on short term success criteria such as time and cost because that is what they are judged on by senior managers.

Project managers are continuously being criticized for project failures that they have little or no influence over. For example, Project Managers have little influence over environmental changes (Nieto-Rodriguez et al., 2004). Projects are sometimes complex because of technical issues but also because of organisational issues (Whitty and Maylor, 2009). IT projects (including IT-enabled projects) are abandoned due to human related, political and organisation issues (Ewusi-Mensah (1997) cited in Pan 2005, p.174). IT-enabled projects display the characteristics of complex projects. Complexity can be a driver for risks that can occur within IT-enabled projects (Xia et al., 2004). Some of the listed risk factors in table 2 associated with failure of IT projects (including IT-enabled projects) are similar to the characteristics of a project with a higher level of complexity (Schmidt et al., 2001).
Table 2. Identified Risk Factors and Categories (Schmidt et al. 2001, p.35)

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Source of risk: nature of risk</th>
<th>Possible type of complexity or relationship to complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate environment</td>
<td>Environment: Changes in the business or political environment or poor alignment of system with organisational culture</td>
<td>Temporal complexity</td>
</tr>
<tr>
<td>Sponsorship/ownership</td>
<td>Mandate: Lack of mandate for the PM to execute the project plan. Lack of trust or poor relationships with the owners of the system</td>
<td>Directional complexity</td>
</tr>
<tr>
<td>Relationship management</td>
<td>User Relationships: Lack of trust and inadequate user involvement. Unclear roles and expectations among users or other stakeholders</td>
<td>Structural complexity</td>
</tr>
<tr>
<td>Project Management</td>
<td>Management: Poor or inefficient management strategy and execution</td>
<td>This issue may be due to the impact of complexity or other issue</td>
</tr>
<tr>
<td>Scope</td>
<td>System Scope: Unclear, changing or partial understanding of the system scope and mission</td>
<td>Directional complexity</td>
</tr>
<tr>
<td>Requirements</td>
<td>Requirements: Inadequate or poor management of system requirements; poor validation of system requirements</td>
<td>Directional complexity</td>
</tr>
<tr>
<td>Funding</td>
<td>Resource management: Too little or badly estimated resources for SD</td>
<td>This issue may be due to the impact of complexity or other issue</td>
</tr>
<tr>
<td>Scheduling</td>
<td>Resource control: Poor management of resource consumption and needs. Poor timing</td>
<td>This issue may be due to the impact of complexity or other issue</td>
</tr>
<tr>
<td>Development Process</td>
<td>Process: Inappropriate or lacking process approach</td>
<td>This issue may be due to the impact of complexity or other issue</td>
</tr>
<tr>
<td>Personnel</td>
<td>Skills: Inadequate personnel skills in development and process management</td>
<td>This issue may be due to the impact of complexity or other issue</td>
</tr>
<tr>
<td>Staffing</td>
<td>Staffing: Changes in personnel or staffing levels, unavailability of key personnel resources</td>
<td>This issue may be due to the impact of complexity or other issue</td>
</tr>
<tr>
<td>Technology</td>
<td>Technology: Inadequate understanding of the chosen technology</td>
<td>Technical complexity</td>
</tr>
</tbody>
</table>

The characteristics of these projects suggest that the traditional view of success based on the iron triangle (time, cost and quality) is not suitable for measuring success of these projects. This supports the need for research in this area to investigate how organisations use the level of project complexity to measure project performance within organisations with several levels of maturity. Figure 2 below presents the theoretical framework of the research. Environmental factors which include the socio-cultural, organisation, process, and technology contribute to the complexity level of IT-enabled projects which impact the success of a project. Hence, a theoretical framework that measures the success of IT-enabled projects based on the level of complexity will be developed.
3 Literature Review

3.1 Project Success

Project success has been defined differently in the field of project management (de Bakker et al., 2010). The dominant view for measuring project success is known as the traditional model; delivering within cost, time and specification. The broader view of project success can be seen as the stakeholder’s assessment of the project characteristics which may include other characteristics as well as cost, time and specification. de Bakker et al., (2010) argued that stakeholders may have different or conflicting views of the degree of project success. There are many projects that finish on time and within budget but are viewed as unsuccessful. There are also projects that experience cost and time overruns but are viewed as successful (de Wit, 1988). de Wit (1988) and Lech (2013) examined some projects and identified that many projects were successful even if they exceed at least one of the project management criteria. It was understood that projects led to meeting business goals even if parameters such as schedule, budget and functionality differed from what was planned due to changing environments. A survey conducted by the Australian Construction Industry identified that stakeholder satisfaction was the highest rated success criteria (Lech, 2013).

However, there is a distinction between the success based on the project and success based on project management effort. Project success results in meeting the objectives of the project and project management success involves delivering to time, cost, and specification. Success of a project is not always dependent on project management effort (Cooke-Davies, 2002; de Wit, 1988). ‘Good project management can contribute towards project success but it is unlikely to be able to prevent project failure’ (de Wit 1988). Serrador and Turner (2015) argued that project management success should not be ignored as there is a correlation between the project management success and project success. It has been observed that what is important to a stakeholder depends on the project phase. Hence the stakeholder’s perception of success or failure is dependent on time. (Avots (1984) cited in de Wit 1988, p.166) stated that ‘during the early phase of the project, schedule is of primary importance, while cost takes second place and quality third. Later in the project, cost becomes the controlling interest, with schedule taking a secondary role. After the project has been completed, schedule and cost problems are forgotten and quality becomes the key’.

Atkinson (1999) has suggested that the traditional project management success criteria is limiting. He suggested that other success criteria could be used to measure the success of a project post implementation. These additional criteria are 1) Technical strength of the system 2) Benefit to organisation 3) Benefit to stakeholders. These could be added to the traditional success criteria to create four success criteria called Square root. Moving from the Iron Triangle, of cost, time and specifications,
to a measure of success that includes other criteria such as stakeholders perception will help to provide a more reliable information on project success (Atkinson, 1999).

de Bakker et al., (2010) also suggested that the project success criterion varies from project to project as it depends on the stakeholders involved and other subjective issues such as urgency, cost, functionality, quality, and profit. For example, if a project is required to increase profit within an organisation, then success to the relevant stakeholders will mean an increase in profitability. Defining the success criteria prior to starting a project and measuring it post implementation allows an appraisal of the investment made. The survey study completed by Wateridge (1998) compared the perception of the criteria for success based on responses from users, sponsors, systems analyst and project manager. It identified that users felt that it was important for systems delivered to meet the requirements and make users happy. On the other hand, project managers argue that making users satisfied with a product was not as important as other success criteria such as budget or time. The study concluded that project manager’s focus on short term success criteria such as time and cost because that is what they are judged on by senior managers. A project manager’s career depends on what they are judged on. The long term uses of the system delivered were more important to the users and meeting strategic objectives may be more important to the sponsor. With divergent views of the meaning of success, it is important that an understanding is made at the start of the project to define the success criteria for the IT-enabled project (Taylor, 2004).

3.2 Complexity
According to Whitty and Maylor (2009) ‘A complex system is a system formed out of many components whose behaviour is emergent. That is to say that the behaviour of a complex system cannot be simply inferred from the behaviour of its component’. Several examples of complex systems include the eco-system, the human body and the brain.

There is a clear distinction between complicated and complex. Complicated is knowable and the behaviour of a system that is complicated can be explained by breaking it into individual parts and each component can be used to explain the entire behaviour. Complex systems cannot be described by its individual components. Their components can change over time and they do not individually explain the behaviour of the entire system. The difficulty in the predicting the nature of a complex system is caused by the interaction of its component (Whitty and Maylor 2009).

The definition of complexity can vary from person to person but some researchers below have provided some widely accepted definitions (Baccarini, 1996). Table 3 below provides a summary of the types of complexity.

<table>
<thead>
<tr>
<th>Type of Complexity</th>
<th>Complexity Definition</th>
<th>How complexity increases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural complexity</td>
<td>Many varied interrelated part</td>
<td>An increase in differentiation and interdependence leads to more complex projects</td>
</tr>
<tr>
<td>Baccarini, (1996)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directional</td>
<td>How well goals are defined</td>
<td>Less well defined goals leads to more complex projects</td>
</tr>
<tr>
<td>Turner and Cochrane, (1993)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical</td>
<td>How clear are the methods for delivery</td>
<td>Less well defined methods leads to more complex projects</td>
</tr>
<tr>
<td>Remington et al., (2007)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporal</td>
<td>Based on project environmental changes</td>
<td>More project environmental changes leads to more complex projects</td>
</tr>
<tr>
<td>Remington et al., (2007)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IT-enabled projects can be described as more complex projects because there are several aspects
involved such as changes to organisational structure, cultural behaviours, process re-engineer and the introduction of a new IT system (Klaus et al. 2015; Weerakkody et al. 2011). According to Baccarini, (1996), complexity impacts cost, time and quality. Complexity therefore has profound implications on the success of IT-enabled projects.

4 Conclusions and Recommendations

Simply measuring the success of IT-enabled projects without considering the level of project complexity allows project managers to focus on short term goals. IT-enabled projects require much more consideration than cost, time and delivering to requirements. Several management approaches are currently being introduced in organisations but to ensure that these approaches are effective, the success measure of IT-enabled projects must consider the complexity levels of IT-enabled projects. Therefore, in order to address the identified shortcomings, using a literature review approach, this paper was aimed at presenting the proposal for investigating how project performance can be measured based on the complexity level of IT-enabled project.

This literature review has helped conclude that there is more to measuring the success of IT-enabled projects. IT-enabled projects introduce organisation change and they exhibit the characteristics of projects with a higher level of complexity because they start up with unclear goals and methods for delivery, they involve multiple stakeholders and they must be flexible to allow negotiation and changes to requirements. Project managers must be aware of the characteristics of projects to effectively communicate and influence project stakeholders. Success is beyond the iron triangle as a lot of projects meet the iron triangle success criteria but yet they remain unsuccessful (de Wit, 1988). Project management is moving from ‘command and control’ to ‘communicating and influencing’ because of a better awareness of the fact that a project manager has little or no control of the environment that the project is being completed in. This is because projects are complex adaptive systems that involve interactions between several stakeholders and the project team learns and adapts to new information received (Weaver, 2007). Therefore, more investigation is required to understand how the level of project complexity can be used to measure success of a project. For example, this could be through conducting empirical studies aimed at exploring the linkages among the concepts as illustrated in Figure 2.

References

Abstract: Real estate market has “hot” and “cold” periods. In the upward housing market, the number of the buyers will increase, and so as the market price. In the expected upward market, the sellers intend to overprice the houses and wait for the better return. The paper develops a simple theoretical model for the optimal listing price strategy with the maximized expected present value of return in the expected upward housing market.

Key words: Price volatility; Binomial tree; Search theory; Housing market.

1 Introduction

Real estate market has “hot” and “cold” periods. In hot housing market, the price is increasing as well as the number of the buyers; while in “cold” market, the price is decreasing, so is the number of the buyers.

Different from stocks which can be traded any time, houses are illiquid assets. There are frictions that hinder the transactions in real estate market including the heterogeneity in the motivations of sellers and buyers, idiosyncrasy in the characteristics of the houses, imperfect information in the housing market, etc. Hence, in the housing market, the sellers can’t find the proper buyers immediately. There is a search process for the sellers to locate the buyers.

In the search process, the sellers want to maximize the sale price, at the same time, minimize the time on the market. In the search-theoretical model, it has been widely studied that there is a trade-off between the sale price and time on the market (Yinger, 1981; Clark & Smith, 1982; Jud, 1983; Wheaton, 1990; Dipasouale & Wheaton, 1992; Baryla & Zumpano, 1995; Zumpano et al., 2003; Cheng & Liu., 2008). There are also some literatures analyzing the relationships between the sellers’ listing price/asking price, sale price, and time on the market (Horowitz, 1992; Yavas&Yang, 1995; Anglin et al., 2003; Merlo, 2004; Haurin et al., 2010). Listing price will truncate the probabilities for the higher bid prices, at the same time listing price highly influences the arrival rate of the potential buyers. In the face of the uncertainties, it is difficult for the sellers to make decisions for the listing price strategy. Various factors influence the decision on listing price strategy including the motivations of the sellers, efforts of the brokers, etc. A non-negligible factor is the market condition. On one hand, the market condition will influence the number of the potential buyers. In an upward market, there will be more potential buyers, while conversely in the downward market, there will be less potential buyers. The number of the arrival rate of the buyers will influence the decisions on listing price strategy. On the other hand, the price volatility in various market condition will influence the expectation of the sellers on the trend of the market in the search process. In an upward market, sellers intend to overprice and wait for higher return, while in a downward market, sellers intend to expected the price will decrease in short future and sell the property quick at the price even lower than the market price.

The concept of the “heat” of the market is firstly discussed by Novy-Marx (2009). In Novy-
Marx (2009)’s work, the “heat” of the market is defined by the number of the potential buyers, and the changes in number of the potential buyers will trigger the chain-effects for the sellers’ decision on the pricing strategy. Following Novy-Marx (2009)’s theoretical model, some empirical analysis on sellers’ search strategy are made in the distressed housing market (Carrillo, 2013; Selcuk, 2013). However, there is barely any literature studying how the market price volatility influencing the decision for sellers’ search strategy.

The real estate market in China is a “hot” market. In the year of 2016, the sale area of the houses increases by 22.5%, and the turnover is 117,627 billion RMB increased by 34.8% from last year. The average price of the real estate market is keeping increasing as shown in Figure 1. In the expected upward housing market, sellers intend to gain the premium rate of the market price. However, as explained, there is a trade-off between the price and time on the market. The paper develops a model to analyze the optimal listing price strategy, especially optimal premium rate in expected upward housing market.

![Figure 1. Real estate price in China](image)

### 2 The model

In order to analyze how the price volatility influencing the sellers’ decisions, the model borrows the idea from the American option pricing model. Several assumptions are made to build the model.

Assumption 1: housing market price is a binomial tree.

\[
Price_{t_0+t} = Price_{t_0} * C
\]

\[
C = \begin{cases} 
  u, & \text{with probability } P \\
  1/u, & \text{with probability } 1 - p
\end{cases}
\]

Assumption 2: housing market price follows GBM with the return rate \( r \) and volatility \( \sigma \).

\[
u = e^{\sigma \sqrt{t}}
\]
Assumption 3: only when the market price is equal or higher than the listing price, the transaction can be made at the listing price.
Assumption 4: the seller will try to maximize the expected present value of return, the time discount factor for each period is denoted as $\delta$.
Assumption 5: transaction can’t be made after $N$ periods ($N$ is big enough).

The dynamic market price tree is shown in Figure 2. According to the decision tree, by maximizing the sellers’ expected present value of return, the optimal listing price can be calculated.

\[
P = \frac{e^{rt} - d}{u - d}
\]

3 Application to Shenzhen

The residential real estate price in Shenzhen from January 2016 to April 2017 is shown in Figure 3. Volatility of the log return is 0.1989, and continuous compounded yearly return rate is 0.12. Using the national debt yearly interest rate 3.85% as the risk-free rate for the time discount. Assume that a seller wants to sell a house with the average quality from April 2017, and the house has to be sold within a year. The average price in April 2017 is 54619 RMB/m², instead listing the market price, the seller use the theoretical model explained in the Section 2 to achieve the optimal listing price.
4 Concluding remarks

In the expected upward housing market, instead of directly listing the market price, the seller will intend to overprice the property, and expected to gain more return from the volatility of the market price. The paper developed a simple theoretical model to analyze the listing price strategy in the upward housing market. With the model, optimal listing price for the maximum expected present value of return can be calculated. The results from Shenzhen indicate that the
seller intend to list a much higher price. In the expected upward housing market, the sellers listing price strategy will boost the price to increase further.

References


Selcuk Cemil, 2013, Motivated Sellers and Predation in the housing market, Economic Modelling, 32: 203-214


HSR-based nodal zones (HNZs) in networked cities: A case of China

Guo Liu¹, Kunhui Ye², Sui Pheng Low³, Xin Hu⁴, Jinding Xing⁵

Abstract: Rapid evolution of high-speed rail (HSR) in the current century has aggregated the development of transportation stations and their surroundings in cities, which are called HSR-based nodal zones (HNZs) in this paper. Although the contribution of HNZ to urban development is tremendous and observable, HNZ’s features in developing countries have not fully been identified. To fill this research gap, a blend of approaches comprising case study, qualitative analysis and statistical analysis were adopted in the study. 219 cases were collected from China for analysis. It was found that (1) HNZ distributes widely in a size ranging from 200 to 3700 m in radius; (2) a vast majority of HNZ is located in urban periphery; and (3) they are endowed with multiple orientations and a portfolio of transport-based mixed functions. The research findings outline the multifaceted nature of this spatial phenomenon in China and by extension shed some lights on the development of HNZ as activities pole for the attainment of urban sustainability in other developing countries.

Keywords: Nodal zone; HSR; Attributes; Urban space; China

¹ Guo Liu
Corresponding author, School of Construction Management and Real Estate, Chongqing University, China
² Kunhui Ye
School of Construction Management and Real Estate, Chongqing University, China
³ Sui Pheng Low
School of Design and Environment, National University of Singapore, Singapore
⁴ Xin Hu
School of Civil Engineering and Built Environment, Queensland University of Technology, Australia
⁵ Jinding Xing
School of Construction Management and Real Estate, Chongqing University, China
1 Introduction

The proliferation of high-speed rail (HSR) has accelerated the pace of connecting one urban space to another to form a larger network of cities\cite{1}. The influence of HSR on urban development goes first to the vicinity of HSR stations, where enormous passengers diverge and diffuse\cite{1, 2}. First, inner-city vehicles (e.g., buses, taxis, metros) are usually supplied in station adjacent areas to facilitate travelers’ arrival and departure\cite{3}. Second, an increasing passenger volume through city network stimulates unforeseeable consumption in the areas\cite{4}. Third, given convenient access to transportation, local people and business are preferred to purchasing properties nearby HSR stations\cite{2}. It seems therefore that the role of station areas in urban development appears to function as a “node magnet” in assembling many kinds of intra- and inter-city elements in a compact urban space\cite{5, 6}.

With the trend of urban development, HSR stations and their surrounding areas, which are termed HSR-based nodal zone (HNZ) to be defined later in this paper, have created a new spatial pattern\cite{7, 8}. The surfacing role of such an emerging urban area attracts considerable governments to place a multitude of urban functions on it\cite{5, 6}. The subject of rail station areas has been examined extensively\cite{1, 2, 7}. While these studies address the definition and attributes of rail stations, a gap exists when applying these research findings to HNZs due to the difference between HNZs and rail stations\cite{9}.

As one of the largest developing countries, China has been experiencing rapid HSR growth. Urban spaces in different cities commence to connect with each other via HNZs\cite{9}. Despite this, sparse efforts have been put to investigate such a new urban phenomenon, leading to a poor perception of HNZs. In effect, the necessity of researching HNZs has been stressed in previous studies\cite{10}. Unsurprisingly, little knowledge has been informed of what HNZs are and how they could be. To fill in this gap, the concept of HNZ will be presented first in this study and the aim of the study is thus to identify the attributes of this analyzed object. The research findings can lay a foundation for parallel examination in other developing countries and favor local governments to utilize HNZs properly.

2 Understanding a HSR-based nodal zone

2.1 Networked cities in China

HSR can be traced back to the 1960s when the first HSR routine was built to connect Tokyo and Osaka in Japan. About 50 years later, the first Chinese HSR operated with a speed of 200 km/h. It was not until 2008 that a newly built HSR line (Beijing-Tianjin) was put into operations with a maximum speed of 350 km/h. This line considerably shortens traveling time between these two major cities and represents a key milestone for China’s intensive involvement with ‘rapid HSR development’.

After a decade of development, the total distance covered by HSR in China amounted to 22000 km by the end of 2016. This is probably the largest scale of its kind in the world. According to the ‘Mid-to-long Term Railway Network Plan’ issued by the Ministry of Railways, the HSR lines would be extended with another 5,000 km in the coming years. Furthermore, 20,000 km’ mixed traffic high speed lines with a designed speed of 200-250 km/h would be put in place by upgrading existing lines by 2020. Hopefully, the whole HSR network in China can connect all parts of the country, providing well developed rail services for approximate 90% of the local population. With the distinctive progress of HSRs, the connectivity of urban areas in different regions can be consolidated into networked cities - cities act as nodes and rail routines between cities play as network line. Therefore, more and more HNZs will take place nationally.
2.2 Definition of HNZs

The definition of HSR-based station area is not universal\[^{[1]}\], such as station area or station catchment area. Generalized cognition still has to be elaborated. A HSR station is similar to a railway station; they could be used interchangeably in terminology. The node-place model proposed by Bertolini\[^{[7]}\] claims that a railway station is characterized with dual characters - a network’s node and a city’s place. These two roles signify a variety of functions that a station area might be assigned\[^{[5,6]}\]. Zemp \textit{et al}\[^{[11]}\] employed five generic functions, such as linking catchment area and transportation network, to present a stakeholder-based perception of a railway station. Furthermore, researchers have advocated complementing the node-place model with extra variables to give an accurate description of a station and its surrounding area. Peek and Louw\[^{[12]}\], for instance, pointed out that the categories of station areas will be deficient if the dimension of location is excluded from analysis.

These studies brought two largely stressed perspectives to the foreground of a HSR station and its environs. One highlights the capability of a station to accommodate a city’s interconnectivity that happens at intervals. The other underlines the potential of its vicinity to be equipped with multiple socio-economic functions. These socio-economic functions in station area are intertwined by the flux of people, capital, and information that are incurred by HSR network\[^{[7]}\]. Therefore, a unique spatial area representative of HSR-based transportation network effect is shaped within a certain geographical boundary of a city\[^{[11]}\]. In appreciating the deficiency of existing concepts (e.g. a railway station and its surrounding areas), a term called HSR-based node zone (HNZ) is offered here to refer to those urban areas impacted by HSR-based city network, radiating beyond certain zone from a HSR station.

A HNZ is a dynamic entity with interactive functions propelled by the dissemination of intra- and inter-city elements (e.g., passengers, information, and the like) among networked cities. This definition can pave the way for investigating the effects of HSR network on urban planning and development.

3 Research methods

According to the European Union, the speed of a HSR should be at least 200 km/h for an upgraded track and 250 km/h for a new one. In line with this criterion, HSRs in this paper refer to those train lines with prefix G (300-350 km/h), C (200-250 km/h for inner-city HSR), and D (200-250 km/h for inter-city HSR).

The majority of HNZs in China are still in an infancy stage. Probably for this reason, data are not available for evaluation\[^{[13]}\]. HNZs are spread geographically across China, and thus an online search was considered useful as an instrument to collect data. Three steps were taken in sequence.

First, since there are multiple centers in a city, according to Lin\[^{[14]}\] and Wang \textit{et al}\[^{[10]}\], the location of a Chinese local government can be set as a key reference point for city center, and the distances between a reference point and a HSR station be measured using parameters of either kilometer or traveling time. The parameters were measured through an online Map tool (map.baidu.com)\[^{[14]}\], which provides detailed information about distance and average traveling time by bus. The combination of these two parameters is to uncover more features of HNZs though not all the 219 HNZs are approachable. The rule for both measurements is the shortest distance and the least time to travel from a reference point to a HSR station.

Second, a rail station based radius was chosen to measure the size of HNZ\[^{[15,16]}\]. The size of a HSR station area usually follows a circle rule. With reference to this rule, Schütz (1998) divided station areas into three circles\[^{[1]}\]. To identify the circle features of HNZ, the design size of HSR-based
areas released by city governments was intended. 57 cases relating to areas of HNZs were collected consequently.

Lastly, since most of HNZs are at an initial development stage, according to Xu et al [13], their design blue prints covering orientation and functional positioning were investigated. To examine primary expectations of local governments, data about orientation and function of HSR-based station and its surroundings was extracted by scanning the planning schemes publicized on governmental websites. 65 cases about orientation and 27 cases about function were owned eventually.

4 Results and findings

4.1 Location

As discussed above, the distance between a station and its city center is good to elicit the location of a HNZ. Figure 1 illustrates the measurement results using the indicators of both kilometers and traveling time with respect to minimum, maximum and quartile values. Based on Figure 1(a), it can be found that the distance varies from 2 to 56 km, displaying a Gaussian curve of \( x \sim N(6.82, 51.21) \). This function indicates that the kilometer-based distance of about 99.73% of HNZs concentrate on the range of 2 to 25.29 km; wherein 75% of HNZs were distributed within the scope of 2 to 15 km. In addition, the time-based distance spans between 20 and 250 minutes (Figure 1(b)). It follows a Gaussian curve of \( x \sim N(57.84, 842.55) \), showing a large disperse distribution. Nevertheless, over 75% of HNZs takes over 50 minutes by bus, manifesting longer time to connect with HNZ and city center.

![Figure 1. Distribution of HNZs in location](image)

4.2 Size

Out of the 57 HNZs observed in the study, seven were found to involve three sub-zones. In view of the prominent influence of HSRs on the primary zone, these HNZs were chosen to examine the features of HNZs in size. For simplicity, the areas of HNZs were tabulated and converted into radius using the equation \( S = \pi r^2 \). Where, \( S \) represents the area, and \( r \) means radius. Considering the minimum, maximum and quartile values (P25, P50, and P75) of the radius, the cumulative size distribution of HNZs, displaying a Gaussian curve of \( x \sim N(2884, 1647112.50) \), is shown in Figure 2. It can be found that the radius of HNZ is distributed from 200 m to 3,700 m. The largest planning area is almost 19 times the smallest one; indicating a large gap between the sizes of HNZs in China. With reference to quartile values, it was found that the distribution of HNZs in radius is as follows: 1,700 m (75%), 1,300 m (50%) and 800 m (25%).
4.3 Orientation

As shown in Figure 3, nine orientations were found by classifying their inherent connections in HNZs. As displayed, those cities with different orientation occupy a share ranging from 6% to 38%. 38% of the analyzed cities designated HNZs with a transportation hub, implying the dominant role of transportation in the development of HNZs. Secondary to this, business service and (sub) center were selected by 32% of the cities. In addition, gateway and city card were considered by 25% and 17% of the cities respectively. These indicate diverse preferences of local governments in determining HNZs’ orientations.

![Figure 3. Distribution of HNZs in orientation](image)

4.4 Function

The functions of 27 HNZs in China were compared and 14 types of functions were listed in Table 1. The top three functions (accounting for 38%) were referred to transportation, suggesting that traffic is a principal function that local governments are apt for.

<table>
<thead>
<tr>
<th>Function</th>
<th>Number</th>
<th>Percent</th>
<th>Function</th>
<th>Number</th>
<th>Percent</th>
<th>Function</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>27</td>
<td>15%</td>
<td>S</td>
<td>17</td>
<td>10%</td>
<td>O</td>
<td>5</td>
<td>3%</td>
</tr>
<tr>
<td>H</td>
<td>24</td>
<td>14%</td>
<td>L/W</td>
<td>13</td>
<td>7%</td>
<td>I</td>
<td>4</td>
<td>2%</td>
</tr>
<tr>
<td>G</td>
<td>21</td>
<td>12%</td>
<td>CO</td>
<td>10</td>
<td>6%</td>
<td>W</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>P</td>
<td>20</td>
<td>11%</td>
<td>LE</td>
<td>6</td>
<td>3%</td>
<td>A</td>
<td>2</td>
<td>1%</td>
</tr>
<tr>
<td>B</td>
<td>19</td>
<td>11%</td>
<td>C/E</td>
<td>6</td>
<td>3%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: T: Transport; H: Housing; G: Greening; P: Public Administration and Public Services; B: Business services; S: Square; L/W: Logistics/Warehousing; CO: Commercial affairs and office; LE: Leisure and entertainment; C/E: Culture/Education; O: Others; I: Industries; W: Water; A: Agriculture.

5 Discussion

5.1 Peripheral location

One of the key factors stipulating the emergence of a HNZ is the location of a HSR station. The study
by Zhu, Yu and Chen [17] revealed that over 90% of HSR stations along the Beijing-Shanghai line were located in the suburbs. In this study, it was found that 75% of HNZs can be reached taking more than 50 minutes, and 25% of HNZs be approachable by 80 minutes from city centers. It can therefore be implied that a vast majority of HNZs in China are situated in city periphery and part of them are even in remote rural areas. Such a locational feature of HSR stations outlines an important attribute of HNZ, namely being located peripherally. This attribute of the HNZ might be ascribed to the presence of key factors that local governments are reliant on in making decisions on locating a HSR station. These can include low building demolition cost, convenient resettlement, easy construction in the suburb [18, 19], government ambition to erect a new-activities pole [7, 17], difficulties in disrupting the existing layout of an urban core [20], and requirements of HSR technologies [18, 21].

This attribute is also representative of China-specific contexts. Valuable economic opportunities generated by HSR network inspire local governments to embark on HNZ programs by supplying sufficient urban lands [17, 19]. Large cities tend to be more competitive in assembling production elements than small- and medium-sized cities. For this reason, the location of a HNZ depends on how large a city is. Furthermore, in appreciating the rapid urbanization pace and the resulting demand for large-scale infrastructure, the location of HNZs in China favors the implementation of sustainable development strategies following an urban decentralization trend.

Nevertheless, peripheral location is always lack of public transport facilities in HNZ, leading to inconvenience to arrive at. This may undermine the attractiveness and benefits that networked cities can bring to a HNZ [18], and aggregate the difficulty in integrating existing facilities within HNZs. Since a disutility of HNZs may be encountered [22], it is very important that in considering the existing HNZs, local authorities should pay closer attention to the interaction between transport and non-transport functions in the boundary of a HNZ and consolidate the HNZ in networked cities to improve node-and-place values in the city.

5.2 Wide distribution of size

As identified above, nearly 12% of the HNZs contain three sub-zones, concurring with previous studies [15, 16]. In comparison with their counterparts in other countries, HNZs in China seem to grow on a larger scale. The reasons for this might be that China’s massive population demands for a huger capacity of HSR transportation services and better accessibility of a HNZ to facilitate passengers to take this new transportation means. A larger HNZ than a regular railway station is thus required.

Most of HNZs are scattered significantly (Figure 2). Since the size of a HNZ is determined by local government, a distinctive disparity between governments’ recognition might exist. For instance, HNZ in Shiyan city was planned merely in a core area, while other cities (e.g., Wuxi) might plant it by spreading to outskirts. Previous studies [23] have revealed that HNZs’ radius would be 2,000 m in eastern China. However, 75% of HNZs identified above are within the scope of 1,700 m in radius, smaller than those in other Chinese cities are. This is mostly because that well-developed tertiary sectors in developed regions drive HNZs to sustain expansion [15]. Second, transport facilities such as metro systems can determine the size of HNZs [15, 24]. A seamless public transportation system helps establish inward connections within the city and outward connections for intercity to attract passengers. Third, the sizes of HNZs are related to development strategies of cities. For instance, the HNZ of Wuxi city was intended to support the development of a new town, and it has the largest size nationwide (3,700 m). Hence, it is inferred that a HNZ’s size is determined by passenger numbers, urban population, status of tertiary industry, public transport preferences, and strategies for HNZ utilization.
5.3 Outspread orientation

HNZ is a part of a city, where either transportation\cite{25} or non-transportation facilities\cite{7, 26} provide a concrete momentum for local governments to develop economies. Bearing this in mind, many governments have the willingness to synthesize a HSR line with local transportation systems and furthermore to foster HNZ as an economic pillar\cite{2}. For instance, HNZ in Lille was appreciated positive to the growth of economies\cite{26}. In considering this, the advent of HSR era offers a valuable opportunity for governments to gain confidence in securing a certain rate of economic growth.

As shown in Figure 3, transportation hub is designed as the most popular orientation in HNZs (38%), which means that transport prioritizes urban function in this domain. 32% of cities assigned business service zones to HNZs, suggesting that precious opportunities and huge potentials to cultivate commercial activities in the HNZs have been aware. Meanwhile, it is noted that a HNZ might share at least two orientations, mirroring local governments’ multiple expectations on the utilization of HNZs.

Nine sub-categories are addressed in a whole picture of HNZs, outlining diverse orientation in this newly emerging urban area in China. The rationale for diversified orientation might be that HNZs are often reckoned as an urban image. For instance, 42% of the cities (Figure 3) have spent considerable resources to fortify the exhibition effect of HNZs as a gateway (25%) and city card (17%). In practice, businessmen perceive and appreciate the quality of a city’s commercial environment by placing an emphasis on HNZs\cite{25}. A good perception enables a city to attract more investment\cite{27} as well as to improve urban live-ability\cite{26}. In this sense, the potential of improving image, publicity and prospective development can also underpin the outspread orientation of HNZs.

5.4 Transportation-led mixed function

Multiple functions are often considered by urban designers for the purpose of maximizing the efficiency of land utilization\cite{26}. As a result of the convergence of flows, such as people, goods, information, and capital, a broad range of urban production and life activities take place frequently in HNZ\cite{28}. A compounding of the urban functions in the area is thus necessitated\cite{29}.

It was found that all the samples were at least assigned with three functions and 89% of them even have over five functions, imaging a multifunctional attribute of HNZs. Despite this, the most cited functions are those related to or concerned with transportation. This suggests that although city governments might pursue a mixture of urban functions within a HNZ, they have to give lower priority to non-transportation or commercial use in the area\cite{9}.

The negotiation mechanism between China Railway (CR) and local governments may explain this attribute. According to the regulation of the Central Government, CR has more right to assert the mobility efficiency of a HSR line and thus HNZs are often restricted to essential retail and recreation function. Such a restriction is often not welcome by local governments due to its weak benefits to local economy. Instead, in order to satisfy the requirements of CR, transportation facilities (e.g., wide roads and huge public squares) ought to dominate a large proportion of land use. In addition, the high construction cost of HSRs and the functional compatibility between HNZ and cities have motivated local governments to input non-transportation function into HNZs\cite{19}.

6 Conclusions

HSR-based networked city has facilitated flows (e.g., people, capital, and information) in stations and their surroundings. Along this trajectory, many local governments are managing to utilize this urban
space to attain sustainability. Complex and multiple changes thus emerge in and around station and its
environs, calling for basic cognition for the spatial phenomenon. However, fragmentary (little)
knowledge has been informed of how to understand this new spatial pattern properly in developing
countries. By gathering samples throughout China, where many HSR networks have been established
recently, four attributes of HNZs were derived, namely a wide spread of sizes, peripheral location,
multiple orientation, and transportation-oriented land use. The identified attributes of HNZs offer a
conceptual recognition for researchers to embed this new space phenomenon in city network. To
conclude, the research findings shed lights on the multifaceted features of HNZs and underscore the
need to focus on HNZ-based urban sustainable design and development in developing countries.
However, due to the infancy stage of Chinese HNZ, analysis in this study is generalized. Future studies
are expected to explore the dynamic development role of HNZ in the domain of urban sustainability.

References

Rotterdam Central. Bruinsma F, et al. Railway development: Impacts on urban dynamics,
impaction urban space, Resources and Environment in the Yangtze Basin, 21(9), 1073-1079.
Planning Studies, 4(3), 331-345.
Iabse, Seoul, 389-397.
area of high-speed rail stations: Based on empirical study of Beijing-Shanghai line, Urban
stations - A conceptual basis for the development of common system understanding and
assessment criteria, Transport Policy, 18(2), 446-455.
dynamics, PhysicaVerlag, 125-143.
of high-speed railway station areas - An empirical analysis based on the case of Beijing -
Shanghai high-speed rail line, Urban Planning Forum, (1), 72-79.


A Note on The Liveability Measure in Melbourne

Sintusingha, Sidh.¹, Wu, Hao.²* and Li, Xiang.³

Abstract: The paper interrogates the notion of liveability and the practices of measuring and ranking liveability. The paper offers a critical review of the evaluation of urban liveability, taking into account social-spatial inequity and urban history using Melbourne, often placed highly in city liveability rankings, as the context. The paper observes that there is a divergent emphasis and practices for urban liveability between media and academic interpretation and application. It is argued that urban development-led policy and planning and image-led global city branding for competition are key driving forces behind this divergence. This calls for the integration of basic human values such health, safety, and dignity that, the paper argues, are the core underlying components for the understanding and evaluation of urban liveability in the historic context.

Keywords: Liveability; City Liveability Ranking; Melbourne; media and academic interpretation and application.

¹ Sintusingha, Sidh.
Faculty of Architecture Building and Planning, the University of Melbourne, Australia

²* Wu, Hao. E-mail: haow@unimelb.edu.au
Corresponding author, Faculty of Architecture Building and Planning, the University of Melbourne, Australia

³ Li, Xiang.
Faculty of Architecture Building and Planning, the University of Melbourne, Australia
1 Introduction

The paper proposes that the conception of urban liveability in Melbourne is relative. It is largely a ‘by-product’ of historic instances. Through time, critical decisions were made that shaped the path towards the city’s current conditions and urban capital. It is difficult to establish direct causal link between a city’s attributes, histories and ‘liveability’. One necessary step for better understanding of urban liveability is to establish comparability of alternative contexts. This paper identifies and focuses on defining features not necessarily covered in popular liveability indicators. Some of the aspects are either closely relevant to or directly against the liveability measure for Melbourne.

This paper provides a local perspective of urban liveability evaluation for Melbourne, and argues from historical and planning expectation perspectives. It does this through review of the directly relevant urban liveability evaluation studies and historical. For inter-city comparison of liveability, the paper also raises the question: from whose perspective and interest the liveability of city is focused? With a critical view of this question, it seeks to understand policy intentions and broader implications of global liveable city ranking and comparison. The paper is firstly reviews the general conception of urban liveability. It then focuses the discussion on liveability at inter and intra city levels and potential bias. It then leads to a historically driven intra-urban perspective that are relevant to a more ‘balanced’ view of liveability measure in Melbourne. Conclusions follow.

2 Liveability

2.1 The Liveability Concept

The formal concept of liveability can be traced back to the four basic factors for human habitat environment specified by the World Health Organisation, namely safety, health, convenience, and amenity [1]. In academia, some have critically examined the meaning, conceptual limit, and practical relevance of the concept [2],[3]. They compare and relate the concepts of liveability to sustainability from a life-course perspective, taken into account associated environmental i.e. physical constraints. Haan et al. attempt to connect liveability, sustainability and transition [4]. They develop and argue for a social psychology based approach to complex concepts such as liveability. Zanella et al develop an evaluation tool to combine urban liveability and sustainability [5]. To demonstrate, they apply the liveability framework to evaluate societal urban water needs. Gough states that “community liveability is constructed by the sum of the physical and social characteristics experienced in places...” that together “…add up to a community’s quality of life” [6]. Sources and changes of liveability measure remains lack of comprehensive understanding [3].

2.2 Urban Liveability

While the liveability concept remains loose and multi-faceted, the notion of place-based liveable city seems more tangible a concept to enable comparison and evaluation. London Commission for Architecture and the Built Environment defines liveability as: the degree to which a place, be it a neighbourhood, town or city, supports quality of life, health and wellbeing for the people who live, work, or visit. Cities considered to have a high degree of liveability tend to have a high level of, and widespread accessibility to, amenity [7]. As per the opinion of the U.S. Department of Transportation Secretary Ray LaHood, liveability means being able to take your kids to school, go to work, see a doctor, drop by the grocery or post office, go out to dinner and a movie, and play
with your kids at the park, all without having to get into your car [8]. It is helpful to recognise that liveability measures tangible outcome of urban physical and human conditions as well as human perception of urban lives [3].

Perhaps the most influential city liveability ranking is one by the Economist Intelligence Unit (EIU), that specifically states that liveability “… assesses which locations around the world provides the best or the worst living conditions. Assessing liveability has a broad range of uses, from benchmarking perceptions of development levels to assigning a hardship allowance as part of expatriate relocation packages” [9]. Critically, EIU claims to “quantifies the challenges that might be presented to an individual’s lifestyle in any given location” which allows for direct place comparisons [9]. The EIU’s assessment, associated with a famous media company, has become an international benchmark despite the many international academic researches on urban liveability [10],[11],[2],[12],[13],[14],[15],[16],[17],[5]. A common feature is that most contain infrastructure, physical and socially-based assessments criteria. Built on the literature, this article argues that assessing the liveable city demands: (1) an understanding of the city’s historical evolution; 2) a vision for built environment e.g. city and region change; (3) both clearly defined and relative, dynamic measures; (4) evaluation from people’s perspective i.e. it is perception based. The fourth point is significant as it concerns such questions as “whose perception of liveability in the city matters”?

3 Evaluations of Melbourne’s Urban Liveability

Having the topped the EIU’s ranking for six straight years to 2016, Melbourne established itself firmly as the global benchmark for liveability. This section discusses two scales of liveability evaluation systems, international and local, that has been applied to Melbourne.

3.1. City Liveability

Based on EIU’s city liveability ranking, every city is assigned a rating of relative comfort for over 30 qualitative and quantitative factors across five broad categories, each with assigned percentage weightings: stability [25% of total]; healthcare [20%]; culture and environment [25%]; education [10%]; and infrastructure [20%] [9]. Table 1 illustrates the scoring system associated with the five categories for six selected cities from across the full rankings.

<table>
<thead>
<tr>
<th>Country</th>
<th>City</th>
<th>Rank</th>
<th>Score</th>
<th>“Stability”</th>
<th>“Healthcare”</th>
<th>“Cul/Env”</th>
<th>“Education”</th>
<th>“Infrastructure”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Melbourne</td>
<td>1</td>
<td>97.5</td>
<td>95</td>
<td>100</td>
<td>95.1</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Canada</td>
<td>Vancouver</td>
<td>3</td>
<td>97.3</td>
<td>95</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>92.9</td>
</tr>
<tr>
<td>Italy</td>
<td>Rome</td>
<td>44</td>
<td>89.0</td>
<td>80</td>
<td>87.5</td>
<td>91.7</td>
<td>100</td>
<td>92.9</td>
</tr>
<tr>
<td>China</td>
<td>Shanghai</td>
<td>78</td>
<td>73.2</td>
<td>75</td>
<td>76.7</td>
<td>64.3</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Egypt</td>
<td>Cairo</td>
<td>121</td>
<td>53</td>
<td>55</td>
<td>45.8</td>
<td>57.4</td>
<td>50</td>
<td>53.6</td>
</tr>
<tr>
<td>Syria</td>
<td>Damascus</td>
<td>140</td>
<td>29.3</td>
<td>10</td>
<td>29.2</td>
<td>44.7</td>
<td>33.3</td>
<td>32.1</td>
</tr>
</tbody>
</table>

One critique of the EIU approach is that it is an expert model “… based on the judgment of in-house analysts and in-city contributors” [9], top-down assessment of city liveability with a clear social bias towards the experience of affluent white-collar expatriate workers. Recent conceptual study [3] and policy study [25] of urban liveability both recognise this fact. It helps justify the need for survey based method to complement expert model for resident experience-based perception.
3.2. Neighbourhood Liveability

Like any global rankings, a key missing factor in city liveability assessment and comparison is equity and the question of how evenly distributed and shared the high quality of life is across individual cities by spatial and social terms. This requires a localized assessment that inevitably leads into a contextualised interpretation of urban liveability, highlighting that liveability appears to be ‘context dependent’. McCrea and Walters conduct an Australian study at intra-urban level using in-depth interview \(^{[18]}\). They analyse the trade-off that urban land use policy needs to balance between liveability and consolidation at inner and outer localities.

A leading Australian real estate media has further elaborated on Melbourne’s liveability and ranked the city’s 321 suburbs, using a different set of indicators that reflected the local, cultural specificities and also biases towards planning/design components. A partner in the exercise is a leading planning, landscape architecture firm in Australia. The Domain Group’s Liveable Melbourne study, currently in its third edition, utilizes 15 indicators to compare and rank local suburbs: 1) proximity to the coast; 2) closeness to the CBD; 3) train and 4) tram and 5) bus services; 6) road congestion; 7) culture; 8) education; 9) shopping; 10) public open space; 11) tree cover; 12) topographic variation; 13) cafés and 14) restaurants; and 15) crime.\(^{[5]}\) Consistent with the real estate media’s priorities, this rating method may be biased towards saleability or marketability. In other words, it is investment driven and therefore correlates with neighbourhood income and wealth. Table 2 displays one top ranked suburb and one medium ranked with specific descriptive notes. The significant volatility of rank change in two consecutive years suggests some possibility of short-run sample bias and evaluation problem.

Table 2. Suburb level ranking (Domain 2017)

<table>
<thead>
<tr>
<th>South Yarra (Ranked: 2, previous rank: 1)</th>
<th>West Footscray (Ranked: 174, previous rank: 55)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“There’s no disputing the liveability of cosmopolitan South Yarra. The suburb continues to perform consistently high in terms of dining, transport, location and shopping, with only crime rates and congested roads contributing to its slipping ranking. Close to the city and coast, South Yarra carries a distinct edge over other inner suburbs, being close to plenty of open space, tree cover and quality schools.”</td>
<td>“West Footscray’s ranking has declined even more significantly than neighbouring Footscray (74), dropping 119 spots since 2011. Unlike Footscray, it does not feature the same proximity to cafes, shopping and schools. Less crime and more public spaces would also improve the area. On the plus side, residents can easily access public transport and the area’s sizeable culture sector.”</td>
</tr>
</tbody>
</table>

4 Where “… each mode was weighted for their importance; trains are worth the most, followed by trams then buses”


4. Critical Aspects of Melbourne Liveability, a historical dimension

Taking cue from the localised argument, this section proposes that liveability cannot be acquired or significantly improved on in the short term as it is heavily historically dependent. It is critical that each city’s historical evolution is interrogated and assessed. Built on deeper understanding of urban infrastructure, socio-economic and cultural history, a long-term strategy may be put in place to assist a city’s trajectory towards higher liveability to the majority of residents of the city. This section discusses some of these key historical components, attributes in the Melbourne context.

4.1. Planning history and approaches to quality of life

---

\(^{[5]}\) Consistent with the real estate media’s priorities, this rating method may be biased towards saleability or marketability. In other words, it is investment driven and therefore correlates with neighbourhood income and wealth. Table 2 displays one top ranked suburb and one medium ranked with specific descriptive notes. The significant volatility of rank change in two consecutive years suggests some possibility of short-run sample bias and evaluation problem.

Table 2. Suburb level ranking (Domain 2017)

<table>
<thead>
<tr>
<th>South Yarra (Ranked: 2, previous rank: 1)</th>
<th>West Footscray (Ranked: 174, previous rank: 55)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“There’s no disputing the liveability of cosmopolitan South Yarra. The suburb continues to perform consistently high in terms of dining, transport, location and shopping, with only crime rates and congested roads contributing to its slipping ranking. Close to the city and coast, South Yarra carries a distinct edge over other inner suburbs, being close to plenty of open space, tree cover and quality schools.”</td>
<td>“West Footscray’s ranking has declined even more significantly than neighbouring Footscray (74), dropping 119 spots since 2011. Unlike Footscray, it does not feature the same proximity to cafes, shopping and schools. Less crime and more public spaces would also improve the area. On the plus side, residents can easily access public transport and the area’s sizeable culture sector.”</td>
</tr>
</tbody>
</table>

---

4 Where “… each mode was weighted for their importance; trains are worth the most, followed by trams then buses”

A key feature in Melbourne’s planning history is that, apart from the CBD, Melbourne’s inner suburbs has been laid out during the influence of the ‘garden city’ movement at critical times when the railway and tram systems became the major transportation technology used by most of the population. This lay important urban structural foundation for the inner suburbs, characterized by low density developments, good to high quality access to public transportation and public parks. Another key episode that sets Melbourne apart from other cities, is its refusal to dismantle the tram network in the post WWII period when the car became the dominant transportation mode. It gave Melbourne a unique urban culture tied to its tram network that manifests as commercial strips along tram corridors.\[19]\.

Another key feature is that Melbourne is known as a creative, cultural city that places high value on planning and design practices to enhance the quality of life. Since the mid 1980’s, the City of Melbourne (CoM), in cooperation with the State Government of Victoria, purposefully shifted Melbourne towards a becoming a post-industrial, global, and 24-hour city through strong leadership in urban planning and design.\[20]\. This occurred in parallel with the de-industrialization of the Australian economy \[21]\ and state government led diversification of Melbourne’s urban economy towards “services, spectacle, and consumption” \[22]\. Critically, the planning tradition focussed on pedestrian’s experience was laid in the 1980s when CoM sort the services of Jan Gehl, the Danish globetrotting architect whose process prioritises “life” and a fine-scaled approach to urban design - the anti-thesis to spectacular architecture impositions preferred by other ambitious cities. Gehl’s process demands engagement with the complexities of the city and its stakeholders at a fine scale and is far more demanding and time-consuming. It is the willingness to invest and sustain this approach that has made significant contribution to many qualities defined as “liveable” today, especially the priority given to pedestrian, cycling and public transportation increasingly the norm in many parts of Melbourne.

The ability to sustain planning and design approaches suggests high government stability and agency. Due to the relatively high political stability, government, at all levels and of different political leanings, has been able to strategically and effectively plan for economic growth and improvement of public realm and infrastructure, or allow for the market a prominent role in catalysing growth. The pro-economic growth policies and practices driven by population increases is reflected in a high proportion of public and private investments into housing, infrastructure and urban amenities – and the identification and planning of future urban growth areas both in the inner city and outer suburbs. This is in contrast to cities where policies are reactive to the scale of problems faced.

4.2. Community participation in local development

Community participation is a key feature of most public developments – whether they are State Government large infrastructure projects or council level projects. This is often enabled and facilitated by local government at the council level – whose role is to both inform and also host workshop sessions with the residents, property owners to deliberate projects. Based on the local residents’ and businesses’ views and/or the council’s interests, councils can also protest/resist both public and private developments – although, ultimately, state government often has the final say.\[7]\.

\[5]\ See an example of this practice in the precinct renewal of Melbourne’s major heritage-listed Queen Victoria Market in https://participate.melbourne.vic.gov.au/queenvictoriamarket

\[6]\ http://www.abc.net.au/news/2017-02-14/jan-gehl-architect-making-melbourne-liveable/8268060
4.3. Cultural Diversity and Multiculturalism

Over a very long period of time Australia has been a migrant nation beginning with the Indigenous population that migrated from Southeast Asia tens of thousands of years ago to the British colonization of the continent beginning in the early 19th century. Since then, the country absorbed waves of migrants from around the world, first letting in preferred migrants from northern Europe, then southern and eastern Europeans – only ending the “White Australia” policy in the 1970s with the exodus of migrants escaping the Vietnam Wars. This openness has led to “proportion of Australians who were born overseas has hit its highest point in over 120 years, with 28 per cent of Australia’s population born overseas” according to the most recent census in 2016. This results in a rich and diverse urban culture that has become a strength and attraction of Australian cities – with claims of Melbourne to be the most open and tolerant, amongst Australian cities.

Diversity has been further enhanced through the liberalization of the education sector in the mid-1990s that led to the influx of international students into all levels of education, in particular tertiary, that has significantly impacted on the urban characteristics of inner Melbourne through both housing and commercial activities. Fincher and Shaw have documented the gentrification effect in central Melbourne due to the rapidly growing transnational tertiary education industry. Many foreign graduates elect to live and work in Melbourne. In contrast to migrants that escaped hardship and instability in their homelands, these recent groups, which also includes inter-state migrants are often more middle and upper middle classes. This could be a contributing factor to problems of contemporary housing affordability and liveability in Melbourne.

4.4. Outer suburbs and exurbs: car-based development and the sprawling city

Perhaps one ‘black spot’ of Melbourne’s liveability is the ‘tale of two cities’, where there is a divide between the inner-city and the outer suburbs. This phenomenon sharply manifests in the local liveability assessment of Melbourne’s 321 suburbs, whereby the further off from the CBD, the poorer quality of public transportation and access to urban assets. Beyond 10kms from the centre, most of Melbourne remains a heavily car-dependent city, a legacy of American-influenced post-WWII planning and development. Contemporary pressures from housing affordability continue to drive the city’s expansion into the hinterlands, that effectively compounds the problem of socio-spatial inequity.

4.5. Power of city image and branding

In essence, the image of well-planned and design urban realm full of quality parks and open spaces hides one of the most sprawled city, still heavily reliant on fossil fuels. In fact, carbon emission per capita consistently remains some of the world’s highest – in Melbourne’s case, partially because coal, as a plentiful resource, is still the major source of energy and export income. There is a movement, slowly gaining in momentum, towards alternative, energy sources – but the transition has been a long-drawn out and politicized process. This includes a strong public and industry promotion for ‘green buildings’ and related energy rating tools and standard for...
residential and commercial buildings. Arguably it forms part of the branding for Melbourne’s global competitiveness to attract consumption and investment.

5. Conclusive Remarks

The multi-scalar and historical components, discussed in part 4, aggregate to form and define the positive (and negative) experiences for residents and visitors alike. There are other dimensions of quality of life that are not necessarily linked to discussions of liveability. The rising concern of social and spatial inequality in large and complex cities and regions indicates an increasing urgency to base urban liveability evaluation on multitude sub-urban, local community of the city. The urban liveability question has its welfare distribitional and social justice dimension, which remains an acute challenge for urban sustainability. This demands survey-based and demographic comparative suburb level analysis (e.g. CBD vs. suburb) for liveability evaluation.

The question: for whom liveability is evaluated, is important. It highlights a potential bias for and frames the quality of life for the specific socio-economic segment. Quality of life inevitably relates to both liveability and affordability, where Melbourne’s success perhaps comes with the curse of attracting more in-migration (interstate and international) further compounds the housing affordability issue. There’s the cultural bias where non-English speaking or non-European cities are often ranked lower. This poses questions on who assesses the cities. The relationship between liveability and affordability will be examined in other studies.

Moreover, rankings can be viewed as a branding exercise to promote an image of liveability. Similar motive and process applies to university rankings and government election cycles. It is observed that these international rankings or opinion polls are often dominated by media companies with inescapable vested interests in the rankings. We question whether these are linked to the neoliberal conditions as a global phenomenon in recent years? We argue that the question remains whether liveability ranking is positively correlated with average quality of life in a city? A critical assessment of quality of life attributes is needed.

The nature of global rankings implies the perpetual competition between cities – and also implies that working on the set criteria will result in improvements in liveability and rankings. The paper suggests that planning, policy, and political will may not suffice and needs to be based on a deep understanding of the city’s historical evolution. This is significant, particularly if liveability is to move beyond a marketing tool (with a clear socio-cultural bias) towards an effective planning tool to genuinely improve urban residents’ quality of life.

Reference


Forecasting & Social Changes, 85, 121-132.


Understanding of Safety Investment and Financial Loss in construction industry – A Literature Review

Ying K.C.¹*, Guomin Zhang², Sujeeva Setunge³

Abstract: Safety investment from different stakeholders influences the total monetary safety input in construction industry. On the other side, financial loss due to accident raises the concern of stakeholders. How does the safety investment in construction industry impact financial loss is a questionable event to be investigated. Concept of safety investment and financial loss in construction project are discussed in this paper. This paper also provides a comprehensive recap of safety investment and financial loss in construction industry through literature review.

The paper introduces the concept and illustrates the key elements in safety investment and financial loss respectively for further studies. Safety investment is commonly understood as safety input in construction industry. Safety investment in a construction project includes input such as safety staffing input, equipment input, training input, promotion input. Financial loss is monetary loss includes direct and indirect cost due to construction accident. For incidence, salary loss of victim, loss from injured person after resuming work, hospitalization expenses, medical expenses other than hospitalization, penalty & legal expenses, time loss of other employees, damage of equipment, loss of materials, equipment or plant loss, idle machinery or equipment,. Throughout the review, insurance premium and claims are the missing link is going to be considered. The paper concludes with research framework and advice on direction for further studies.

Keywords: Safety investment, Financial loss, Insurance, construction industry, Hong Kong

¹* Ying K.C.  
Corresponding author, PhD candidate, School of Engineering, RMIT University, Australia  
E-mail: s3361735@student.rmit.edu.au

² Guomin Zhang  
School of Engineering, RMIT University, Australia

³ Sujeeva Setunge  
School of Engineering, RMIT University, Australia
1.0 Background

Construction accident is unpredictable and unexpected no matter how much efforts contributed and resources are provided for precaution measure. Construction accident induces time delay, redo of work, loss of time, plant or materials, cease of work, prosecution, penalty and finally monetary expenses. Researchers pay a lot of effort to investigate how much impact does the construction accident induced and what kind of method can be applied to improve the safety performance. Besides, stakeholders would like to learn about the relationship between the financial loss and safety investment in construction industry. Stakeholders (government, developers, contractors and concern groups) would like to have a clear picture about the relationship between safety investment and financial loss in construction industry for cost prediction, accident prevention and loss elimination.

In construction industry, safety investment commonly understand as input such as training on accident prevention, safety precaution talk, hire some safety supervisors and officers, tool-box talk, safety promotion, safety activities (such as safety walk, meeting, drill test, audit, exercise) and others input (such as innovation design, setting up safety system, system audit and investigation).

Financial loss in construction industry simply understands as monetary loss after accident occurs. The loss includes direct and indirect cost where the details are going to be covered in the following chapter.

2.0 Introduction

Researchers perform a lot of study to investigate the relationship between safety inputs (investment) to safety outcome? The more is invested in safety of the project, the lesser the accident rate is expected. Tang produced a figure to show the relationship based on Hong Kong data [22] and Feng further investigated the relationship between safety investment and safety performance in Singapore [5]. In Feng’s study, he applied regression model to explain the relationship quantitatively. This is expected that safety performance of a construction project will be affected significantly by safety investment [1,16,17]. However, it does not predict whether the financial loss is huge or not. Good safety performance may understand as less number of accident incidence but it does not reflect the severity of accident and the monetary loss of that accident. In a contrast, poor safety performance (a lot of reported accident) does not imply severity of accident and huge monetary loss. Therefore, relationship between safety investment and financial loss in construction accident is questionable. Analysis in safety investment and financial loss is a hot topic and their relationship is of high concern. Stakeholders would like to understand the principal of safety investment and financial loss respectively. This paper aims to provide a comprehensive review in concept development of safety investment and financial loss of construction industry. Besides, it proposes a framework through literature review for further studies and analysis.

3.0 Safety Investment

Safety investment simply means as safety input into construction project in different aspect. Researchers agree that notwithstanding monetary spent on safety investments, has a positive effect and good return on safety performance on construction industry. The components stated by researchers including safety planning, acquisition of equipment, personnel training, staffing, safety measurement and accident investigation [1,16,17].

Time passed, researchers suggested different consideration or classification in safety investment but the basic concept that safety investment is the safety input into construction project has not yet changed. Brody et al. discussed safety investment in three categories included fixed prevention costs, variable prevention costs and unexpected prevention costs provided an idea regarding safety investment in construction [1].
Safety investment usually acts as a status to do comparison with safety performance. Tang et al. intended to find out the relationship between safety investment and safety performance in Hong Kong market [22]. They divided safety investment in following components: salaries of staffing, expenditures on personal protection equipment, safety training and promotion. Their team found out that there is only a weak correlation, the $R^2$ is only 0.25. They did not identify the factors how it influenced safety performance. Feng also investigated the relationship between safety investment and safety performance. He suggested six components of safety investments included safety staffing costs, safety training costs, safety equipment and facilities costs, costs of new technologies methods or tools for safety, safety committee costs and safety promotion & incentive costs [4].

Coble R.J. et al. proposed “investment in safety” is a kind of “cost of safety” [2]. Investment on safety such as materials, resources or manpower incurred is safety input. Besides, investment on safety can reduce the occurrence of accident or injuries. Components of safety investment include substance abuse testing, staffing, training, personal protective equipment, safety committees, investigations, preparation and implementation of safety program and safety incentives. They prefer to use “investment in safety” to prevent any negative connotation. They defined that monetary expenses on safety as “cost of safety” including direct or indirect costs as investment. They pinpointed an idea in his decision tree analysis that if the investments in safety are high, the probability of incurring injury cost becomes low. On the other hand, if the investments in safety are low, the chance of incurring high injury cost becomes high. However, from the theory of probabilities, low safety cost input may even lead to low cost of injuries. There may be No injuries and Nil cost of injuries even if there are no expenditures on safety [2].

Hinze stated that safety control activities aimed at reducing risks or preventing the occurrence of accident. The investment in safety control activities are defined as cost or investment. The cost of safety control include safety training, safety incentives, staffing for safety, safety equipment (PPE), safety program or other activities [12].

Jervis, S., and Collins, T.R investigated return on safety investment. They found that Hazard prevention & control, management leadership & employee involvement, concurrence of bargaining agent, worksite analysis, review of documentation and safety & Health training are the key factors that if money spend on those, it can help to improve overall safety performance [15].

Lopez-Alonso M. et al. explained that safety cost to ensure health and safety at the workplace should include prevention costs, costs of non-safety and other extraordinary cost. The costs are to improve working conditions and reduce accident rates in construction sites [18].

Feng stated safety investments which is monetary expense on the accident prevention and time invested in accident prevention. He summarized seven components affecting safety investment such as staffing costs, safety equipment & facilities costs, compulsory training costs, in-house training costs, safety inspections & meetings costs, safety incentives & promotions cost and safety innovation costs. According to his model analysis, he found that safety inspections and investigations, safety committees & meetings, safety promotions & incentives and in-house safety training & orientation are the most effective safety measures for construction safety performance improvement. He also stated that according to the model analysis, employment of safety professionals, provision of personal protection equipment and enforcement of formal safety training courses are less relatively cost-effective. He summarized that the higher the safety investment, the better the safety performance is NOT a must. Investments in staffing personnel for accident investigations, safety inspections, safety committee meeting, in-house safety training and incentive are more effective to improve safety performance [5].

3.1 Insured/ Un-insured cost and Insurance Premium

Rowlinson discussed safety management system and legislative requirement of Hong Kong construction industry. He introduced the safety training system in Hong Kong which is the main safety investment. He indicated that employee’s compensation is obviously the cost of accident
which should be investigated. He explained about insured and un-insured cost. Insured cost means
contractor paid insurance for the project. The insured cost included employers’ liability, public or
tired party liability and contractor’s all risk policies. In Hong Kong, the Employee’s
Compensation Ordinance covered all workers no matter they work in construction industry or not.
Workers are protected by the ordinance that it is compulsory for all contractor companies to pay
for that insured cost. Once accident happened, insurance company and the contractor share the
injury compensation. If the contractor did not buy insurance for the worker, the contractor bear all
legal liability and uninsured cost [20].

In Hong Kong, the main contractor should pay the insurance premium for the construction project.
According to the General Condition of Contract, the premium indeed comes from part of contract
value but the main contractor has to pay the insurance fee [2, 7]. Therefore, the insurance premium
is treated as safety investment. The premium is calculated as project-based or company-based and
it depends on the company safety record or complexity of the project. The amount varies and is
being treated confidentially. The contractor should pay the premium as project-based or company-
based. Ying et al. provided a table extracted from the Office of the Commissioner of Insurance [27]
in Hong Kong that the total premium paid in Hong Kong should be taken into consideration [28].

3.2 Safety Management Costs

George B & Garvey T introduced safety management costs and the costs can be separated into
four areas: design costs of control features, project-based operational costs, administrative costs
and costs incurred in maintaining and improving the system [8]. They explained the costs in detail
including (i) “Design costs of redundant”: money should invest on equipment to protect workers,
safety system to improve appropriate safety margin, system to remove hazard substances,
additional costs to modify design on site. (ii) “Operational costs”, they explained different
supplementary expenses includes salaries and overhead for design and implement safety program,
supervision cost and employee induction, accumulative cost for tools and personal protective
equipment, introduction of innovative equipment etc... (iii) “Administrative costs”, the costs
comprise salaries of staffing, developing measurement systems, safety audit, safety investigation
and hazard analysis, communication costs etc… (iv) “Maintenance and improvement of safety
program”, it includes costs expenses in design phase, operational phase and administration.

No matter how researchers analyse the influence due to safety investment, the common
understanding of safety investment consists of five components which summarized as staffing
input, equipment input, training input, promotion input (incentive cost, innovation cost ant safety
program) and other input (any monetary expenses in safety).

4.0 Loss in Construction Accident

Loss in construction accident can be defined as different categories and is listed as follow:

4.1 Direct and Indirect cost

Direct costs of accidents can be simply classified as sick leave payments, employee’s
compensation payments, personal injury claims, public liability claim, repair of damage to
buildings, repair of damage to plant and equipment, replacement of products and overtime
payment [20].

Henrich listed out 11 items in indirect costs of accident which includes: cost of lost time of injured
employee, cost of time lost by other employees who stop work, cost of time lost by foremen,
supervisors or other executives, cost of time spent on the case by first aid attendant and other staff,
cost due to damage of machinery, tools, property and materials, incidental cost due to interference
on overall production, cost to employer for continuing wages of injured worker, cost due to loss in
profit due to reduced worker productivity, cost due to loss in profit due to idle equipment, cost
incurred because of subsequent injuries partially caused by the incident and cost of overheads [10].
11. R.J. Coble, J. Hinze and T.C. Haupt further listed out indirect costs due to medical case injuries and costs related to restricted work/lost workday injuries [2].

Hinze J. and Appelgate L. pinpointed that direct cost of construction accident and listed out five main items includes medical cost, indemnity, general liability, miscellaneous and other. They also listed out 19 items regarding indirect cost of construction accident includes injured worker (Loss of productivity on day of injury, follow up treatment and resuming work), crew of injured worker (Assisting injured worker, completing additional work due to accident, loss productivity due to accident and inspection), crew in vicinity of accident due to watching events and discussing accident, replacement worker (Reduced productivity of replacement worker, training the replacement worker, cost of transporting injured worker), supervisory and administrative (staff time assisting injured worker, investigating accident, preparing reports, time with the media and project owner, time with regulatory inspector), damaged property (repairing damage and material damage), and impact cost [13].

Accident undoubtedly induces costs no matter direct or indirect cost. Researchers indicated costs induced by construction accidents. Starting from Heinrich indicated that the ratio between indirect to direct costs is 4:1 [10]. R.J. Coble, J. Hinze and T.C. Haupt clearly explained about cost of safety and cost of injuries [2]. They explained that costs of safety including all form of training, testing, safety incentive, staffing for safety, personal protective equipment and safety program. They also pointed out cost of injuries included costs associated direct and indirect costs. Indirect costs related to medical case injuries and indirect cost related to restricted work/lost in workday.

4.2 Other costs

Everett J.G. and Frank P.B. tried to find out the costs of accidents and injuries in the construction industry. They found that the costs of accidents and injuries have risen from a level of 6.5% of construction costs in 1982 to about 7.9% - 15% in 1996 [3]. However, they mentioned that their estimation did not include the cost of Occupational Safety and Health Administration (OSHA) fines and hearing, decreased employee morale, loss of future work and inability to attract and retain employees due to poor reputation. On the contrary, the authors suggested that fines, legislative administration and some indirect cost should be counted when estimating the total cost of accident in monetary term.

R.J. Coble, J. Hinze and T.C. Haupt pointed out that inflation drastically distort the true costs of injuries. Inflation is a specific economic concept and makes it difficult for readers to compare the absolute value [2]. For example, $100 in year 1980 is definitely worth less nowadays due to inflation. As inflation varies between years, it is difficult to calculate the exact value impacted. Therefore, instead of measuring the implication of inflation, a ratio is used for comparison [23].

Saram and Tang regarded pain, suffering and loss of amenities (PLSA) as social cost in construction accident [21]. It is a sense of sociology and out of control in construction industry. PSLA stated in Judgment statement is considered as compensation claim which is a monetary payment due to the accident. They also introduced emphasised that social costs incurred by six public organizations like Hong Kong Police Force, Fire Services Department, Labour Department, Social Welfare Department, Legal Aid Department and The Courts in construction accidents [19, 23, 24].

Indeed, accident incurs direct, indirect cost and different other cost. It is understandable that researchers estimated different relationship in different aspect to explain different phenomenon and social effect.

4.3 Claims from accident

Claims from accident should be shared by insurance company and main contractor. However, the amount and percentage of sharing is unknown. Ying et al. showed the claims from construction accident for consideration in a table format. They provided an exact amount about monetary claim
which was extracted from the Office of the Commissioner of Insurance, Hong Kong for further investigation [27, 28].

4.4 Financial loss

Further to Hinze J. and Appelgate L., they included all direct cost and indirect cost, the monetary expenses was defined as financial loss in construction accident. They pointed out at least 19 indirect costs imposed by an accident [13].

Teo and Feng have summarized factors illustrated by Scholars in previous accident cost researches [25, 26]. Feng et al. further reviewed the factors affecting the workplace accident costs of building projects. According to Feng et al., there were 13 possible components in Singaporean practice which will lead to loss in productivity. These 13 possible components are: (1) the injured worker; (2) crew of injured worker; (3) other workers in vicinity of accidents; (4) investigation or inspections as a result of the injury; (6) replacement of injured worker; (7) damaged equipment or plant; (8) Stop Work Orders (SWO); (9) cost of supervisory or staff effort; (10) transportation of injured worker; (11) additional work required; (12) consumption of the first-aid materials and (13) additional benefits to the injured worker beyond the Work Compensation Act (WCA). The consumption of the first-aid materials can be regarded as safety input of the contractors. In Hong Kong, as there is no similar requirement of additional benefit from the WCA, this point will not be referred in this paper [6].

Researchers investigated accident cost imposed on contractor for construction project including Day loss of injured person and his % of disability, any amount of compensation for sympathy money, equivalent loss after resuming work, medical services and expenses, fines & legal expenses, lost time of other employees such as site agent, engineer, foreman, other labour, loss in plant & equipment, damaged material or finished work, idle plant or machinery and other costs items [19, 23, 24]. Tang et al., explained “financial cost” included the indirect cost suffered by society, cost in Pain, Suffering and Loss of Amenity (PSLA) of the victim and impact on family and society can be defined as social cost of work injuries. In this study, financial loss refers to the losses born by contractor firms [23].

In summary, financial loss is treat as monetary loss in construction accident includes salary loss of victim, loss from injured person after resuming work [23], hospitalization expenses, medical expenses other than hospitalization, fines & legal expenses, time loss of other employees, equipment or plan loss, damaged material or finished work, idle machinery/ equipment, other costs items [9, 28].

5.0 Relationship between Safety investment To Financial Loss

Safety investment can help to improve safety performance (risk exposure) in general perception [4, 20]. Relationship between safety performance and safety investment was analysed. Feng used regression model to explain which independent of safety investment affect the dependant variable (safety performance) significantly [4]. He summarized that the higher the safety investment, the better the safety performance and investments in accident prevention are NOT profitable which are inconsistent with previous suggestions of other researchers. Furthermore, safety performance is NOT in-line with financial loss: good safety performance usually understands as less reported accident case; however the severity of accident case is unexpected. The reported case may be a fatal accident or serious case which induce compensation, court argument and involve huge claims. Researchers found out that compensation from court judgment of construction accident case may be more than ten million Hong Kong dollars. In the contrast, poor safety performance was understood as plenty of construction accident. However, the plenty of reported accident case may be mild and it does not imply a lot of compensation or claims [19, 28].

Heinrich introduced an accident pyramid to estimate the frequency of accident case. There were three levels to show the severity of accident case. He classified accident into three categories and indicated the relative ratios of the three categories of accident as accident with no-injury accident,
minor injuries and Major or lost-time injury and the ratio is 1:29:300 respectively. Although it is believed that project with good safety performance may not easy to produce severe accident, it is hard to say the cost implication due to each accident no matter an mild, moderate, severe or fatal accident case.

Researchers pinpointed that safety performance depends on the risk/ scope of the project. If a project is of high risk (such as demolition work or confined spaces work), the project may be associated with high chance of severe accident and incur more compensation and long period of absence. Therefore, safety performance may have significant relationship with safety investment but insignificant to financial loss. Financial loss due to accident is different to be predicted.

Throughout a comprehensive literature review, if recommended to use quantitative method to explain how safety investment affects the financial loss. To fill the research gap, objective of a regression analysis has been set: To develop a model for determining financial loss. Null hypothesis of the further study set as: There is no relationship between financial losses to safety investment. The regression analysis is going to present in the next phase of work.

6.0 Concluding Remarks

Safety investment is commonly understood as safety input in construction industry. Safety investment in a construction project has been summarized as safety staffing input, equipment input, training input, promotion input and other input.

Financial loss is referring to monetary loss due to construction accident which includes direct and indirect cost. Financial loss is treat as monetary loss in construction accident which consists of salary loss of victim, loss from injured person after resuming work, hospitalization expenses, medical expenses other than hospitalization, fines & legal expenses, time loss of other employees, equipment or plan loss, damaged material or finished work, idle machinery/ equipment, other costs.

Safety performance is significantly affected by safety investment but insignificantly related to the financial loss. Financial loss of a project due to the severity of accident may be varied no matter the safety performance index of a project is good or not. Even when safety performance index of a project is good, the financial loss can be huge if there are serious accidents occur.

To investigate the effectiveness and efficiency of safety investment, it is suggested to study the relationship between safety investment and financial loss. By using a quantitative model between financial losses to safety investment, it provides insight to stakeholders what is the significant factor causing financial loss. By knowing the key factor, government and stakeholder can input more on particular item which is believed to provide a significant reduction in financial loss. Insurance premium can be treated as a kind of safety investment and claims as financial loss are necessary for further consideration. Ying et al. provided an exact value for further studies. An overall framework, regression model and validation will be further presented in the coming future.

Reference

Knowledge mapping of Building information modelling research – A visual analysis using CiteSpace

Yang, Y.N.¹, Zhang, Y.D.²*, Huang, W.T.³, Xie, H.M.⁴, Chen, J.L.⁵ and Cai, C.Y.⁶

Abstract: By employing CiteSpace, a tool for visualizing patterns and trends in scientific literature, this paper analyzes the co-cited references of research articles of building information studies published between 2000 and 2016. The data were retrieved from 12 world authoritative journals of translation studies via the Web of Science. This paper studies the high impact literature with the highest co-citation counts, the turning points with high betweenness centrality, literature with citation bursts, key and hot research topics, as well as the key and front research domains of world building information studies. The aim of this paper is to facilitate the understanding of the development of building information studies in the past two decades, the knowledge structure of building information studies, as well as to detect the research fronts and emerging trends of building information studies.

Keywords: Building information modeling; information management; citespace; visual analysis; cluster analysis

¹Yang, Y.N.
Department of Civil Engineering, Zhe Jiang University, China
E-mail: yyn@zju.edu.cn

²* Zhang, Y.D.
Corresponding author, Department of Civil Engineering, Zhe Jiang University, China
E-mail: 3130102512@zju.edu.cn

³ Huang, W.T.
Department of Civil Engineering, Zhe Jiang University, China
E-mail:

⁴ Xie, H.M.
College of Economics and Management, Zhejiang University of Technology, China
E-mail: hmxie@zjut.edu.cn

⁵ Chen, J.L.
Department of Civil Engineering, Zhe Jiang University, China
E-mail:

⁶ Cai, C.Y.
Department of Civil Engineering, Zhe Jiang University, China
E-mail:
1 Introduction

In the past decades, there has been a growing interest of the construction sector in using Building Information Models (BIM) due to many benefits and resource savings during pre-planning, design, and construction of buildings and infrastructures (Volk, et al., 2014). As a relatively young discipline of study, the great interest in academia and practice of BIM has led to a considerable amount of publications in recent years (Kristen and Kenneth, 2012). The inter-disciplinary nature as well as technical and nontechnical potentials and challenges of BIM are some of the main reasons for the rapid development (Azhar, et al., 2015).

Review of previous research are considered valuable activities to gain in-depth understanding of a research area. Through a systematic examination of existing studies, state-of-the-art advancements and emergent trends can be identified with the purpose of spurring encouragement for future studies. Knowledge mapping is one of the most important methods in knowledge management and can present concepts, knowledge and links in visual formats (Li, et al., 2017). CiteSpace is one of the most useful tools for knowledge mapping (Chen, et al., 2010). It is particularly designed to support the network analysis and visualization based on article citations to reveal the structure of a particular research field. The remainder of this paper is organized as follows. Section 2 briefly describes the methodology of this study. Section 3 presents the discussion on clusters of co-citation analysis. Finally, section 4 concludes the discussions.

2 Research methodology

The evaluation of scientific productivity and investigation on different aspects of scholarly writings are the main areas of scientometric studies. Scientometric studies primarily address the evaluation of scientific productivity as these evaluations play a pivotal role in decision-making and policy-making process of any academic field (Jabeen, et al., 2015). Scientometric has proved to be a prominent research field for decades in building information research (He, et al., 2016).

The collection of relevant publications establishes the foundation for a scientometric analysis of a specific research area (Heilig and Vob, 2014). As indicated, this study intends to cover a large part of peer-reviewed BIM articles published in the past seventeen years. By this, we aim to obtain empirical evidence for supporting this scientometric study. Through network modeling and visualization, scientometric research aims to analyze the intellectual landscape of a knowledge domain and forms an overview of how a scientific field has been evolving (Chen, 2006). In this section we describe our proceeding regarding data collection and processing, and methods.

2.1 Data Collection and Processing

Data used in the study has been downloaded from the Web of Science (WoS), a well-renowned and reliable data source, frequently used for scientometric studies and scientific research. It provides a large scale of data on author, journal, and subject-based information (Herther, 2009).

To study the latest trends and changes of BIM research, we collected the literature data between 2000 and 2016 from the WoS (download on November 26, 2016). We used “information model” or “information management” or “information platform” as TS (theme), and “civil” as WC (category), and obtained 975 records. The contents such as title, abstract and references of each record will be put into CiteSpace III. The number of publications per year is showed in figure1.
2.2 Methods and Tools

Due to a wide spectrum of research topics in relation to BIM, there is little prospect of characterizing the overall field through manual literature analysis. Therefore, the current study provides a holistic analysis of BIM using the scientometric technique. This technique is a quantitative method used to map the structure and evolution of numerous subjects (He, et al., 2016). Through network modeling and visualization, scientometric research aims to analyze the intellectual landscape of a knowledge domain and its salient characteristics (the dynamics, most cited authors or papers, bursting concepts, etc.). CiteSpace III is used as a tool to analyze the evolution and emerging trends of decision making in the fields of BIM, which generate and analyze networks of co-cited references based on bibliographic records retrieved from the WoS.

3 Clusters of co-citation analysis

Based on the actual data, we get the co-citation visual graph as shown in Figure 2. The surrounding ring is called citation tree ring, which has larger radius means the greater number of citations co-cited. Next, we used log-likelihood ratio (LLR) algorithm to extract the cluster labels and adjust the size and position of them. Then, calculate the betweenness centrality (importance index) and burst (suddenness). The software automatically forms the clusters according to the relation between literature points, and starts coding from 0. Smaller the number is, more documents are contained in the cluster. Figure 3, 4, 5 respectively represent the cluster analysis diagrams with the label of title, key words and abstract. Results that modularity=0.8784>0.3 and mean silhouette =0.5216>0.5, mean that the clustering is remarkable, and the visualization results reflect the temporal and spatial relationships between the literatures in good accordance with the actual data.
3.1 Specific analysis on cluster #0-#7

Cluster is a collection of citations with a highly relevant topic, and the cluster labels are the high frequency words extracted from the title, keywords or abstract of the literature, three main fields that authors typically use to describe a publication. As shown in table 1, we figure out the research direction and list the clusters with their corresponding labels.

Table 1. Information of cluster #0-#7

<table>
<thead>
<tr>
<th>Cluster ID</th>
<th>Size</th>
<th>Silhouette</th>
<th>Mean (Year)</th>
<th>Label (Title)</th>
<th>Label (Keywords)</th>
<th>Label (Abstract)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>85</td>
<td>0.826</td>
<td>2009</td>
<td>Building information modeling</td>
<td>BIM</td>
<td>Building information modeling</td>
</tr>
<tr>
<td>1</td>
<td>45</td>
<td>0.853</td>
<td>2005</td>
<td>Synchronous on-site data collection</td>
<td>Speech technologies</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>39</td>
<td>0.889</td>
<td>2007</td>
<td>Radio frequency identification</td>
<td>Space planning</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>28</td>
<td>0.968</td>
<td>2003</td>
<td>Nd model application</td>
<td>Industry foundation classes</td>
<td>Steel bridge information</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>1</td>
<td>1996</td>
<td>Integrated construction environment</td>
<td>Integrated construction environment</td>
<td>Integrated construction environment</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>0.92</td>
<td>2010</td>
<td>Point cloud</td>
<td>Laser scanning</td>
<td>Virtual model</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>0.956</td>
<td>1998</td>
<td>Performance measurement</td>
<td>Performance measurement</td>
<td>Project information management</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>0.973</td>
<td>1999</td>
<td>Construction project document</td>
<td>Text categorization</td>
<td>Information organization</td>
</tr>
</tbody>
</table>

3.2 Specific analysis on Cluster #0 BIM (Building Information Modeling)

The study of BIM, the most powerful word of cluster #0, always rely on the full understanding of concepts, making high-cited literatures are almost about theoretical foundation and application.

Table 2. Information of high-cited bibliographic in cluster #0

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Burst</th>
<th>Centrality</th>
<th>Author</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>84</td>
<td>5.05</td>
<td>0.07</td>
<td>Eastman C</td>
<td>2008</td>
<td>BIM HDB GUIDE BUILDI</td>
</tr>
<tr>
<td>61</td>
<td>0.01</td>
<td></td>
<td>Eastman C</td>
<td>2011</td>
<td>BIM HDB GUIDE BUILDI</td>
</tr>
</tbody>
</table>
3.3 Specific analysis on Cluster #1 synchronous on-site data collection

The label of cluster #1 is “synchronous on-site data collection” extracted from titles and keywords, but “speech technologies” when the extraction part is “abstract”. “Integrating wireless and speech technologies for synchronous on-site data collection” shows a synchronizing system combining with wireless and voice technology. “Automatic rule-based checking of building designs” surveyed rule checking systems that assess building designs and some industrial efforts in detail, all relying on IFC building models as input. “Benchmark tests for BIM data exchanges of precast concrete” introduces the benchmark tests for BIM data exchange through complex small models, which tends to use the exchange file format (such as IFC and SAT) to explore the most advanced data interoperability. In short, information collection and interaction is a prerequisite for the BIM process, that’s why many researchers are engaged in applying advanced information technologies.

3.4 Specific analysis on Cluster #2 radio frequency identification

Radio frequency identification, shorted as RFID, is a kind of radio communication technology, the rapid and accurate feedback of which makes it possible in assembly buildings. As the core of life cycle management, BIM deals with design information, construction information and management information to manage the whole project comprehensively. Hartmann summed up all aspects of BIM implementation. Russell A studied how to apply models to the linear programming process. Again the emphasis is on the information collection technology in the application.

3.5 Specific analysis on Cluster #3 industry foundation classes

The labels of cluster #3 are “model application”, “industry foundation classes” and “steel bridge information”, when they are respectively extracted from title, keyword and abstract. Two articles should be mentioned. The first one is “Parametric 3D modeling in construction building with example from precast concrete”, which suggests to establish a series of supporting prefabricated functions. The second one published by Sacks, et al. (2004) is based on the comparison of prefabricated buildings and the relative economic review of the global, analyzing the models and
aspects of the underlying management procedures, such as types of contracting arrangements, cost estimating, design communication, product diversity and so on.

Table 5. Information of high-cited bibliographic in cluster#3

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Burst</th>
<th>Centrality</th>
<th>Author</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>4.08</td>
<td>0.07</td>
<td>Sacks R</td>
<td>2004</td>
<td>AUTOMAT CONSTR</td>
</tr>
<tr>
<td>6</td>
<td>3.27</td>
<td>0.05</td>
<td>Eastman Charles</td>
<td>1999</td>
<td>BUILDING PRODUCT MOD</td>
</tr>
</tbody>
</table>

3.6 Specific analysis on Cluster #4 integrated construction environment

The label of cluster #4 is “integrated construction environment”. It is an important part of the construction, but people only pay attention to the progress of projects, quality, and investment. What’s more, as the techniques and methods mentioned in this cluster have been developed for years, the reference value is limited and leads to the reduction in cited-frequency.

Table 6. Information of high-cited bibliographic in cluster#4

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Burst</th>
<th>Centrality</th>
<th>Author</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>Aouad G</td>
<td>1993</td>
<td>CONSTRUCTION MANAGEM</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Ames A</td>
<td>1996</td>
<td>VRML SOURCE BOOK</td>
</tr>
</tbody>
</table>

3.7 Specific analysis on Cluster #5 laser scanning

The labels of cluster #5 are “point cloud”, “laser scanning” and “virtual model”, when they are respectively extracted from title, keyword and abstract, and three articles should be stressed. The first one is “Automatic reconstruction of as-built information models from laser-scanned building point clouds: A review of related techniques”. Laser scanners are used to capture dense 3D measurements of a facility’s as-built condition and the resulting point cloud can be manually processed to create an as-built BIM. The second article by Bosché (2010) presents a new method for automatic recognition of 3D CAD model objects using laser scanning and point matching. The third one by the same writer(2008) stressed the potential applications of it. In short, the cluster #5 is mainly about the information technology, and more articles will be cited in this area.

Table 7. Information of high-cited bibliographic in cluster #5

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Burst</th>
<th>Centrality</th>
<th>Author</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>3.45</td>
<td>0</td>
<td>Tang PB</td>
<td>2010</td>
<td>AUTOMAT CONSTR</td>
</tr>
<tr>
<td>19</td>
<td>0</td>
<td>0</td>
<td>Zhang SJ</td>
<td>2013</td>
<td>AUTOMAT CONSTR</td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>0</td>
<td>Bosche F</td>
<td>2010</td>
<td>ADV ENG INFORM</td>
</tr>
<tr>
<td>13</td>
<td>0.03</td>
<td>0</td>
<td>Bosche F</td>
<td>2008</td>
<td>AUTOMAT CONSTR</td>
</tr>
<tr>
<td>10</td>
<td>0.01</td>
<td>0</td>
<td>Xiong XH</td>
<td>2013</td>
<td>AUTOMAT CONSTR</td>
</tr>
<tr>
<td>10</td>
<td>2.94</td>
<td>0</td>
<td>Golparvar-fard M</td>
<td>2009</td>
<td>J COMPUT CIVIL ENG</td>
</tr>
</tbody>
</table>

3.8 Specific analysis on Cluster #6 performance measurement

Extracted from titles and keywords, the label of cluster #6 is “performance measurement”, and as for abstracts is “project information management”. Since the above bibliographies are general research guides, they are not cited a lot. Betts and Smith (1999) bring together the views of scholars from IT Company and the project management experts, so as to highlight the importance of IT display technology and communication in the industry.
Table 8. Information of high-cited bibliographic in cluster#6

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Burst</th>
<th>Centrality</th>
<th>Author</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>Fellows R F</td>
<td>1997</td>
<td>RES METHODS CONSTRUC</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>Betts M</td>
<td>1999</td>
<td>STRATEGIC MANAGEMENT</td>
</tr>
</tbody>
</table>

3.9 Specific analysis on Cluster #7 information organization

Extracted from title, keywords and abstract, the labels of cluster #7 are respectively “construction project”, “text categorization” and “information organization”. An important article by Anumba and Evbuomwan (1999), stressed on effective communication, which requires a clear understanding of the communication facets (or interfaces) in the implementation of concurrent engineering, and proposed a taxonomy to identify the key aspects. Another keyword is called “MasterFormat”, which provides a master list of divisions, and section numbers with associated titles to organize information about a facility’s construction requirements and associated activities.

We believe that the cluster #7 mainly emphasize on the gradual development of information classification, collation and processing capacity in the face of specific construction projects. Taking the advantages into account, the relevant research articles will be cited more frequently.

Table 9. Information of high-cited bibliographic in cluster#7

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Burst</th>
<th>Centrality</th>
<th>Author</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.01</td>
<td></td>
<td>Anumba C</td>
<td>1999</td>
<td>Computer-Aided Civil and Infrastructure Engineering</td>
</tr>
<tr>
<td>2</td>
<td>0.01</td>
<td></td>
<td>*constr SPEC I</td>
<td>1995</td>
<td>MASTERFORMAT</td>
</tr>
</tbody>
</table>

4 Discussions and conclusions

BIM attracts a lot of inter-disciplinary attention and is an expanding field of study incorporating many knowledge domains within the Architecture, Engineering and Construction industry (Succar, 2009). In this paper, we conduct a scientometric analysis with the assistance of the CiteSpace software to comprehensively investigate the development and current state of BIM related publications based on a large bibliographic data basis provided via the WoS.

This study reveal that past and current BIM research is predominantly influenced by fundamental and highly recognized scientists and publications. Given the results of the keyword analysis it is obvious that the past and current focus of BIM research lies mainly on the technology itself rather than on socio-economic issues. This may help to increase the overall value of BIM and may facilitate further adoption in both an academic and practical context. Thus, the results of the scientometric analysis help the relatively new field of BIM to define itself in order to provide a clear direction and objectives for research. The analysis of main contributing affiliations and highly influential authors and publications may help, especially new generations of scholars, to get an overview of important publications, topics and outlets, and to identify main contributors and driving forces in the area of BIM. Thus, the results can be used to better understand patterns, trends and other important factors for directing individual research activities, efficiently extending research networks and selecting appropriate publication outlets for sharing individual knowledge.
5 Acknowledgments

The authors are grateful for the kind support and cooperation of the Highways Department of HKSAR in providing valuable data, relevant manuals and other needed information. The authors thank the anonymous reviews for their valuable suggestions. The work is supported by the Natural Science Foundation of China, Grant No.71673240, the Natural Science Foundation of Zhejiang poince, Grant No. LY16G020009.

References

Modular approach for processing experience in sustainable urbanization

Yan, H.¹, Wu, Y.², Zhang, X.³

Abstract: In order to share experiences more effective, this study introduces a modular approach to process and store experiences in the practices of sustainable urbanization. The concept of “Experience Module” which consists of three parts (city background, the problem encountered, and the solution adopted for addressing the problem) is introduced to represent an experience. Data standardization techniques are adopted to standardize three components of experience module. An Experience Module Database System (EMDS) is built by aggregating individual experience modules for handling experience. This modelling approach can increase significantly the efficiency in retrieving the previous experiences gain in practices for supporting decision-making in promoting sustainable urbanization.

Keyword: Experience modular; Sustainable urbanization; Data standardization; Experience Module Database System

¹ Yan, H.
Corresponding author, School of Construction Management and Real Estate, Chongqing University, China

² Wu, Y.
School of Construction Management and Real Estate, Chongqing University, China

³ Zhang, X.
Urban Research Group, City University of Hong Kong; Hong Kong, China
1 Introduction

Urbanization has been one of the most prominent tendencies in the 21st century around the world. More than half of the world’s population now reside in cities, and millions of people move from the rural areas to urban areas every year. Given current development, it is anticipated that approximately 66% of the population will be urbanized by 2050[1]. However, the rapid urbanization movement around the world has provoked countless unsustainable problems, such as global warming, choking pollution, traffic congestion, resource scarcity, and insufficient housing, which are in turn harm the health of cities[2-4]. Therefore, how to solve these unsustainable problems or so called “city diseases” confuses city governments.

The principle of sustainable development, which pursues the balance between socio-economic development and environmental development, is incorporated into the urbanization process to therapy “city disease”. In line with this, many scholars, international institutions and local governments around the world have been making an effort in promoting sustainable urbanization. For example, National Development and Reform Committee (NDRC) in China introduced “the Low-carbon City” initiative to tackle environmental degradation and pursuing sustainable urban development[5]. United Nations Human Settlements Programme (UN-Habitat), United Nations Development Programme (UNDP) have dedicated efforts to promote the practice of sustainable urbanization. These efforts have generated a lot of good experience in practicing sustainable urbanization. This experience is invaluable for government decision makers if they can refer to the past good experience to resolve the new current problem.

Experience-mining System (ExMS) is proposed by Shen et al.[6] for sharing successful experience in promoting sustainable urbanization. ExMS refines valuable experience from previous best practices for supporting a decision making process for a new problem. Three major components of ExMS are Sustainable Urbanization Practice Database (SUPD), a Refinery process, and a Mine-sweeper. The first and important task in ExMS is to represent experience and establish SUPD to store the collected practice cases. However, research of Shen et al.[6] just provides a rough idea for constructing architecture of database. On the other hand, some international organizations such as UN-Habitat, C40 and New York government have launched best practice databases which just provide display and simple search functions. Furthermore, diverse terminologies are adopted to describe the same concept in different databases which lead to the barriers in data exchanging. Therefore, this study aims to introduce a new modular method to represent experience of best practice cases and establish a corresponding database system to store the processed experience. The concept of “experience module” is first introduced to represent the knowledge stored in best practices of sustainable urbanization. Experience module contains the minimum but critical information of a certain case. It is composed of three parts: problems, solutions, and city background. Furthermore, some standardization techniques are adopted to eliminate discrepancies in definitions and terminologies of three components. All collected case reports are transformed into experience modules which constitute the prototype of Experience Module Practice Database (EMPD).

2 Research method

This study adopted Case Base Reasoning (CBR) approach to represent experiences of collected case. CBR is an approach to using the solutions derived from past experience to solve new similar

621
problem by recalling similar experiences\cite{7}. As the core process of CBR, case representation is a task of designing a conceptual models and enabling the computer to recognize, store, and process experiences. For a problem-solving CBR system, a case consists primarily of two parts: the problem part and the solution part. Other information should be included in experiences depend on the domain as well as the purpose for which cases will be used. Therefore, experiences may be represented by different attributes in different circumstances. This study refers to the case representation of CBR medical system which diagnoses disease based on the doctor’s past experience. In a typical CBR diagnose system, a case usually includes three types of feature, namely, patient characteristics (age, height, weight), symptoms, and treatments\cite{8} (Figure 1). Similarly, a city can be treated as a patient with some “diseases” described by symptoms. City diseases can be cured by referring to experience in similar historical cases. Therefore, the collected cases in this study are represented by three components and transformed into experience modules as shown in Figure 1.

![Figure 1. Three components of experience module](image)

### 3. Data standardization of experience module

After defining the structure of experience module, another issue is to standardize three components in experience module in order to ensure data consistency. Data standardization defines a unified way to represent city background, problems, and solutions of cases with common terms and definition. It consists of some basic operations such as integrating multiple expressions about the same concept, removing noise and inconsistencies, and reducing redundancy.

#### 3.1 Standardization of city background

It is an intricate system that involves a large set of interrelated components across environment, economic, social, and other dimensions\cite{9}. Therefore, the multidimensionality of city leads to difficulty in describing the background of a city. Many scholars have adopted various urban features or indicators to describe a city from different aspects\cite{10-12}. Based on the previous literatures, six typical urban features are selected from three perspectives economic, environmental, and social, where landform and climate represent the environment perspective, urban scale and development level represent the social aspect, Gini coefficient and GDP performance represent the economics perspective. Each type of urban feature is measured by certain indicators are summarized in Table 1.
Table 1 Urban features and their indicator/attribute

<table>
<thead>
<tr>
<th>Urban feature</th>
<th>Indicator/Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landform</td>
<td>Hills, Mountains, Plains, Plateaus</td>
</tr>
<tr>
<td>Climate</td>
<td>Tropical, Dry, Mild temperate, Snow, Polar</td>
</tr>
<tr>
<td>Urban scale</td>
<td>Total population</td>
</tr>
<tr>
<td>Development stage</td>
<td>Urbanization rate</td>
</tr>
<tr>
<td>Income distribution</td>
<td>Gini Coefficient</td>
</tr>
<tr>
<td>Economic performance</td>
<td>GDP per capita</td>
</tr>
</tbody>
</table>

3.2 Standardization of the problem

Recently, there is no uniform indicator system which can cover all kinds of city problems or city diseases. Several organizations such as UN-Habitat, New York City Global Partners, and Sustainable Cities Collective have proposed different classifications of city problems. This study compares the classification of these organizations and establishes a uniform vocabulary of city problem as listed in Table 2.

Table 2 Problem vocabulary

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Sub-dimension</th>
<th>Detail problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td></td>
<td>Water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fresh Water Protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water Supply</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water Pollution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Waste Water Treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Renewable Energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fossil Energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy Storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy Saving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy Production</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land Desertification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Landscape Protection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Land Pollution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greenhouse Gases</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Haze</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inflation</td>
</tr>
<tr>
<td>Economic</td>
<td></td>
<td>Employment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unemployment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Income Gap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enterprise Development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enterprise Scale</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enterprise Culture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Competitiveness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Workforce Development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labor Cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Staff Training</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial Structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tourism Development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Industrial Development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Investment Development</td>
</tr>
</tbody>
</table>
In Table 2, city problems are organized into four main dimensions: environmental, economic, social, and governance. Each dimension has several sub-dimensions which are consisted of diverse detailed problems. However, this city problem vocabulary could not cover all problems in the urbanization process. Therefore, this vocabulary will be updated periodically by adding new types of problem.

### 3.3 Standardization of the solutions

The solution describes the manners of dealing with or resolving the problem. It usually includes the selection of methods, process, and outcome. Solution is the most crucial part which contributes to majority content in the practice reports. Likewise, there is no unified classification of solutions in sustainable urbanization discipline. Content analysis is adopted in this study to extract the solution information from sustainability reports. This method was carried out during April to May in 2017 by experts in urban development research area. Firstly, every expert read the collected practice reports and extracted detail solutions. Secondly, all extracted solutions are classified into several groups after a discussion in a workshop. The solution vocabulary is established as shown in Table
### Table 3 Solution vocabulary

<table>
<thead>
<tr>
<th>Solution category</th>
<th>Solution name</th>
</tr>
</thead>
</table>
| Technology        | Green building (Green roofs, Green building materials, Energy retrofit of buildings)  
|                   | Promotion of clean energy (wind energy, solar energy, geothermal power)  
|                   | Green infrastructure (construction of bicycle-related infrastructure, construction of pedestrian infrastructure, construction of ecologic corridor)  
|                   | Transportation system (bus rapid transit system, motorway underground)  
|                   | Safety facilities or counter-terrorism facilities (monitor system, check point)  
|                   | Green space (plant trees, monitor and remove invasive plant)  
|                   | Information technology (build a website to provide professional guidance, telephone chain, propagate public health by bus TV programs)  
|                   | Waste disposal technique (waste incinerators plants, segregation of waste)  
| Economy           | Subsidy or allowance (housing subsidy, transportation subsidy)  
|                   | Market approach (set up a recyclable waste market, develop a self-sustaining market, build a pump-priming local market, innovation sanitation marketing)  
|                   | Tax (Tax incentives, energy tax, increase excise tax of cigarettes)  
|                   | Charge (congestion charge, charge for pollution)  
|                   | Financial approach (carbon bank, BOT, carbon credit)  
| Management        | Standards and code (promotion of LEED, BREEAM)  
|                   | Legislation (solar thermal ordinance, human rights, protect disabled people)  
|                   | Education or training (set up curricula, academic forum)  
|                   | Contract  
| Organization      | Establish institution, committees, agencies  
|                   | Job rotation  
|                   | decentralization  
|                   | Multi-partnership  
|                   | Public integrity |

All these solutions are classified into four dimensions including technological, economic, organization, and management. Similarly, this solution vocabulary cannot include all possible solutions so that new solutions will be added to vocabulary periodically.

#### 3.4 Transformation from case reports to experience module

Information related to the city background, problems, and solutions is extracted from each case report through manual work. In order keep data consistency, the extracted information is transformed into the standardized form in problem and solution vocabularies.

#### 4 Experience Module Database System

##### 4.1 Database Design

In order to establish a database to store experience module, a conceptual schema should be developed firstly. The conceptual schema describes all relations stored in the relational database system. These relations contain information about entities and relationships. An entity is an object
in the real world that is distinguishable from other objects. It can be described by a set of attributes. As a rule, each entity must have a unique identifier called as primary key. Four entities (problem, solution, city, and experience module), their attributes, and data type are shown in Table 3.

Table 4 Entities and their attributes in EMDS

<table>
<thead>
<tr>
<th>Entity</th>
<th>Attribute</th>
<th>Data type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem</td>
<td>Problem id</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Problem name</td>
<td>String</td>
</tr>
<tr>
<td></td>
<td>Problem description</td>
<td>String</td>
</tr>
<tr>
<td>Solution</td>
<td>Solution id</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Solution name</td>
<td>String</td>
</tr>
<tr>
<td></td>
<td>Solution description</td>
<td>String</td>
</tr>
<tr>
<td>City</td>
<td>City id</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>City name</td>
<td>String</td>
</tr>
<tr>
<td></td>
<td>Country</td>
<td>String</td>
</tr>
<tr>
<td></td>
<td>Climate</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td>Landform</td>
<td>String</td>
</tr>
<tr>
<td></td>
<td>Population</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Urbanization rate</td>
<td>Double</td>
</tr>
<tr>
<td></td>
<td>Gini Index</td>
<td>Real</td>
</tr>
<tr>
<td></td>
<td>GDP per capital</td>
<td>real</td>
</tr>
<tr>
<td>Experience Module</td>
<td>Module id</td>
<td>Integer</td>
</tr>
<tr>
<td></td>
<td>Case title</td>
<td>String</td>
</tr>
<tr>
<td></td>
<td>Problem id</td>
<td>List&lt;Integer&gt;</td>
</tr>
<tr>
<td></td>
<td>Solution id</td>
<td>List&lt;Integer&gt;</td>
</tr>
<tr>
<td></td>
<td>City id</td>
<td>Integer</td>
</tr>
</tbody>
</table>

The entity relationship diagram is a simple semantic network model for designing a database. The ER diagram for the Experience Module Database System is shown in Figure 3. The relationship between City entity and Case entity is “one-to-many” which means that one city can be associated with many cases. The relationship between case entity and problem entity and the relationship between case entity and solution entity can be taken as “many-to-many”.

Figure 3 The ER diagram of the Experience Module Database System
4.2 Data collection

Nearly 200 case reports are collected from websites of interactional organizations including UN-Habitat, New York City Global Partners, and 40 Cities. Each case report provides a detailed description of the process how to solve the problems in the urbanization process. All these cases have been proved to achieve success and provide immeasurable value for the developing cities.

4.3 Experience Module Database System

Experience Module Database System (EMDS) was developed based on experience module model. EMDS provides an interface for administrators to input and modify information about experience module as shown in Figure 4. The main options of EMDS include method, problem, city, and case management. Administrators can input the new types of method, problem or city through sub-menu of each corresponding option. Finally, each collected case will be transformed into an experience module through “case management” sub-menu (Figure 4).
5. Conclusion

In order to share experience effectively, this research has introduced a new method to manage and store the experiences of sustainable urbanization. The concept of “Experience Module” is first proposed to representing cases in a systematic manner. The inspiration of this method comes from the case representation of typically CBR medical diagnose systems. Data standardization techniques are conducted to standardize three components of experience module. A database called EMDS is established to provide an interface for the administrator to input and store best practices. However, it is impossible to set-up a rich and informative database within one or two days, or even weeks. Therefore, EMDS is just a prototype which needs further development by inputting data continuously. Our research team will corporate with some organizations and local governments to improve and perfect EMDS.

Acknowledgments

This research work was supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant Nos. “15AZD025” and “15BJY038”.

Reference

Key carbon emission sectors in China: application of input-output analysis

Yingli Lou¹*, Yali Huang² Liyin Shen³ and Michael C.H. YAM⁴

Abstract: The carbon emissions from a specific sector may be large, but it may be the results driven by other sectors as the production of this sector is heavily demanded by other sectors. On the other hand, the emissions from a sector may be small, but this sector can drive other sectors to release carbon emissions as this sector consumes products made by other sectors. Therefore, this research examines the key emission sectors in China from a driving-driven perspective. By referring to Input-Output Table and China Energy Statistical Yearbook in the year of 2012, 31 emission sectors are mapped out and key emission sectors are identified. The driving-dominant sector is sector 13 (Nonmetal mineral products). Driven-dominant sectors are sector 3 (Petroleum and natural gas extraction), sector 29 (Wholesale, retail trade, lodging and catering services), and sector 31 (Others). The driving-driven sectors are sector 2 (Coal mining and dressing), sector 11 (Petroleum processing and coking), sector 12 (Chemical products), sector 14 (Smelting and pressing of metals), sector 25 (Electric power, steam and hot water production and supply), and sector 30 (Transportation, storage, postal and telecommunications services). The finds provide important reference for governments to adopt effective carbon reduction measures addressing the key emission sector to achieve the largest extent carbon reduction.

Keywords: Carbon emission, Input-output, Key sectors, China study

¹* Yingli Lou.
Corresponding author, School of Construction Management and Real Estate, International Research Centre for Sustainable Built Environment, Chongqing University, China
E-mail: 20160302057t@cqu.edu.cn

² Yali Huang.
School of Construction Management and Real Estate, International Research Centre for Sustainable Built Environment, Chongqing University, China

³ Liyin Shen.
School of Construction Management and Real Estate, International Research Centre for Sustainable Built Environment, Chongqing University, China

⁴ Michael C.H. YAM
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong
1 Introduction

The traditional perspective on key carbon emission sectors is that the sector which releases more carbon will be the key sector\cite{1-5}, such as transportation, smelting of iron and steel, electric power generation. This method is effective for us to realize the distribution of carbon emissions in different sectors and take further reduction measures. However, this method ignores the complicated relationship between different economic sectors. The carbon emissions from a specific sector may be large, but it may be the results driven by other sectors as the production of this sector is heavily demanded by other sectors. On the other hand, the emissions from a sector may be small, but this sector can drive other sectors to release carbon emissions as this sector consumes products made by other sectors. In other words, its upstream sectors release carbon emissions in the production process production driven by the demand of other sectors. So, both driving and driven effects should be considered when evaluating carbon emissions from a specific sector.

As the largest carbon emitter in the world, China has given increasing attention to reduce carbon emission and promulgated an ambitious carbon mitigation plan in 2015. According to this plan, the carbon emission per unit of Gross Domestic Product (GDP) in China will be reduced by 60%-65% during 2005-2030\cite{6}. The achievement of this goal will rely on the effective emission mitigation achieved in various economic sectors where emissions come from\cite{7}, for which the understanding on the emission contributed by each sector from driving-driven perspective is particularly important.

In applying input-output analysis method, previous researchers have studied the energy consumption and carbon emission of a specific economic sector. Zhang et al.\cite{8} estimated the embodied energy consumed by 30 economic sectors in Beijing. Chang and Lin\cite{9} examined the emission trends of 34 sectors in Taiwan. Morán and González\cite{10} identified the most carbon emissions-intensive sectors in Spain. Nevertheless, these studies do not consider the emission effects of one sector on other sectors.

In consideration of driving and driven effects of an economic sector, Alcantara and Padilla\cite{11} have identified the key sectors in energy consumption in Spain using the data of 1995. Othman and Jafari\cite{12} have identified the key sectors that produce CO\textsubscript{2} emissions in Malaysia using the data of 2005. However, they have not examined the effects that the key sectors have on the other sectors. Therefore, this paper aims to identify the key economic sectors that produce carbon emissions in China and further examine effects that the key sectors have on the other sectors.

The remainder of this paper is organized as follows: Section 2 introduces the method and data used in this research. Section 3 presents the procedures for identifying the key sectors. Section 4 displays the discussion on the effects that the key sectors have on the other sectors. Section 5 draws a conclusion of this study.

2 Research method and data sources

Input-output method is used in this study to analyze both the driving and driven effects of a specific economic sector on carbon emission. The driving effect is expressed by the percentage change in total carbon emission in response to 1% increase in the value added generated by a specific sector. And the driven effect is denoted by the percentage change in the total carbon emission released by
a specific sector in response to 1% increase in the total value added of all sectors. The methods for calculating these two kinds of effects are explained as follows.

Firstly, the connections between various sectors and the parameters should be defined. Every economic sector needs the input of products from other sectors, which called intermediate input. On the other hand, each sector also needs primary input, such as the depreciation of fixed assets, compensation for employees, net production taxes. The total primary input is called value added. Supposing there are $n$ sectors, $a_{ij}$ refers to the input of sector $i$ in a unit production of the output of sector $j$. $v_j$ refers to the valued added in a unit production of the output of sector $j$. Thus, the input-output coefficients framework is shown in Table 1.

**Table 1 Input-output framework**

<table>
<thead>
<tr>
<th>Input/Output</th>
<th>Sector 1</th>
<th>Sector 2</th>
<th>...</th>
<th>Sector n</th>
</tr>
</thead>
<tbody>
<tr>
<td>sector 1</td>
<td>$a_{11}$</td>
<td>$a_{12}$</td>
<td>...</td>
<td>$a_{1n}$</td>
</tr>
<tr>
<td>sector 2</td>
<td>$a_{21}$</td>
<td>$a_{22}$</td>
<td>...</td>
<td>$a_{2n}$</td>
</tr>
<tr>
<td>Intermediate</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>input</td>
<td>$a_{nt}$</td>
<td>$a_{nt}$</td>
<td>...</td>
<td>$a_{nt}$</td>
</tr>
<tr>
<td>Total of</td>
<td>$a_1=\sum_{i=1}^{n} a_{i1}$</td>
<td>$a_2=\sum_{i=1}^{n} a_{i2}$</td>
<td>...</td>
<td>$a_n=\sum_{i=1}^{n} a_{in}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary Value added</th>
<th>$v_1$</th>
<th>$v_2$</th>
<th>$v_j$</th>
<th>$v_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total input</td>
<td>$a_1+v_1=1$</td>
<td>$a_2+v_2=1$</td>
<td>$a_j+v_j=1$</td>
<td>$a_n+v_n=1$</td>
</tr>
</tbody>
</table>

Every economic sector $j$ will release direct carbon emission denoted by $C_j$ and $C$ is the total direct carbon emission of all sectors. $g_j$ is the proportion of sector $j$ to the total carbon emissions, as shown in equation (1).

$$g_j = \frac{C_j}{C} \quad (1)$$

Thus, let $A$ be the $n \times n$ matrix, $I$ be the $n \times n$ unit matrix, $v$ be the $n \times 1$ matrix, $g$ be the $n \times 1$ matrix. $A$, $I$, $v$, $g$ are displayed detailly in equation (2)-(5).

$$A = \begin{bmatrix}
            a_{11} & a_{12} & \cdots & a_{1n} \\
            a_{21} & a_{22} & \cdots & a_{2n} \\
            \vdots & \vdots & \ddots & \vdots \\
            a_{n1} & a_{n2} & \cdots & a_{nn}
        \end{bmatrix} \quad (2)$$

$$v = (v_1 \quad v_2 \quad \cdots \quad v_n)^T \quad (3)$$

$$g = (g_1 \quad g_2 \quad \cdots \quad g_n)^T \quad (4)$$

$$I = \begin{bmatrix}
            1 & 0 & 0 & 0 \\
            0 & 1 & 0 & 0 \\
            0 & 0 & 1 & 0 \\
            0 & 0 & 0 & 1
        \end{bmatrix} \quad (5)$$

The emission elasticities can be obtained by using equation (6), which is deduced by Othman and Jafari [12] based on the work by Alcantara and Padilla [11].

$$E = \tilde{g}(I - A^T)^{-1}\tilde{v} \quad (6)$$

Where, $E$ is the matrix of emission elasticities, $\tilde{g}$ is the diagonal matrix of $g$. $\tilde{v}$ is the diagonal matrix of $v$. $A^T$ is the transposed matrix of $A$. 
As a result, $E$ is a $n \times n$ matrix.

$$E = \begin{bmatrix}
e_{11} & e_{12} & \cdots & e_{1n} \\
e_{21} & e_{22} & \cdots & e_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
e_{n1} & e_{n2} & \cdots & e_{nn}
\end{bmatrix}$$

(7)

Let $E_{Tj} = \sum_{i=1}^{n} e_{ji}$, $j = 1, 2, 3 \cdots n$.

(8)

$$E_T = \frac{1}{n} \sum_{i=1}^{n} E_{Ti}$$

(9)

$$E_{Di} = \sum_{j=1}^{n} e_{ji}, \quad i = 1, 2, 3 \cdots n$$

(10)

$$E_D = \frac{1}{n} \sum_{i=1}^{n} E_{Di}$$

(11)

$E_{Tj}$ is the percentage change in total carbon emission in response to 1% increase in the value added generated by sector $j$.

$E_{Di}$ is the percentage change in the total carbon emission generated by sector $i$ in response to 1% increase in the total value added of all sectors.

We use $E_T$ and $E_D$ as filters to identify key sectors, as shown in Table 2.

<table>
<thead>
<tr>
<th>$E_{Ti} &lt; E_T$</th>
<th>$E_{Ti} &gt; E_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{Di} &gt; E_D$</td>
<td>Driven-dominant key sectors: driven to release carbon emissions</td>
</tr>
<tr>
<td>$E_{Di} &lt; E_D$</td>
<td>Driving-driven key sectors: driving and driven to release carbon emissions</td>
</tr>
<tr>
<td>$E_{Di} &lt; E_D$</td>
<td>Non-relevant sectors</td>
</tr>
<tr>
<td>$E_{Di} &lt; E_D$</td>
<td>Driving-dominant key sectors: driving to release carbon emissions</td>
</tr>
</tbody>
</table>

For conducting the calculation on equation (6), there are three kinds of data that we should collect, namely $A$, $v$, $C_j$.

$A$ and $v$ are aggregated from 2012 Input-Output Table issued by the Chinese Input-Output Association. $C_j$ is calculated using the data from China 2012 Energy Statistical Yearbook issued by the National Bureau of Statistics of China. The calculation of $C_j$ is conducted by using the following formula (12), issued by the IPCC (Intergovernmental Panel on Climate Change) Guidelines for National Greenhouse Gas Inventories [13].

$$C_j = \frac{44}{12} \times \sum_{k=1}^{m} E_j^k \times LCV_k \times CF^k \times O^k$$

(12)

Where $\frac{44}{12}$ means the molecular weight ratio of carbon dioxide to carbon, $E_j^k$ represents the consumption of the type $k$ energy in sector $j$. Assuming that there are $m$ types of energy. $LCV_k$ represents the lower calorific value of the energy $k$, $CF^k$ represents the carbon emission coefficients of the energy $k$, and $O^k$ is the oxidation rate of the energy $k$.

### 3 Procedures for identifying the key sectors

#### 3.1 Aggregation of economic sectors

The classification on economic sectors is different between Input-Output Table and China Energy Statistical Yearbook. It is therefore necessary for aggregating economic sectors for enabling further analysis. By referring to Input-Output Table and China Energy Statistical Yearbook in the year of
2012, 31 sectors are mapped out to cover all sectors, as shown in Table 3.

**Table 3 Aggregation of economic sectors**

<table>
<thead>
<tr>
<th>Number</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Farming, forestry, animal husbandry, fishery and water conservancy</td>
</tr>
<tr>
<td>2</td>
<td>Coal mining and dressing</td>
</tr>
<tr>
<td>3</td>
<td>Petroleum and natural gas extraction</td>
</tr>
<tr>
<td>4</td>
<td>Metals mining and dressing</td>
</tr>
<tr>
<td>5</td>
<td>Nonmetal and other minerals mining and dressing</td>
</tr>
<tr>
<td>6</td>
<td>Food and tobacco</td>
</tr>
<tr>
<td>7</td>
<td>Textile industry</td>
</tr>
<tr>
<td>8</td>
<td>Garments, leather, furs, down and related products</td>
</tr>
<tr>
<td>9</td>
<td>Timber processing and furniture manufacturing</td>
</tr>
<tr>
<td>10</td>
<td>Printing, and cultural, educational and sports articles</td>
</tr>
<tr>
<td>11</td>
<td>Petroleum processing and coking</td>
</tr>
<tr>
<td>12</td>
<td>Chemical products</td>
</tr>
<tr>
<td>13</td>
<td>Nonmetal mineral products</td>
</tr>
<tr>
<td>14</td>
<td>Smelting and pressing of metals</td>
</tr>
<tr>
<td>15</td>
<td>Metal products</td>
</tr>
<tr>
<td>16</td>
<td>Equipment for general purposes</td>
</tr>
<tr>
<td>17</td>
<td>Equipment for special purposes</td>
</tr>
<tr>
<td>18</td>
<td>Transportation equipment</td>
</tr>
<tr>
<td>19</td>
<td>Electric equipment and machinery</td>
</tr>
<tr>
<td>20</td>
<td>Electronic and telecommunications equipment</td>
</tr>
<tr>
<td>21</td>
<td>Instruments, meters, cultural and office machinery</td>
</tr>
<tr>
<td>22</td>
<td>Other manufacturing industry</td>
</tr>
<tr>
<td>23</td>
<td>Comprehensive utilization of waste resources</td>
</tr>
<tr>
<td>24</td>
<td>Metal products, machinery and equipment repair</td>
</tr>
<tr>
<td>25</td>
<td>Electric power, steam and hot water production and supply</td>
</tr>
<tr>
<td>26</td>
<td>Gas production and supply</td>
</tr>
<tr>
<td>27</td>
<td>Tap water production and supply</td>
</tr>
<tr>
<td>28</td>
<td>Construction</td>
</tr>
<tr>
<td>29</td>
<td>Wholesale, retail trade, lodging and catering services</td>
</tr>
<tr>
<td>30</td>
<td>Transportation, storage, postal and telecommunications services</td>
</tr>
<tr>
<td>31</td>
<td>Others (such as finance, property, education, public facility)</td>
</tr>
</tbody>
</table>
3.2 Establishment of direct consumption coefficient matrix \((A)\) and Value added matrix \((v)\)

The direct consumption coefficient matrix \(A\) for 31 sectors needs to be established. Because the 31 sectors are mapped out to cover all sectors, certain sector in \(A\) covers several sectors that in the initial Input-Output table. For example, Sector 29 (Wholesale, Retail Trade, Lodging and Catering Services) in \(A\) covers two sectors in the initial Input-Output table in 2012, namely, wholesale and retail (Sector 29-1), Hotels and Catering Services (Sector 29-2). The use of input of sector 29 in a unit production of output of sector 2 \(a_{29,2}\) is the sum of input of sector 29-1, and sector 29-2 in a unit production of output of sector 2, which is expressed in equation (16). The use of input of sector 2 in the unit production of output of sector 29 \(a_{2,29}\) is the weighted mean of input of sector 29-1, and sector 29-2 in a unit production of output of sector 2. And the weight of sector 29-1, and sector 29-2 is calculated according to actual total input of these two sectors. The actual total input can be obtained from the basic flow matrix which is included in the Input-Output table. The actual total input of sector 29-1, and sector 29-2 respectively is 7215.534 billion yuan, and 2333.449 billion yuan. The calculation is expressed in equation (17). The valued added coefficient of sector 29 \(v_{29}\) is the weighted value of the valued added coefficient of sector 29-1, and the valued added coefficient of sector 29-2. As a result, the matrix \(A\) and the matrix \(v\) are obtained.

\[
a_{29,2} = 0.014 + 0.004 = 0.018 \tag{13}
\]

\[
a_{2,29} = (0.000 \times 7215.534 + 0.111 \times 2333.449)/(7215.534 + 2333.449) = 0.027 \tag{14}
\]

3.3 Calculation of direct carbon emission in various sectors

Direct carbon emission in various sectors will be calculated by applying the formula (12). For conducting the calculation, the data on various types of energy consumption by each sector need to be collected, which is shown in Table 4. The values for the parameters of LCV, CF and O for different energy are listed in Table 5.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Raw</th>
<th>Coke</th>
<th>Crude</th>
<th>Gasoline</th>
<th>Kerosene</th>
<th>Diesel</th>
<th>Fuel Oil</th>
<th>Natural</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17.661</td>
<td>0.575</td>
<td>0.000</td>
<td>1.929</td>
<td>0.012</td>
<td>13.355</td>
<td>0.020</td>
<td>0.064</td>
</tr>
<tr>
<td>2</td>
<td>261.633</td>
<td>0.654</td>
<td>0.000</td>
<td>0.163</td>
<td>0.022</td>
<td>2.152</td>
<td>0.009</td>
<td>0.748</td>
</tr>
<tr>
<td>3</td>
<td>4.779</td>
<td>0.000</td>
<td>10.504</td>
<td>0.142</td>
<td>0.000</td>
<td>0.634</td>
<td>0.133</td>
<td>12.294</td>
</tr>
<tr>
<td>4</td>
<td>3.129</td>
<td>1.394</td>
<td>0.000</td>
<td>0.144</td>
<td>0.004</td>
<td>1.483</td>
<td>0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>5</td>
<td>8.061</td>
<td>0.461</td>
<td>0.237</td>
<td>0.131</td>
<td>0.000</td>
<td>2.048</td>
<td>0.022</td>
<td>0.905</td>
</tr>
<tr>
<td>6</td>
<td>38.502</td>
<td>0.144</td>
<td>0.001</td>
<td>0.510</td>
<td>0.002</td>
<td>0.907</td>
<td>0.144</td>
<td>1.289</td>
</tr>
<tr>
<td>7</td>
<td>0.630</td>
<td>0.000</td>
<td>0.000</td>
<td>0.009</td>
<td>0.000</td>
<td>0.034</td>
<td>0.010</td>
<td>0.174</td>
</tr>
<tr>
<td>8</td>
<td>3.079</td>
<td>0.035</td>
<td>0.002</td>
<td>0.250</td>
<td>0.006</td>
<td>0.295</td>
<td>0.062</td>
<td>0.104</td>
</tr>
<tr>
<td>9</td>
<td>4.551</td>
<td>0.042</td>
<td>0.002</td>
<td>0.128</td>
<td>0.001</td>
<td>0.220</td>
<td>0.005</td>
<td>0.103</td>
</tr>
<tr>
<td>10</td>
<td>45.827</td>
<td>0.055</td>
<td>0.001</td>
<td>0.229</td>
<td>0.004</td>
<td>0.363</td>
<td>0.093</td>
<td>0.677</td>
</tr>
<tr>
<td>11</td>
<td>364.502</td>
<td>0.737</td>
<td>424.134</td>
<td>0.408</td>
<td>0.002</td>
<td>0.209</td>
<td>13.081</td>
<td>9.889</td>
</tr>
<tr>
<td>12</td>
<td>201.031</td>
<td>26.112</td>
<td>30.608</td>
<td>0.799</td>
<td>0.040</td>
<td>1.430</td>
<td>5.223</td>
<td>26.137</td>
</tr>
</tbody>
</table>
By referring formula (12) and formula (1), and the data in Table 4 and Table 5, the $C_j$ and $g_j$ are calculated and the results are shown in Table 6.

<table>
<thead>
<tr>
<th>sector number</th>
<th>Direct carbon emission ($C_j$)</th>
<th>Proportion ($g_j$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8100.330</td>
<td>0.008</td>
</tr>
<tr>
<td>2</td>
<td>48597.080</td>
<td>0.049</td>
</tr>
<tr>
<td>3</td>
<td>7302.710</td>
<td>0.007</td>
</tr>
</tbody>
</table>
3.4 Identifying the key sectors

By referring formula (6), the matrix of emission elasticities $E$ is obtained. By referring formula (11), (13), the driving effects of each sector $E_{Di}$ and driven effects of each sector $E_{Dj}$ are calculated, as shown in Table 7.

<table>
<thead>
<tr>
<th></th>
<th>Driving Effects</th>
<th>Driven Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1468.875</td>
<td>0.001</td>
</tr>
<tr>
<td>5</td>
<td>2565.935</td>
<td>0.003</td>
</tr>
<tr>
<td>6</td>
<td>7822.758</td>
<td>0.008</td>
</tr>
<tr>
<td>7</td>
<td>172.667</td>
<td>0.000</td>
</tr>
<tr>
<td>8</td>
<td>781.112</td>
<td>0.001</td>
</tr>
<tr>
<td>9</td>
<td>971.520</td>
<td>0.001</td>
</tr>
<tr>
<td>10</td>
<td>8712.319</td>
<td>0.009</td>
</tr>
<tr>
<td>11</td>
<td>200987.182</td>
<td>0.204</td>
</tr>
<tr>
<td>12</td>
<td>61864.080</td>
<td>0.063</td>
</tr>
<tr>
<td>13</td>
<td>50557.601</td>
<td>0.051</td>
</tr>
<tr>
<td>14</td>
<td>166352.018</td>
<td>0.168</td>
</tr>
<tr>
<td>15</td>
<td>1343.359</td>
<td>0.001</td>
</tr>
<tr>
<td>16</td>
<td>3373.864</td>
<td>0.003</td>
</tr>
<tr>
<td>17</td>
<td>1255.137</td>
<td>0.001</td>
</tr>
<tr>
<td>18</td>
<td>3098.810</td>
<td>0.003</td>
</tr>
<tr>
<td>19</td>
<td>1284.763</td>
<td>0.001</td>
</tr>
<tr>
<td>20</td>
<td>732.784</td>
<td>0.001</td>
</tr>
<tr>
<td>21</td>
<td>112.861</td>
<td>0.000</td>
</tr>
<tr>
<td>22</td>
<td>1015.982</td>
<td>0.001</td>
</tr>
<tr>
<td>23</td>
<td>105.147</td>
<td>0.000</td>
</tr>
<tr>
<td>24</td>
<td>94.017</td>
<td>0.000</td>
</tr>
<tr>
<td>25</td>
<td>322291.311</td>
<td>0.326</td>
</tr>
<tr>
<td>26</td>
<td>2214.577</td>
<td>0.002</td>
</tr>
<tr>
<td>27</td>
<td>135.854</td>
<td>0.000</td>
</tr>
<tr>
<td>28</td>
<td>3975.604</td>
<td>0.004</td>
</tr>
<tr>
<td>29</td>
<td>6660.742</td>
<td>0.007</td>
</tr>
<tr>
<td>30</td>
<td>59333.366</td>
<td>0.060</td>
</tr>
<tr>
<td>31</td>
<td>14012.186</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Table 7 Driving and driven effects of various sectors in 2012
<table>
<thead>
<tr>
<th>Sector</th>
<th>Driving effect</th>
<th>Driven effect</th>
<th>Sector</th>
<th>Driving effect</th>
<th>Driven effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.007</td>
<td>0.030</td>
<td>17</td>
<td>0.001</td>
<td>0.006</td>
</tr>
<tr>
<td>2</td>
<td>0.049</td>
<td>0.117</td>
<td>18</td>
<td>0.003</td>
<td>0.006</td>
</tr>
<tr>
<td>3</td>
<td>0.007</td>
<td>0.126</td>
<td>19</td>
<td>0.001</td>
<td>0.009</td>
</tr>
<tr>
<td>4</td>
<td>0.001</td>
<td>0.030</td>
<td>20</td>
<td>0.001</td>
<td>0.007</td>
</tr>
<tr>
<td>5</td>
<td>0.003</td>
<td>0.015</td>
<td>21</td>
<td>0.000</td>
<td>0.005</td>
</tr>
<tr>
<td>6</td>
<td>0.007</td>
<td>0.013</td>
<td>22</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>7</td>
<td>0.000</td>
<td>0.004</td>
<td>23</td>
<td>0.000</td>
<td>0.015</td>
</tr>
<tr>
<td>8</td>
<td>0.001</td>
<td>0.002</td>
<td>24</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>9</td>
<td>0.001</td>
<td>0.003</td>
<td>25</td>
<td>0.327</td>
<td>0.155</td>
</tr>
<tr>
<td>10</td>
<td>0.009</td>
<td>0.008</td>
<td>26</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>11</td>
<td>0.204</td>
<td>0.061</td>
<td>27</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>12</td>
<td>0.062</td>
<td>0.049</td>
<td>28</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>13</td>
<td>0.051</td>
<td>0.023</td>
<td>29</td>
<td>0.007</td>
<td>0.049</td>
</tr>
<tr>
<td>14</td>
<td>0.169</td>
<td>0.068</td>
<td>30</td>
<td>0.060</td>
<td>0.054</td>
</tr>
<tr>
<td>15</td>
<td>0.001</td>
<td>0.006</td>
<td>31</td>
<td>0.015</td>
<td>0.122</td>
</tr>
<tr>
<td>16</td>
<td>0.003</td>
<td>0.010</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1 Driving and driven effects of various sectors in 2012**

Using $E_T$ (0.032) and $E_D$ (0.032) as filters, and referring the rules in Table 2, key sectors are identified, as shown in Figure 1. The key driving-driven key sectors are sector 2 (Coal mining and dressing), sector 11 (Petroleum processing and coking), sector 12 (Chemical products), sector 14 (Chemical products), sector 15 (Chemical products), sector 16 (Chemical products), sector 17 (Chemical products), sector 18 (Chemical products), sector 19 (Chemical products), sector 20 (Chemical products), sector 21 (Chemical products), sector 22 (Chemical products), sector 23 (Chemical products), sector 24 (Chemical products), sector 25 (Chemical products), sector 26 (Chemical products), sector 27 (Chemical products), sector 28 (Chemical products), sector 29 (Chemical products), sector 30 (Chemical products), sector 31 (Chemical products).
(Smelting and pressing of metals), sector 25 (Electric power, steam and hot water production and supply) and sector 30 (Transportation, storage, postal and telecommunications services). And the driving-dominant key sector which only dramatically drives other sectors to release emissions is sector 13 (Nonmetal mineral products). Driven-dominant sectors which are dramatically driven to release emissions are sector 3 (Petroleum and natural gas extraction), sector 29 (Wholesale, retail trade, lodging and catering services), and sector 31 (Others).

4 Discussion

4.1 Driving-dominant key sectors

Driving-dominant sectors induce more carbon emissions, when the value added of these sectors increases. As shown in Figure 1, sector 13 (Nonmetal mineral products) is driving-dominant sectors. As shown in Table 7, 1% increase in the value added generated by Nonmetal Mineral Products would cause 0.051% increase of the total carbon emission. Emissions from these sectors are more likely to be self-generated or induce other sectors to release carbon emissions to attain own value-added economic growth. Because, the driving-dominant sector needs the supply of other sectors which may release plenty carbon emissions. It can be further examined through input coefficient \((a_{ij})\). The input of sector 2 (Coal mining and dressing), sector 5 (Nonmetal and other minerals mining and dressing), sector 12 (Chemical products), sector 13 (Nonmetal mineral products), sector 25 (Electric power, steam and hot water production and supply) is relatively high in a unit production of the output of sector 13, which respectively is 0.051, 0.071, 0.078, 0.198, 0.057. In referring to Table 6, the emissions in sector 25, sector 13, and sector 2 are relatively high, respectively is 3222.913 million tons, 505.576 million tons, 485.971 million tons. It means that sector 13 drives carbon emissions in two ways. On the one hand, the manufacture of nonmetal mineral products emits a large amount of carbon emission. On the other hand, the manufacturing nonmetal mineral products need the supply of electricity, water, and coal, thus, emissions from other sectors increase. Therefore, supply-side management and the improvement of manufacturing technology are necessary in driving-dominant sectors to reduce total carbon emissions \([16, 17]\).

4.2 Driven-dominant key sectors

Driven-dominant sectors released carbon emissions deeply provoked by overall economic growth. As shown in Figure 1, Driven dominant sectors are sector 3 (petroleum and natural gas extraction), sector 29 (Wholesale, retail trade, lodging and catering services), and sector 31 (Others). Especially, sector 3 is pronounced driven-dominant sectors. For example, as shown in Table 9, 1% expansion in the value added of all sector would cause 0.126% increase in the total carbon emission emitted by Petroleum and natural gas extraction. It means that Petroleum and natural gas extraction released carbon emissions deeply due to the demand derive from other sectors, such as sector 11 (Petroleum processing and coking), and sector 26 (Gas production and supply). Therefore, demand-side management and user-focused strategies are necessary in driven-dominant sectors to reduce total carbon emissions \([18-20]\).

4.3 Driving-driven key sectors

Driving-driven key sectors release carbon emission provoked by overall economic growth, and the
economic growth in these sectors also induce more carbon emissions. As shown in Figure 1, the driving-driven sectors are sector 2 (Coal mining and dressing), sector 11 (Petroleum processing and coking), sector 12 (Chemical products), sector 14 (Smelting and pressing of metals), sector 25 (Electric power, steam and hot water production and supply), and sector 30 (Transportation, storage, postal and telecommunications services). These sectors should be given high priority to achieve the largest carbon reduction. Because these sectors are largely tied up with economic growth by influencing other sectors from driving and driven sector. Thus, both demand-side management and supply-side management are necessary in these sectors to reduce total carbon emissions.

5 Conclusion

This research identifies the key carbon emission sectors in China from driving-driven perspective. Driving effects are prominent in the sector of 2, 11, 12, 13, 14, 25, 30, and the total driving effects of these sectors are 0.922. Driven effects are prominent in the sector of 2, 3, 11, 12, 14, 25, 29, 30, 31, and the total driven effects of these sectors are 0.830. Therefore, the sector of 2, 3, 11, 12, 13, 14, 25, 29, 30, 31, are the key sectors that determine whether the carbon reduction commitment will come true.

The finds provide important reference for governments to adopt effective reduction measures. It is a priority to take reduction measures in the key sector under the condition of limited capital and manpower. Adopting supply-side management in driving sectors and demand-side management in driven sectors should be considered to achieve the largest extent of carbon reduction.

This study identifies key carbon emission sectors from a new perspective, which is helpful to realize the complex relation between various emission sectors. However, the relation between various emission sectors will vary when the economy develops, and the key sectors may be changed. Thus, key sectors under different economic level are suggested in further study.

Acknowledgement

This research work is supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant Nos. “15AZD025” and “15BJY038”.

Referencee


Case Studies on the Barriers to Small Towns Development

—— A Perspective of Southwest China

Ren, Y.T.1*, Xiong, N.2, Shen, L.Y.3

Abstract: The urbanization process in China has brought enormous economic improvement. However, it appears that the development of small towns is severely lagged behind, this is particularly the case in Southwest China. This paper examines the barriers to the development of small towns in Southwest China. 12 major barriers are examined and analyzed in this study. 17 case townships are selected from four provinces in Southwest China for conducting field surveys, which include interview discussions, on site visits and document collections. And each barrier is discussed in depth combining with the practical cases extracted from field surveys. The findings from this study provide valuable reference in searching for effective approaches for promoting the development of small towns and contributing to a balanced urban-rural development in China.

Key Word: Small towns development, Barriers, Case study, Southwest China

1*Ren, Y.T.
Corresponding author, School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China
E-mail: rtyiyia@163.com

2 Xiong, N.
School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China

3 Shen, L.Y.
School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China
1 Introduction

China’s urbanization has been attracting global attention in recent years. In the year 2015, the urbanization rate in China has reached to the level of 56.1% and the urban population has increased to 771.16 million by the year 2015, in comparing with 351.74 million in 1994, the urban population in China has turned over two times in the past two decades. The rapid urbanization process contributes to the steady improvement of the economic growth in China, with the evidence that the gross domestic product (GDP) has increased from 734.5 billion in 1995 to 11065 billion in 2015, becoming second largest GDP value worldwide in 2015.

However, it has been appreciated that the urbanization in China has brought series of problems\textsuperscript{[1-2]} since resources are largely concentrated on urban area through central government policy. Typical problems include the disparity between urban and rural area, the difficulty of resettlement for rural migration in urban area, the unemployed population in cities, the urban-rural conflicts emerged during urbanization process. Figure 1 indicates the disparity of per capita net income between urban and rural residents from 1995 to 2015, it can be seen that the average per capita net income of the urban residents is almost three times as that of rural residents by 2015. This shows the gap between urban and rural in China has been increasing in line with the urban sprawl in the process of urbanization. It is considered that this growing gap can affect the stability of society, and then threat both to the political order and continued growth of economy\textsuperscript{[3-4]}.

![Figure 1. The per capita net income of urban and rural residents between 1995 to 2015](image)

Under this circumstance, as the connector and transfer station of urban-rural areas, small towns are positioned in essential roles, which is addressed in “The National New-type Urbanization Plan (2014-2020)” \textsuperscript{[5]}. Small towns are important to narrow the gap between urban-rural area, and to achieve successfully the mission of new-type urbanization in China.

Nevertheless, it appears that small towns are still severely underdeveloped comparing with large cities in China\textsuperscript{[6-7]}. And this is particularly the case in Southwest China (refers to Sichuan province, Yunnan province, Guizhou province, Chongqing Municipality City and Tibet Autonomous Region). In fact, the small towns in Southwest China are weak in investment attraction, self-govern jurisdiction, industry cultivation and population aggregation. These weaknesses have not only hindered the development of small towns, but also impeded the further urbanization process in China. Also, according to official statistics, the number of small towns in Southwest China is 39789 and accounts for 23% of the total number of small towns in the whole country. Therefore, the development of small towns in southwest China is a crucial part of a healthy and sustainable urbanization in China.
The barriers to the development of small towns are multiple, such as lack of autonomous administrative power, investment shortage for infrastructure construction. These barriers present bottlenecks in promoting the development of small towns, which in turn hinders the urban-rural balanced development and healthy urbanization process in the whole country. Therefore, it is highly-needed to focus on the small towns development under the content of Southwest China region. And it is the aim of this study to analyze the barriers to the development of small towns from the perspective of Southwest China.

2 Research Method

Firstly, literature review is conducted to gain theoretical understanding of the barriers affecting township development in China, particularly to those located in Southwest region. Following the literature studies, the major barriers hindering the development of small towns in Southwest China is identified from multiple dimensions.

By using the barrier list formulated, field surveys are conducted to 17 case townships to analyze the performance of individual barriers, namely, how does the specific barrier hinder the township development. These 17 case townships are selected from Chongqing Municipality City, Sichuan Province and Guizhou Province, and the field surveys were conducted by the research team, during the period of March to October 2016, with the details in Table 1. These 17 case townships are considered having representative characteristics of townships in Southwest China. In the survey process for each case township, semi-structured interviews were conducted with the township officials who are in charge of the key sectors of township development, for example, the infrastructure construction, public security, education, environment protection and others. The theoretical framework of semi-structured interview is shown in Appendix 1.

The content data of semi-structured interview are used to analyze the performance of specific barrier to the township development, combining with the statistic yearbook of small towns as well as other official documents. Thus, discussions are conducted by applying case-study approach.

Table 1 Basic information of 17 case townships in Southwest China

<table>
<thead>
<tr>
<th>Case Townships</th>
<th>Location</th>
<th>Investigate Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degan</td>
<td>Chongqing Municipality City</td>
<td>March, 2016</td>
</tr>
<tr>
<td>Tanghe</td>
<td>Chongqing Municipality City</td>
<td>March, 2016</td>
</tr>
<tr>
<td>Fenshuiling</td>
<td>Luzhou, Sichuan Province</td>
<td>April, 2016</td>
</tr>
<tr>
<td>Fangshan</td>
<td>Luzhou, Sichuan Province</td>
<td>April, 2016</td>
</tr>
<tr>
<td>Zhongliang</td>
<td>Chongqing Municipality City</td>
<td>June, 2016</td>
</tr>
<tr>
<td>Tiaodeng</td>
<td>Chongqing Municipality City</td>
<td>June, 2016</td>
</tr>
<tr>
<td>Lushi</td>
<td>Guangan, Sichuan Province</td>
<td>July, 2016</td>
</tr>
<tr>
<td>Gaoxing</td>
<td>Guangan, Sichuan Province</td>
<td>July, 2016</td>
</tr>
<tr>
<td>Huangyang</td>
<td>Zunyi, Guizhou Province</td>
<td>August, 2016</td>
</tr>
<tr>
<td>Dalucao</td>
<td>Zunyi, Guizhou Province</td>
<td>August, 2016</td>
</tr>
<tr>
<td>Xiazi</td>
<td>Zunyi, Guizhou Province</td>
<td>August, 2016</td>
</tr>
<tr>
<td>Chaole</td>
<td>Zunyi, Guizhou Province</td>
<td>August, 2016</td>
</tr>
</tbody>
</table>
3 Barrier Identification

This study integrates the results of barrier identifications presented in previous studies. Based on the literature review foundations, this study has identified the major barriers to the township development from multi-dimensions, which composes of institutional barriers, economic barriers, social barriers and ecologic barriers, as shown in Figure 2.

![Figure 2. The major barriers to township development in urbanization process](attachment:image.jpg)

4. Case-based Analysis

The analysis on the major barriers to the development of small towns is conducted from dimensional viewpoint in this section.

4.1 Institutional Barriers
China adopts a hierarchical administrative management system (HAMS), in which towns are at the bottom of the hierarchy. Thus, the allocation of resources is always biased towards the upper-level administrations, such as county seats and cities, while the demand of township development is often neglected.

**Lack of independent financial power**

The township government lacks independent financial power, causing the local taxation of small town is dominated by the county-level government, also the funds for operation of small towns mainly relys on the transfer payment from upper-level government. Therefore, the limited financial resources are severely insufficient to meet the financial demand of small town development.

For example, Zhongliang Township, located in Chongqing Municipality, according to the interview, the township government hands over all the township tax income to Shapingba District of Chongqing Municipality City. Shapingba District appropriates 10 to 11 million RMB yearly to Zhongliang Township, which is considered only being able to cover the administration cost, with very little left for other township development programs.

**Restriction of jurisdiction power**

Small towns enjoy very limited jurisdiction power in China. They have limited authority to plan development programs within their territory. To take two representative towns the authors’ research team have investigated----Yongxing Town and Fangshan Town as examples.

According to the interview discussions with the officials in Yongxing Township, the independent jurisdiction powers of the towns are very limited, but the township governments have the responsibilities in protecting land, forestry and animal husbandry. They have no jurisdiction for any of these aspects, for instance, they can only exhort the traffic perpetrator while has no jurisdiction to punishment. Thus the towns cannot make effective administrative decisions on the development of the town.

On the other hand, the later example, Fangshan Township, which is in Luzhou city. There is a buddhist tourism resort within Fangshan Township, which is famous among west Sichuan region, named Fangshan Scenic Spot. The Fangshan Scenic Spot is under the management of Fangshan Scenic Spot Management Council, which is at an upper level in HAMS than the Fangshan Township government. Based on the condition mentioned above, the income of Fangshan Scenic Spot is turned over to Fangshan Scenic Spot Management Council, while the responsibilities from the perspective of transportation, commercial activity and security around the scenic spot is accountable for the local government of Fangshan Township. This unbalanced distribution between jurisdiction power-management responsibility-benefits severely restrict the township development. It is implied that the development of Fangshan Township is much left behind in the Luzhou region. And this not only refer to Fangshan Township, but also to those townships having the self-borne tourism resources, facing the same embarrassed situation as Fangshan Township.

**Lack of construction land use quotas**

Land is the main elements and resources of local economic development in China, the formulation and fluctuation of land policy make conspicuous influence on the direction and speed of urbanization. In China, the central government takes an overall control of construction land use quotas (amount) to protect the cultivated land and to preserve food security.

Under this system background, construction land use quotas are distributed to each province, and then allocated to lower level administrations hierarchically. While the government of each
hierarchical administrative level tends to put the development of their own in the first place, as a result, the construction land use quota can be allocated into townships are much circumscribed. Without enough construction land, the development of small town is heavily restricted from the perspective of attracting external investment, promoting non-agriculture industry, etc.

Take Yanwo Township as an example, which located in Chongqing Municipality city, the construction land use quotas allocated to Yanwo are insufficient and fragmented geographically. Yanwo township can neither utilize the construction land intensively nor achieve scale economies effect in production, it even appears land desolation in this township. According to the interview discussion, lack of construction land is considered a severe barrier to the Yanwo township development.

## 4.2 Economic Barrier

Based on the major barrier list formulated in Section 3, combing with the results of field surveys in 17 case townships in Southwest region, it is commonly found that the development of small towns in Southwest China is facing with various barriers in economic perspective.

### Limited financial channels

At present, the development of small towns in China enjoy limited financial channels. The effective system to absorb social capital has not been formed, it is difficult to redeploy the idle social capital to township development. In fact, though the investment and financial system of small towns presents to become more multivariant, local government is still the most important investor towards small town development.

During the interview discussion in Fenshuiling township, located in Luzhou city, the officials opined that it is inaccessible to ensure the long-term and sustainable development only depending on the government fiscal revenue. For instance, the construction of road network in Fenshuiling is totally relied on the appropriation from upper administrative level, which even presenting the phenomenon that “once the appropriation comes, then the construction continues”. This project remains uncompleted due to the insufficiency of finance. The project could be completed earlier if the project finance comes from multi-channels.

On the other hand, according to the interviews in Zhongliang, Fenshuiling, Tanghe, Yanwo, Tiaodeng, Huangyang, the township officials pointed out that the appropriation from upper administrative level is usually project-based. Especially, the financial support from national government requires that the township programs should reach upon the scale of one hundred million RMB, then it can be considered to be financial support. While, the scale of township projects is usually at the scale of tens of million RMB, thus it is usually unapproachable for township projects to be financial supported by central government.

Actually, the infrastructure construction programs of small towns are not capable to provide attractive return of investment in a short time generally. Thus, the key to achieve success in township construction is to combine the government behavior with the market behavior. For example, public-private-partnership(PPP) construction model can be introduced into the construction of township projects.

### Mono-industry structure and low level of agricultural industrialization

There are various economic activities that dominate the growth of China’s small towns, but for any given towns it is most likely that its economy is dominated by a single activity \(^6\).
According to the field surveys, the economic development of 17 case townships in Southwest China is mainly dominated by traditional agriculture, representing by primary industry, which mainly refers to traditional agriculture, referring to traditional crop production. And it is commonly found that the agriculture in small towns still only focuses on production with low-industrialization level and little value-added. And the internal impetus of agricultural production in the township disconnects with the external market environment. Thus the economic development of most township is still at low level even it has good products.

Also, from the field surveys, it is found that lots of case townships are planning to develop tertiary industry, mainly referring to the tourism. Nevertheless, the tourism-oriented development model needs for commercial supports and professional skills, of which the townships in Southwest China usually lacks. Thus, it is difficult for townships to cultivate tourism with its own characteristics and attractiveness.

**Slowdown development of Township and Village Enterprises (TVEs)**

After the reform and opening-up policy, especially from the mid of 1980s, the rise of Township and Village Enterprises (TVEs) made tremendous promotion for the economic development of small towns.

While, with the growth of market-oriented economy and the beginning of ownership reform of TVEs in mainland China, the development of TVEs has shown a slowdown. The amount of TVEs and the capacity to absorb laboring power of TVEs continually decreased since the year 1997. From then on, the non-agricultural industry development of small towns has presented a sluggish condition.

**5.3 Social Barrier**

Many small towns particularly in Southwest China have been losing a lot of labor forces and talents during the urbanization process. China’s urbanization process has led to population flow from rural to either cities or small towns. According to the push-pull theory, the migration of population is implemented by the synergy of the “push force” from out-migrating area and the “pull force” of in-migrating area.

**Loss of labor-force population and lack of talents for township development**

In the field survey and investigation process, it is found that the development of economic industry and the public service of small towns usually present feebleness in terms of absorbing rural population, thus the “pull force” of small towns is weaker than that of cities at different scales. Under this circumstance, rural population tend to choose “mode one” to migrate into cities for jobs and education opportunities, resulting in the loss of labor-force and talents for small towns development.

During the field survey in Tanghe Township, according to the interview discussion, over 50% of labor-force population have left the township for cities to pursue better education for children and better employment opportunities for living. In fact, there is an urgent need for labors to participate in the township infrastructure construction. Tanghe township has planned to develop ancient town tourism, which needs for the inputs of labors and talents. The lack of labors and talents in Tanghe presents major barrier to the development of its tourism plan.

**Low level of township management**
Another social barrier for small towns development is the low level of management. The administrators of small towns are insufficient in amount and unprofessional at occupational skills to a large extent.

In light of the interview discussion in Tanghe, Dalucao, Lushi, Yanwo, Xiazi Townships, the official of local governments can always be multiple-job holding, and they are not capable to be professional at many different tasks in the same time. The segmentation positions severely lack professional counterparts, such as environmental resources utilization and protection, township tourism development. Furthermore, it is revealed from the interview discussion in case Township that the training programme for local governments officials is not professional, not relevant to the township development.

5.4 Ecologic Barrier

**Topographic complexity and limited carrying capacity of ecosystem**

In China, Southwest region is a typical mountainous area, in which the mountainous area takes up over 90% of the territory. The topography in this region tends to be various and complex, and the carrying capacity of ecosystem in this region is limited. These conditions hinder the development in cluster and scale in these townships. Therefore, the agriculture, infrastructure, industry and other aspects are severely lagged behind.

According to the field survey in Lushi Township, which is a typical mountainous township, the land in this township is barren and in steep gradient, which is neither drought resistant nor flood preventative. Consequently, the development in this township is largely hindered, with the evidence of low level of grain production and land desolation. In fact, it is difficult for the townships with poor topographic conditions to find alternative development approaches.

5. Conclusions

The urbanization process in China has brought dramatic economic improvement in the past several decades, while the disparity between urban-rural areas is still significant. As the connector and transfer station of cities and countryside, small towns play crucial roles in narrowing the gap between urban-rural areas and promoting the balanced and healthy urban-rural development. However, it appears that small towns particularly in Southwest China are underdeveloped to a large extent. This study examines the barriers to the development of small towns in Southwest China. These barriers are in multi-dimensions, 12 major barriers are identified. These barriers are analyzed and discussed in depth with the observations and interviews in 17 case townships.

The findings provide important reference to help find the approaches for the balanced urban-rural development. The application of these findings contributes to the policy establishment for a better township development. And the study contributes to enriching the literature in the field of urban-rural studies.
Acknowledgement

This study was supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant No. “15BJY038” and “15AZD025”.

Reference

Measuring the relationship between transport infrastructure and regional economic growth: the case of Chongqing

Chen, Y.1*, Zhou, Y.J.2, Wei, X.X.3 and Shen, L.Y.4

Abstract: Since the implementation of the ‘Great West Development Strategy’, the impact of the various means of transport road, air and water on local economic growth has remained controversial and undetermined, especially for the developing cities in Western China. This paper employs a grey relational model to examine the relationship between the various means of transport and regional economic growth over the period 2003-2015 using Chongqing as its case study. The results of the research suggest that air transport has the biggest influence on economic development followed by the introduction of expressways. In addition, the correlation between the various means of transport and economic growth in the rural areas is much weaker than in the urban areas. The research here provides valuable guidance for the relevant government departments for their transport plans and will help them determine a proper traffic layout so as to ensure the optimal development of the regional economy.

Key words: Transport infrastructure; Economic impact; Grey correlation model; Chongqing in China
1 Introduction

Accelerating the construction of transport infrastructure has always been regarded as a significant measure that can be taken to encourage economic development, especially in some developing countries such as China \cite{1}. Since 2000 the Chinese government has begun to implement an extensive long-term national strategy for supporting the Western region of China in an attempt to rectify the gap economically between the Eastern and Western regions. It is known as the ‘Great West Development Strategy’ \cite{2}. One of the main measures taken in support of this strategy has been to strengthen the construction of transport infrastructure such as highways, railways, airport, and waterways. However, some research results opined that the regional economic imbalance between the East and the West has not in fact seen any improvement in the past more than 10 years \cite{3}. In addition, the contribution that transport infrastructure investment has made to the Western economic growth has not been in line with expectations \cite{4}. Therefore, it is essential to find the right way forward out of this impasse so that we see transport infrastructure truly facilitating economic growth and government funding and investment being effective in the West. The key to solving these problems is to examine the relationship between the various means of transport and their impact on economic growth, and to determine what needs to be done with the various means of transport in the different stages of economic development.

Research has been conducted on these areas \cite{5-8}. For example, some scholars presented a two-order spatial econometric model to measure the relationship between transport accessibility and economic growth in Jiangsu province in China, and the results showed that the development of transport creates an economy-friendly climate \cite{9}. Furthermore, some scholars proposed that in Xinjiang province in China the extent of the interaction between transport accessibility and economic development greatly depends on the degree to which there is proper co-ordination between transport and the economy \cite{10}. However, some scholars have intimated that transport accessibility actually has no obvious impact on economic performance over time in Eastern Asia \cite{11}. The above research regards transport as a holistic system. Few of them focus on the relationship between the specific means of transport and economic performance. Indeed, there are some research papers which have studied the relationship between the specific means of transport and economic growth, but they only focused on one or two specific means of transport while ignoring the rest \cite{12, 13}. For example, some scholars mainly concentrated on the study of the correlation between railways and economic growth, and other means of transport were not included in their studies \cite{13}.

Research has tended to focus on the relationship between transport accessibility and economic growth, and it appears that little research has been conducted on the relationship between the spatial economic performance and different specific means of transport which constitute the holistic traffic system. Furthermore, there is little research focusing on Chongqing Municipality in China. Chongqing, as the sole municipality in Western China and the biggest economic center in the upper reaches of Changjiang River, is in the forefront of the process of implementing the ‘Great West Development Strategy’ \cite{14}. In recent years, Chongqing has been undergoing an economic transformation, and a new round of transport infrastructure planning and construction is now underway. How to devise a transport infrastructure layout which will effectively facilitate economic growth; how to optimize traffic systems, and how to avoid or reduce the loss of transport construction capital in Chongqing, are key issues for relevant
departments. Therefore, there is an urgent need to measure the relationship between different specific means of transport and the spatial economic performance in Chongqing. An understanding of this area will assist in determining both the scale of construction and the layout of the different modes of transport in Chongqing.

The aim of this study is to provide guidance for relevant government departments as to the layout of various transport constructions. The specific objective of this study is, therefore, defined as measuring the relationship between various transport infrastructure and regional economic growth with reference to Chongqing Municipality of China.

2 Research methods

In order to pursue the research aims, the grey relational analysis method is introduced to measure the relationship between the various transport infrastructure and regional economic growth. The best indicators for measuring the status of transport construction and regional economic performance will be selected. The validity of these indicators will be discussed through interviews. Data about the performance of these indicators has been collected and can be found in the Chongqing Statistical Yearbook (2003-2015).

Grey relational analysis has been widely employed in the field of the dynamic assessment of sustainability performance [19, 20], decision making on multiple objectives [21-24], research on industrial structure [25, 26], and factor analysis [27]. It is based on the principle that objects are more closely correlated if their developing tendencies are extremely similar or different. But the prerequisite of using grey relational analysis is that the interrelationship of the objects must exist [24]. Compared with regression analysis, variance analysis and principal component analysis, grey relational analysis overcomes the disadvantages of failing to deal with the non-optimal data, demanding large amounts of data, and the heavy burden of data operation. It can even avoid the occurrence of abnormal calculation results [28]. Therefore, grey relational analysis is quite suitable to be used in this study to measure how close the correlation degree between different subjects is.

The procedure for using the grey relational analysis for measuring the relationship between various transport infrastructure and regional economic growth is as follows.

Step 1 Reference and comparative sequence definition

Reference sequence should be defined when employing the grey relational analysis. The reference sequence is the basis for comparing data sequences of the other factors in the system, and is the intermediary series used to describe the changing trends among the data series, which can be selected or specified. The reference sequence is defined as $X_0=\{X_0(k) | k=1, 2, \cdots, t \};$ and the comparative sequences which influence the behavior of a system is defined as $X_i=\{X_i(k) | k=1, 2, \cdots, t \}, i=1, 2, \cdots, n; k$ stands for different time.

Step 2 Normalization of variables

The units of these sequences are different from each other, and the data cannot be calculated directly. It is necessary to normalize these sequences based on following equation:

$$x_i(k) = \frac{X_i(k)}{X_i(I)}, \quad k = 1, 2, \cdots, t; \quad i = 1, 2, \cdots, n$$  \hspace{1cm} (1)

where $x_i(k)$ denotes normalized sequence; $X_i(I)$ denotes standard value, which can be chosen from reference sequence or other references; $X_i(K)$ denotes the sequence needed to be normalized.
Step 3 Calculation of correlation coefficient

The correlation coefficients between reference sequence $X_o(k)$ and comparative sequence $X_i(k)$ can be evaluated as follows:

$$\xi_i(k) = \frac{\min_{i} \min_{k} |x_o(k) - x_i(k)| + \rho \cdot \max_{i} \max_{k} |x_o(k) - x_i(k)|}{|x_o(k) - x_i(k)| + \rho \cdot \max_{i} \max_{k} |x_o(k) - x_i(k)|}, k = 1, 2, \ldots, t$$

(2)

Where $\xi_i(k)$ denotes the correlation coefficient between comparative sequence $X_i$ and reference sequence $X_o$ in time $k$; $\rho$ denotes distinguishing coefficient which will affect the distinguishing information degree. Its value range is $(0, 1)$, and the smaller its specific value is, the greater the difference between the correlation coefficients. In this paper, the value of $\rho$ is specified as 0.5.

Step 4 Calculation of correlation degree

The correlation coefficient is the degree of association between the comparative sequence and reference sequence at different moments. If it is more than one, the distinguishing information is too scattered to facilitate a holistic comparison. Therefore, it is necessary to concentrate the correlation coefficients of each moment into a value, that is, to calculate their average value which is expressed as the correlation degree between the comparative sequence and the reference sequence. The correlation degree can be calculated as follows:

$$r_i = \frac{1}{t} \sum_{k=1}^{t} \xi_i(k), k = 1, 2, \ldots, t$$

(3)

where $r_i$ denotes the correlation degree between the comparative sequence and reference sequence at $k$ moment.

Step 5 Sequencing of correlation degree

The correlations $r_i$ are ranked from high value to low. If $r_1 < r_2$, reference sequence $X_o$ is more similar to the comparative sequence $X_2$. That means the correlation degree between the reference sequence $X_o$ and comparative sequence $X_2$ is closer than that with the comparative sequence $X_1$.

After sequencing the correlation degrees, the extent of interaction between the various means of transport and economic performance can be examined. In other words, the relationship between various transport infrastructure and regional economic growth can be measured. And then, semi-structured interviews with officials who work in the traffic department in Chongqing have been conducted for the purpose of seeing what the far-reaching implications of these results might be.

3 Data collection

This section consists of two parts. The first part presents specific indicators which are selected in a principled way. And the second part briefly describes the data collection process and gives a presentation of the data.

3.1 Establishment of indicators

In the pursuit of developing a set of effective indicators for guiding relevant government departments in their layout of various transport constructions, some principles should be followed. (1) Purpose-driven: In general, different indicators are going to serve different purposes. It is
therefore necessary to link indicators to specific research aims\textsuperscript{15}.\n\hspace{1em}(2) Applicability: The indicators selected to measure the performance of transport construction and economic growth should be available through the means of current technology and specific situations\textsuperscript{16}.
\hspace{1em}(3) Locality: The selection of indicators should take local characteristics into consideration.

The indicators which can holistically reflect the transport infrastructure construction in Chongqing are selected with regard to the above principles, including length of navigable inland waterways, length of railways in operation, length of highways, length of expressway, and throughput of civil aircraft in Chongqing airport. And the indicators by economic performance are assessed include gross domestic product (GDP), per capita GDP, GDP of the tertiary industry, GDP of transport, total number of employed persons in tertiary industry, and per capita annual disposable income.

After the selection of indicators, the validity of these indicators is analyzed by conducting interviews with three experts (coded as I\textsubscript{1}, I\textsubscript{2}, I\textsubscript{3}). Interviewee I\textsubscript{1} has been engaged for 8 years in the study of sustainable transport and is presently a professor in Southwest Jiaotong University. Interviewee I\textsubscript{2} has worked in the Chongqing Traffic Sector for 10 years and has held the position of head of Chongqing Traffic Commission since 2014. And interviewee I\textsubscript{3} is a professor in Chongqing University who has spent several years studying the regional economic development.

Interviewee I\textsubscript{1} and I\textsubscript{3} both agree with the selection of those traffic-related indicators, as they are a good reflection of the state of transport construction in regard to land, air and water. But they emphasize that Chongqing is known as “Bridge City” because of its abundant inland water, and bridges should be taken as an important part of transport infrastructure in Chongqing. Therefore, the “extended length of highway-bridges” is a part of the indicator system. Interviewee I\textsubscript{2} advises that light rail, which is supported by the Chongqing municipal government, should definitely be seen as a very important part of the transport system. Thus the number of light rail transit vehicles under operation is included as an indicator. In addition, interviewee I\textsubscript{1} and I\textsubscript{3} suggest that the single category per capita annual disposable income should be replaced by per capita annual net income of rural households and per capita annual disposable income of urban households because the various means of transport impact urban areas and rural regions differently.

Based on the above discussions, the indicator system established includes 7 items from the perspective of transportation construction and 7 items from the perspective of economic performance as shown in Table 1.

| Table 1. Establishment of indicator system |
|-----------------|----------------|----------------|
| **Dimension**    | **Code**      | **Indicators**             |
| Transportation   | T\textsubscript{1} | Length of navigable inland waterways (km) |
| infrastructure   | T\textsubscript{2} | Extended length of highway-bridges (extended meter) |
|                   | T\textsubscript{3} | Length of railways in operation (km) |
|                   | T\textsubscript{4} | Length of highways (km) |
|                   | T\textsubscript{5} | Length of expressway (km) |
|                   | T\textsubscript{6} | Throughput of civil aircrafts in Chongqing airport (10,000 flights) |
|                   | T\textsubscript{7} | Number of light rail transit vehicles under operation (unit) |
| Economic performance | E\textsubscript{1} | Gross domestic product (billion yuan) |
|                   | E\textsubscript{2} | Per capita GDP (yuan) |
E₃  Gross domestic product of tertiary industry (billion yuan)
E₄  Gross domestic product of transportation, storage, postal services (billion yuan)
E₅  Total number of employed persons in tertiary industry (10,000 persons)
E₆  Per capita annual net income of rural households (yuan)
E₇  Per capita annual disposable income of urban households (yuan)

### 3.2 Data collection

With the need to clearly understand the relationship between transport construction and economic growth during the period of implementing the Great West Development Strategy in Chongqing, it is essential that the data selected for that period of time must be a true reflection of what was occurring during that period of time. It was in the year 2000 that Chinese Central Government first proposed the 'Great West Development Strategy’. And after two years, related policies are being put into effect in Chongqing [17]. Therefore, the data is collected from 2003 to 2015. It should be noted that light rail in Chongqing has been operating since 2005. Thus the data for the years 2003 and 2004 is lacking. According to the theory of grey relational analysis, the research results will not be influenced because of the lack of a snapshot of information [18]. In other words, this method can overcome this drawback. Thus the values of “number of light rail transit vehicles under operation” in 2003 and 2004 are equal to zero.

Data about the performance of the above indicators are collected from the Chongqing Statistical Yearbook (2003-2015) as presented in Table 2.

**Table 2. Transportation constructions and economic growth in Chongqing**

<table>
<thead>
<tr>
<th>Year</th>
<th>Indicators</th>
<th>E₁</th>
<th>E₂</th>
<th>E₃</th>
<th>E₄</th>
<th>E₅</th>
<th>E₆</th>
<th>E₇</th>
<th>T₁</th>
<th>T₂</th>
<th>T₃</th>
<th>T₄</th>
<th>T₅</th>
<th>T₆</th>
<th>T₇</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td></td>
<td>2556</td>
<td>9098</td>
<td>1081</td>
<td>167</td>
<td>476</td>
<td>2215</td>
<td>8094</td>
<td>4086</td>
<td>210699</td>
<td>632</td>
<td>31407</td>
<td>580</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td></td>
<td>3035</td>
<td>10845</td>
<td>1230</td>
<td>191</td>
<td>486</td>
<td>2510</td>
<td>9221</td>
<td>4222</td>
<td>248278</td>
<td>632</td>
<td>32344</td>
<td>714</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td>3468</td>
<td>12404</td>
<td>1440</td>
<td>219</td>
<td>495</td>
<td>2809</td>
<td>10244</td>
<td>4222</td>
<td>352913</td>
<td>1117</td>
<td>98218</td>
<td>748</td>
<td>7</td>
<td>40</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>3907</td>
<td>13939</td>
<td>1649</td>
<td>260</td>
<td>504</td>
<td>2874</td>
<td>11570</td>
<td>4337</td>
<td>363719</td>
<td>1262</td>
<td>100299</td>
<td>778</td>
<td>9</td>
<td>52</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>4676</td>
<td>16629</td>
<td>2012</td>
<td>294</td>
<td>516</td>
<td>3509</td>
<td>13715</td>
<td>4337</td>
<td>396557</td>
<td>1257</td>
<td>104705</td>
<td>1049</td>
<td>11</td>
<td>60</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td>5794</td>
<td>20490</td>
<td>2632</td>
<td>377</td>
<td>533</td>
<td>4126</td>
<td>15709</td>
<td>4337</td>
<td>417727</td>
<td>1258</td>
<td>108632</td>
<td>1165</td>
<td>11</td>
<td>60</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>6530</td>
<td>22920</td>
<td>2985</td>
<td>428</td>
<td>549</td>
<td>4478</td>
<td>17191</td>
<td>4337</td>
<td>519804</td>
<td>1285</td>
<td>110951</td>
<td>1577</td>
<td>13</td>
<td>136</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>7926</td>
<td>27596</td>
<td>3709</td>
<td>501</td>
<td>567</td>
<td>5277</td>
<td>19100</td>
<td>4451</td>
<td>598892</td>
<td>1396</td>
<td>116949</td>
<td>1861</td>
<td>15</td>
<td>108</td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td>10011</td>
<td>34500</td>
<td>4704</td>
<td>592</td>
<td>590</td>
<td>6480</td>
<td>21955</td>
<td>4451</td>
<td>606928</td>
<td>1386</td>
<td>118562</td>
<td>1861</td>
<td>17</td>
<td>296</td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td>11410</td>
<td>38914</td>
<td>5295</td>
<td>604</td>
<td>618</td>
<td>7383</td>
<td>22968</td>
<td>4451</td>
<td>620520</td>
<td>1452</td>
<td>120728</td>
<td>1909</td>
<td>20</td>
<td>558</td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td>12783</td>
<td>43223</td>
<td>5968</td>
<td>660</td>
<td>650</td>
<td>8332</td>
<td>23058</td>
<td>4451</td>
<td>700664</td>
<td>1680</td>
<td>122846</td>
<td>2312</td>
<td>21</td>
<td>702</td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td>14263</td>
<td>47850</td>
<td>6673</td>
<td>706</td>
<td>677</td>
<td>9490</td>
<td>25147</td>
<td>4451</td>
<td>711530</td>
<td>1774</td>
<td>127392</td>
<td>2401</td>
<td>24</td>
<td>888</td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td>15717</td>
<td>52321</td>
<td>7498</td>
<td>761</td>
<td>707</td>
<td>10505</td>
<td>27239</td>
<td>4451</td>
<td>760912</td>
<td>1929</td>
<td>140551</td>
<td>2525</td>
<td>27</td>
<td>1208</td>
</tr>
</tbody>
</table>

Remarks: For the detailed description of the data meaning, please refer to the Table 1.

### 4 Data analysis

This section will analyze data presented in previous sections by employing grey relational analysis. In this study, sequence T₁, T₂, T₃, T₄, T₅, T₆, and T₇ are defined as the reference sequences, and sequence E₁, E₂, E₃, E₄, E₅, E₆, and E₇ are defined as the comparative sequences.
In applying the data in Table 2 to the Model (1), it has been assumed that the sequence in the year 2015 is taken as standard value for the normalization of variables. The results of data normalization for each year have been obtained, as shown in Table 3.

**Table 3. Normalization of variables**

<table>
<thead>
<tr>
<th>Year</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$E_1$</td>
</tr>
<tr>
<td>2003</td>
<td>0.163</td>
</tr>
<tr>
<td>2004</td>
<td>0.193</td>
</tr>
<tr>
<td>2005</td>
<td>0.221</td>
</tr>
<tr>
<td>2006</td>
<td>0.249</td>
</tr>
<tr>
<td>2007</td>
<td>0.298</td>
</tr>
<tr>
<td>2008</td>
<td>0.369</td>
</tr>
<tr>
<td>2009</td>
<td>0.415</td>
</tr>
<tr>
<td>2010</td>
<td>0.504</td>
</tr>
<tr>
<td>2011</td>
<td>0.637</td>
</tr>
<tr>
<td>2012</td>
<td>0.726</td>
</tr>
<tr>
<td>2013</td>
<td>0.813</td>
</tr>
<tr>
<td>2014</td>
<td>0.907</td>
</tr>
<tr>
<td>2015</td>
<td>1.000</td>
</tr>
</tbody>
</table>

By applying the data normalized in Table 3 to the Model (2), the correlation coefficients between transport construction and economic growth can be calculated. As the calculation process is complicated, the statistic software MATLAB2013b is employed. The calculation results are shown in the following correlation coefficient matrices.

$$
\xi_{E_1-T_1}(k) =
\begin{pmatrix}
0.333 & 0.333 & 0.341 & 0.342 & 0.358 & 0.384 & 0.403 & 0.432 & 0.510 & 0.579 & 0.669 & 0.803 \\
0.768 & 0.739 & 0.608 & 0.622 & 0.628 & 0.677 & 0.585 & 0.572 & 0.701 & 0.808 & 0.778 & 0.932 \\
0.696 & 0.737 & 0.513 & 0.482 & 0.516 & 0.571 & 0.601 & 0.632 & 0.822 & 0.934 & 0.868 & 0.969 \\
0.861 & 0.911 & 0.441 & 0.448 & 0.458 & 0.483 & 0.502 & 0.535 & 0.646 & 0.739 & 0.861 & 0.997 \\
0.849 & 0.808 & 0.833 & 0.864 & 0.762 & 0.803 & 0.644 & 0.619 & 0.790 & 0.926 & 0.787 & 0.897 \\
0.886 & 0.883 & 0.875 & 0.814 & 0.794 & 0.873 & 0.819 & 0.862 & 0.989 & 0.944 & 0.973 & 0.969 \\
0.699 & 0.662 & 0.668 & 0.647 & 0.604 & 0.542 & 0.555 & 0.476 & 0.491 & 0.588 & 0.619 & 0.687 \\
\end{pmatrix}
$$

$$
\xi_{E_2-T_2}(k) =
\begin{pmatrix}
0.333 & 0.334 & 0.343 & 0.344 & 0.362 & 0.390 & 0.410 & 0.440 & 0.522 & 0.592 & 0.681 & 0.813 \\
0.783 & 0.758 & 0.621 & 0.637 & 0.647 & 0.703 & 0.603 & 0.589 & 0.729 & 0.838 & 0.797 & 0.948 \\
0.708 & 0.756 & 0.521 & 0.490 & 0.527 & 0.588 & 0.620 & 0.555 & 0.863 & 0.976 & 0.893 & 0.986 \\
0.882 & 0.942 & 0.446 & 0.454 & 0.466 & 0.494 & 0.514 & 0.550 & 0.669 & 0.764 & 0.886 & 0.979 \\
0.870 & 0.831 & 0.863 & 0.899 & 0.792 & 0.842 & 0.666 & 0.640 & 0.827 & 0.968 & 0.806 & 0.911 \\
0.909 & 0.912 & 0.909 & 0.845 & 0.828 & 0.921 & 0.860 & 0.909 & 0.953 & 0.988 & 0.941 & 0.951 \\
0.681 & 0.642 & 0.646 & 0.625 & 0.581 & 0.521 & 0.533 & 0.459 & 0.473 & 0.569 & 0.603 & 0.675 \\
\end{pmatrix}
$$

$$
\xi_{E_3-T_3}(k) =
$$
By following the example, other coefficient degrees between other economic performance indicators and various transport indicators can be obtained. Ultimately, the calculation results can be classified as a correlation degree matrix, shown as follows:

$$r_{E1-T1} = 0.499; \quad r_{E1-T2} = 0.724; \quad r_{E1-T3} = 0.719; \quad r_{E1-T4} = 0.683;$$

$$r_{E1-T5} = 0.814; \quad r_{E1-T6} = 0.899; \quad r_{E1-T7} = 0.634$$
Based on the above correlation degree matrix, the dominance degrees of various transportation means are ordered as follows:

\[ I \quad r_{E1-T6} > r_{E1-T5} > r_{E1-T2} > r_{E1-T3} > r_{E1-T4} > r_{E1-T7} > r_{E1-T1} \]

\[ II \quad r_{E2-T6} > r_{E2-T5} > r_{E2-T2} > r_{E2-T3} > r_{E2-T4} > r_{E2-T7} > r_{E2-T1} \]

\[ III \quad r_{E3-T6} > r_{E3-T5} > r_{E3-T2} > r_{E3-T3} > r_{E3-T4} > r_{E3-T7} > r_{E3-T1} \]

\[ IV \quad r_{E4-T5} > r_{E4-T6} > r_{E4-T2} > r_{E4-T3} > r_{E4-T4} > r_{E4-T7} > r_{E4-T1} \]

\[ V \quad r_{E5-T4} > r_{E5-T6} > r_{E5-T2} > r_{E5-T5} > r_{E5-T1} > r_{E5-T6} > r_{E5-T7} \]

\[ VI \quad r_{E6-T5} > r_{E6-T6} > r_{E6-T2} > r_{E6-T3} > r_{E6-T4} > r_{E6-T7} > r_{E6-T1} \]

\[ VII \quad r_{E7-T2} > r_{E7-T5} > r_{E7-T3} > r_{E7-T6} > r_{E7-T4} > r_{E7-T1} > r_{E7-T1} \]

For example, based on the inequality \( I \), it is understood that the factor of \( T_6 \), namely, that the airport is most closely correlated with gross domestic product (\( E_1 \)) in Chongqing, and was followed by the expressway, bridge, railway, highway, light-rail, and shipping. Thus the construction of the airport has the most significant impact on the GDP level, and the impact of other transport factors follow on from that according to their significance. The principle of other inequalities can be interpreted as the same as inequality \( I \).

5 Discussion

Discussions on the above research results are conducted by engaging a semi-structured interview in order to gain an in-depth understanding of the implications of the sequences of dominance degrees. Interviewees \( I_1 \), \( I_2 \), and \( I_3 \) are invited again for this discussion. In addition, another three interviewees (coded as \( I_4 \), \( I_5 \), and \( I_6 \)) are invited. Interview \( I_4 \) is the vice-president of Jiangjin Fairway Management Section of Chongqing in China. Interviewee \( I_5 \) is a professor who focuses on the study of sustainable public infrastructure in Southwestern University in Chongqing. And interviewee \( I_6 \) is a PhD student in Chongqing University who is working on the study of sustainable urbanization.

By referring to the dominance degrees between transportation infrastructure means and economic performance in the previous section, it was observed that the indicators including airport, expressway, bridge, railway, highway, light-rail, and shipping are closely related to those indicators of economic performance, and the dominance degrees are almost higher than 0.6, some even higher than 0.8, which to some extent means the expansion of transportation system has a great and positive influence on economic growth over the period 2003-2015. It was found that the
six interviewees are united in proposing the view that Chongqing’s transportation infrastructure has a direct impact on local development and is a strong driving force for local economic development, and the value of supporting funding provided by the Great West Development Strategy is fully realized. Furthermore, in the future, Chongqing will continue to be entrusted with the mission of being the engine house in the drive to see the Southwest develop.

Although the transport infrastructure system has played a significant role in the development of economy, different means of traffic have different levels of influence. Compared to other means of transport, the airport has the greatest correlation with GDP ($E_1$), per capita GDP ($E_2$), GDP of tertiary industry ($E_3$), GDP of transport ($E_4$), and per capita annual net income of rural households ($E_6$) respectively, which means air transport has the greatest impact on economic growth in Chongqing. This is corroborated in the discussions. Respondent I3 explained that air transportation usually provides a quality and expensive service for time-sensitive customers or goods; therefore, this way of transport is frequently utilized in a region which is dominated by third industry. It is interesting to note that the proportion of the industrial structure of Chongqing in the primary, second and third industry is $7.3:45.0:47.7$ in 2015, and the proportion of the third industry has been rapidly increasing in recent years, which means the third industry develops quite actively, and gradually occupies the leading position in the economic growth. That is why it makes sense that air transport has the greatest influence on the economic development in Chongqing. However, in referring to the research results in the previous section, air transport has the lowest contribution rate to the growth of employed persons in tertiary industry. Respondent I2 opined that this phenomenon is due, to a great extent, to fixed air-line, fixed take-off and landing times, inflexible airports and a monopoly operation model in air transport. In addition, the air transport management and operations harness a sophisticated system and high-tech devices. These characteristics make air transport rigid and mean it has limited value in improving employment prospects. It has been suggested that local government should consider improving the upstream and downstream chains of air transport and impose more regulations on the management of air services in order to maintain the competitiveness of air transport and continuously drive economic growth forward in Chongqing.

It is furthermore interesting to note that the dominance degree between water transport and economic development is lower than other modes of transportation. Interviewee I1 and I4 asserted that the lower dominance degree does not means water transport makes little contribution to the economic development. On the contrary, water transportation has played an important role in business and logistics from the central and western regions to Chongqing. The reason for such a contradictory result is that the development of Chongqing waterways is relatively static and it is hard to make further gains in such a short time. Another reason is that shipping, to a large extent, relies on natural inland waterways or port endowments; therefore, it is difficult to develop other large-scale channels. These factors mean that water transport is contributing less than other transport models. In other words, the lower dominance degree of water transport to economic growth is due to different changing trends between the growth speed of water transport and the growth rate of economy in Chongqing.

Moreover, from the perspective of per capita annual net income of rural households and urban households, it appears that the dominance degrees of various transport infrastructure with per capita annual net income of rural households is obviously lower than that of the per capita
annual disposable income of urban households, which means the effectiveness of transport investment in rural areas is not as satisfactory as that in urban areas. The next step in traffic planning and construction in Chongqing is to consider how to drive the economic development of rural areas, how to open up the sales and transport channels of agricultural products, and how to improve the transportation efficiency in rural areas.

### 6 Conclusion

This paper employs a grey relational model to measure the relationship between the various means of transport and regional economic growth over time based on the case of Chongqing. It concludes that, in general, air transport plays the most significant role on economic growth in Chongqing, followed by expressways. The construction of bridges and railways has a great influence on promoting the economic development of Chongqing. However, the effectiveness of them is slightly lower than that of air transport and the highways. It has been suggested that government needs to pay more attention to optimizing the portfolio of various means of transport. Furthermore, the increase in transport infrastructure affects rural economic development far less than urban economic development. Therefore, a new round of planning for traffic is needed for rural economic development and it is a key emphasis in future work.

The research results provide valuable information for relevant government departments for determining the manner and layout of various transport construction. Armed with an in-depth understanding of the specific relationship between economic growth and various transport constructions, decision-makers will have clear ideas on how they might balance the gap between urban and rural areas in regard to transport layout and construction. The research methods employed in this paper are suitable for use in other regions in the Southwest China. This research is also expected to inspire further research work particularly in the following:

- Examining how transport construction can effectively drive forward rural economic development and narrow the gap between urban and rural areas.
- Deciding what transport layout is useful for creating more employment opportunities.

### Acknowledges

This research work is supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant Nos. “15AZD025” and “15BJY038”.

### References


[4] Liu Xuehua1, Zhang Xueliang, Peng Mingming. Traffic infrastructure investment and


Research on stage characteristics of low carbon city

Ya Wu ¹, Chenyang Shuai ², Hang Yan ³, Xiaolin Zhang ⁴

Abstract: Developing low-carbon city (LCC) is an important strategy for achieving carbon emission reduction. However, cities present different development stages and characteristics. Different from previous studies on dividing development stages by a single economic-index, this study develops an economic development stage framework by incorporating carbon emission characteristics with associating to Environmental Kuznets Curve (EKC), and analyze the performance of characteristics impact on carbon emission in different stages. The Kaya Identity is adopted to decompose emission characteristics into energy structure (ES), energy intensity (EI), economic output (EO), industrial structure (IS) and population scale (P). Results show that these five emission characteristics have different performances in different development stages, simply imitating or copying existing experience of low-carbon city (LCC) will not be effective. The findings not only provide decision-makers with scientific basis for taking effective measures to reduce carbon emission, but also provide cities internationally a new approach for establishing LCC through focusing on different development stages.

Keywords: Low carbon city; Development stage; Emission characteristics; Environmental Kuznets Curve (EKC); Kaya Identity.

¹ Ya WU
Corresponding author, School of Construction Management & Real Estate, Chongqing University, China
International Research center for Sustainable Built Environment, Chongqing University, China
Email: mswuya@126.com

² Chenyang Shuai
School of Construction Management & Real Estate, International Research center for Sustainable Built Environment, Chongqing University, China.
Department of Building & Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong.

³ Hang YAN
School of Construction Management & Real Estate, Chongqing University, China
International Research center for Sustainable Built Environment, Chongqing University, China

⁴ Xiaolin Zhang
Department of Public Policy, City University of Hong Kong, Hong Kong
1. Introduction

It is commonly appreciated that Climate change caused by carbon emission has led to temperature increase and sea level rise as well as more frequent extreme climate events in global context, and become a severe threat to natural ecological system and human beings [1-3]. Conducting carbon emission reduction has become a top agenda at global level. As the basic unit of economic growth and development engines, cities account for 70% of global energy consumption and 70% of global carbon emission. Additionally, owing to the inherent resource and technology, cities have great potential to carbon emission reduction [4, 5]. In this regard, developing low carbon city (LCC) is the necessary choice for in addressing global warming.

In fact, an increasing number of cities have launched their own low-carbon initiatives. It was reported that approximately 1050 cities in the United State, 40 cities in India, 100 cities in China, 83 cities in Japan established an objective of low-carbon development [6, 7]. All these sustainable initiatives have produced a large amount of valuable experiences on how to formulate low carbon strategies which may be similar to what experienced in the past [8]. For example, the Chinese government has launched a demonstration program of pilot low carbon city since 2010, and the experience from these pilot cities have been investigated and recommended for extension to the whole country [9]. However, cities have different characteristics (e.g., industrial structure, economic development, urbanization), and are at different development stages with varying carbon emission performance [10, 11]. Simply imitating or copying existing low carbon development experience at city level without consideration of characteristics in different development stages may not be adaptable to solve effectively a target problem [8]. Moreover, Lu, Qin [12] further pointed out the fact that owing to cities are at different development stages and have different characteristics accordingly, comprehensive understanding of low carbon city is a remaining issue to be solved. Thus, further study with careful consideration of the different development stages and different characteristics at city level are imperative.

Although an increasing number of studies are now focusing on low carbon city development, there is little existing study in addressing how to analyze the development stages at city level. Kang, Zhao [13] performed a decomposition analysis on the greenhouse gas emission in Tianjin during the periods 2001-2005 and 2005-2009, which shows that economic growth was the most important factor for the increase in emission. Wang and Yang [14] studied the delinking phenomenon between industrial growth and environmental pressures in the Beijing-Tianjin-Hebei economic band from 1996 to 2010, by separating the survey period into three stages, namely, 1996-2000 (the 9th Five-year Plan), 2001-2005 (the 10th Five-year Plan) and 2006-2010 (the 11th Five-year Plan). Xu, Han [15] investigated empirically the effects of energy structure, energy intensity, proportional output on national carbon intensity in different regions from the perspective of the Chinese Five-year Plan. Dhakal, Kaneko [16] pointed out that per capita carbon emission in cities at higher economic development stages (Tokyo and Seoul) were lower than that at lower economic development stages (Beijing and Shanghai). The literature above appreciate that few researchers adopted different development stages at city level according to economic performance. Nevertheless, the economic division on development stages conveyed little information on carbon emission characteristics, which is significant for adopting emission mitigation measures. It is necessary to define development stages with consideration of both economic performance and carbon emission characteristics [17]. In this regard, Environmental Kuznets Curve (EKC) which
suggests that economic growth and environmental friendliness are related, providing a theoretical basis for defining development stage framework by incorporating carbon emission characteristics and economic performance [18, 19].

The objectives of this study are: (1) developing a development-stage framework that can reflect the complex processes of LCC development by associating to EKC. (2) Analyzing the city characteristics based on the development stage framework accordingly. The findings provide references not only for scholars to advance the existing literature on low carbon city, but also for governments to enact effective and targeted emission reduction measures according to their stage characteristics.

2. Research methods

To realize the two objectives above, the research works are planned to two tasks.

2.1 EKC hypothesis

EKC hypothesis describes that the relationship between environmental quality and economic development (per capita) is plotted as an inverted U-shape curve [19]. In other words, this hypothesis implies that although economic growth usually results in environmental deterioration in the early stage, it was mostly likely to attain a decent environment when economic development reaches a certain level [20]. This theory has been widely adopted in academic research and policy, and the validity has generated a rich literature [21]. Particularly, it was also widely used for analyzing the relationship between carbon emission and economic growth [22].

Conventionally, a typical EKC is tested by the following model [23]:

\[ \ln y = \beta_0 + \beta_1 (\ln x) + \beta_2 (\ln x)^2 + \beta_3 (\ln x)^3 + \epsilon \]  \hspace{1cm} (1)

Where the \( y \) is the dependent variable, namely the carbon emission measure in this study, \( x \) is the independent variable of per capita GDP. \( \beta_0, \beta_1, \beta_2, \beta_3 \) are the estimated coefficients, \( \epsilon \) represents the error term. When \( \beta_1 > 0, \beta_2 < 0 \) and \( \beta_3 = 0 \), then an inverted U curve will be obtained, this curve is called an EKC.

2.2 Identifying characteristics impact on carbon emission by Kaya Identity

To identify characteristics impact on carbon emission, there are various methods. Among which, IPAT (the impact of population, affluence and technology), STIRPAT (stochastic impact by regression on population, affluence and technology) and the Kaya Identity are the main approaches [24]. However, it is considered that the results from the IPAT and STIRPAT models are quite changeable in comparing to that from Kaya Identity. This may owing to the fact that the two methods identify emission factors from the perspective of population, affluence and technology, while these three factors can be denoted by various indicators, for example population consist of population scale, population age structure, urbanization. Thus, this study adopts the Kaya Identity to identify emission characteristics at city level.

According to Kaya identity, the carbon emission (\( C \)) is expressed as follows [25]:

\[ C = \frac{E}{E} \times \frac{E}{GDP} \times \frac{GDP}{P} \times P = ES \times EI \times EO \times P \]  \hspace{1cm} (2)
To analyze industrial structure, which have significant influence on energy conservation and carbon emission, the carbon emission for the industry \( m \) can be written as:

\[
C_m = \frac{C_m}{E_m} \times \frac{E_m}{GDP_m} \times \frac{GDP_m}{GDP} \times \frac{GDP}{P} \times P = ES_m \times EI_m \times IS_m \times EO \times P \tag{3}
\]

Where \( C_m \) is carbon emission of industry \( m \), \( E_m \) is energy consumption of industry \( m \), \( GDP_m \) is the GDP output of industry \( m \). Thus, factors influencing carbon emission can be decomposed as energy structure \((C/E)\), denoted as ES; energy intensity \((E/GDP)\), denoted as EI; industrial structure \((GDP_m/GDP)\), denoted as IS; economic output \((GDP/P)\), denoted as EO; and population scale \( P \). In this study, we consider three industries, including primary industry, secondary industry, and tertiary industry. In other words, \( m \) assumes a value of three.

3. Results and discussion

3.1 Developing a development stage framework

Based on EKC principle, economic growth and carbon emission can be incorporated by an inverted U curve, and this provides a theoretical basis for defining development stage framework. In fact, the research by Chen, Liu [26] opined that there are three kinds of successive EKCs between carbon emission and economic growth (per capita GDP), namely the EKC of carbon emission intensity, EKC of carbon emission per capita, and EKC of total carbon emission respectively, as graphically shown in Figure (1).
It can be observed from Figure 1 that each EKC have a turning point (TP), and the three turning points (TP_M, TP_N, and TP_P) appear successively. By using these three TPs, four stages can be identified, namely S_1, S_2, S_3 and S_4. In fact, it is widely appreciated that carbon emission intensity, per capita carbon emission and total carbon emission are the most important indicators to describe carbon emission characteristics [27].

3.2 Analyzing the emission characteristics in different stages

In referring to the development stage framework in Figure 1, each stage corresponds to different characteristics in the growth process. The details of the characteristics of the five emission force (ES, EI, IS, EO, and P) are shown in Table 1.

For stage S_1, it is in the prometaphase of industrial stage. Owing to the fact that prioritization of economic growth, large amount of population migration from rural to urban areas, and massive fossil consumed [28], all the three carbon indicators increase in the stage [29]. This is called the scale effect on carbon emission. In other words, the increase of carbon emission is mainly generated as a result of increasing production and extraction of energy resources [30]. Simultaneously, the rapid economic growth gives the opportunity of improving production techniques. On one hand, this technological progress contribute to the decrease of energy intensity, and offsetting the carbon emission [31]. On the other hand, the improvement in technology can propel the plant capacity, and discharge larger amount of carbon emission. Thus, all the five emission factors are contributor to carbon emission increase in this stage.

When technological progress reach a certain level, the outdated technology will be eliminated and energy efficiency will be improvement. This results in the increasing speed of carbon emission is slower than that of economic development, and the carbon emission per GDP will decrease. That is the turning point for carbon intensity, and symbolize the coming for stage S_2. In stage S_2, carbon intensity is decreasing, while per capita carbon emission and total carbon emission are increasing. Economic growth is still the top priority, and the emerging economic activities inevitably lead to the increase of carbon emission [17]. Particularly, this dramatically increase of economy is mainly due to secondary industry, which mainly depends on fossil fuels and accounts for the largest proportion of energy consumption and carbon emission [32]. Thus, both per capita carbon emission and total carbon emission growth fast. Similarly, great advances have been made in technology, when the decrease of carbon intensity is faster than the increase of per capita GDP, the turning point for per capita carbon emission will obtain.

At the phase S_3, both carbon intensity and per capita carbon emission are decreasing, while total carbon emission is still increasing. However, with the improvement of economic development, followed by improved social indicators and households’ willing to environmental protection, the local government are concerned more with environmental quality. In other words, when economy developing to certain extent, cities would like to spare more efforts on the quality of economic growth rather than the speed [1, 33]. To do that efficient, the energy structure of the oil-depended or coal depended had to be transformed with the cleaner energy, while the heavy industry had to shift towards information-based industries and services which are less polluting. Moreover, the development of cleaner technologies which can substitute the old and dirtier
technologies for productions are required \cite{34}. However, the accelerated urbanization and industrialization in cities lead to the energy structure dominated by coal cannot be changed in the short term, as well as the upgrade of industrial structure \cite{17}. Consequently, the total carbon emission will remain to be increasing for a period.

In fact, total amount target is difficult to achieve, due to it has great negative effects on economic growth than the intensity targets and per capia target, as well as has more complex impact factors \cite{35, 36}. As the economy crosses the industrialization stage and moves to the post-industrialization, improved technology and environmental protection consciousness diffusion limit the material basis of economy and result in reduced carbon emission \cite{37}. In this regard, the renewable energy or cleaner energy which contributes to lower carbon emission will be widespread, and households become more willing to protect environment, they have high awareness of expenditures towards cleaner goods and assets \cite{29, 38}. In all, this is the ideal state for energy conservation and emission mitigation, and technology is the dominate driving factor for the reducing of total carbon emission.

<p>| Table 1. The characteristics of the five emission force (ES, EI, IS, EO, and P) in different development stages |</p>
<table>
<thead>
<tr>
<th>Stage</th>
<th>ES</th>
<th>EI</th>
<th>IS</th>
<th>EO</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Fossil energy based structure</td>
<td>Increase</td>
<td>Agriculture growth</td>
<td>Growth</td>
<td>Steady growth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Secondary industry growth</td>
<td></td>
<td>Low environmental awareness</td>
</tr>
<tr>
<td>S2</td>
<td>Fossil energy based structure</td>
<td>Slow decrease</td>
<td>Secondary industry based structure growth</td>
<td>Rapid growth</td>
<td>Relative rapid growth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low environmental awareness</td>
</tr>
<tr>
<td>S3</td>
<td>Fossil energy cleaner/renewable energy rapid decrease</td>
<td>Secondary industry Tertiary industry decrease</td>
<td>Steady growth</td>
<td>Rapid growth</td>
<td>Low to high environmental awareness</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>Cleaner/renewable energy based structure rapid decrease</td>
<td>Tertiary industry based structure growth</td>
<td>Slow growth</td>
<td>Slow growth</td>
<td>High environmental awareness</td>
</tr>
</tbody>
</table>

**Conclusion**

This paper attempts to analyze the characteristics impact on carbon emission based on the development stage framework at city level. Results provide clear evidence that different development stages present different emission characteristics. Thus, it is important for decision makers to take mitigation measures for implementing LCC with consideration of development stages. For example, cities position in different stages shall promote carbon emission reduction by focusing on the corresponding TPs, as well as the dominate emission characteristics.

Two limitations of this study are appreciated and for further research. First, there are still
some other emission characteristics should be considered, such as urbanization level. Second, this research only focuses on qualitative analysis, the performance of the characteristic results have not been evidenced. Further study is recommended to quantitative evidence the validity of characteristics results by examining larger amount of cities at global level.

Acknowledgments
This research work was supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant Nos. “15AZD025” and “15BJY038”.

Reference

[5] IPCC. (2014). Climate change 2013: the physical science basis: working group I contribution to the fifth assessment report of the intergovernmental panel on climate change.


Case Studies on Evaluation of Sustainable development of Small Towns in Southwest China

Wei, X.X.*1, Chen, Y. 2, Xiong, N. 3

Abstract: The sustainable development of small mountainous towns in southwest China is great significance to ensure national ecological security and promote regional sustainable development. In order to make small mountainous towns in southwest China develop healthy and continuously, this paper selected 24 indicators from three dimensions: economic, social and environment. Based on panel data of 12 townships in mountainous regions in Southwest China in 2015, the sustainable development level is measured by AHP-entropy method, which is the combination utilization of analytic hierarchy process and entropy weight method. The results suggest that the level of the sustainable development of small mountainous towns is lower throughout the country, especially in the economic construction, which because the lag of economic structural adjustment. Finally, the pertinent suggestions are put forward to enhance the sustainable construction level of small mountain towns in southwest China, such as the integration of township industrial parks and the development of ecological tour.

Key words: Small mountainous towns; Sustainable development; AHP-entropy method; Southwest China

1 *Wei, X.X.
Corresponding author, School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China
E-mail: 260119465@qq.com

2 Chen, Y.
School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China

3 Xiong, N.
School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China
1 Introduction

The sustainable development of small towns is of great importance as it contributes to reduce urban-rural disparities and coordinate urban-rural developments\(^1\). The construction of small towns has made gratifying achievements in China in the past 40 years, the number of organic townships from 2173 in 1978 surges to 20515 in 2015\(^2\). However, the paces of development of small towns in southwest China are lagged behind in the average national level of obviously\(^3\). Meanwhile, many problems have been raised in southwest China, such as frequent natural disasters, the reduction of arable land, the decrease in biodiversity\(^4\). Some townships even sacrificed the environment for economic development, such as Tonghai town in Yuxi county, Yunnan province. So, it is very important to correctly evaluate the sustainable development level of small towns in southwest China, in other words, the development of small towns in southwest China can be of great importance for the speedup of urbanization and sustainable economic and social development in China. Therefore, it is quite necessary to assess the status of sustainable development of small mountainous towns in southwest China in formulating future policies.

So far, many existing literatures have paid more attention to the sustainable development of small towns in China. Fan et al. constructs an index system to to figure out the sustainable development of small towns in the eastern coastal areas from three aspects: geographical environment, dynamic support system and institutional environment\(^5\). Based on the entropy weight method, Ma et al. developed the indicator system to assess the sustainable development of 16 townships in Yangtze River Delta region\(^6\). By evaluating the sustainable construction of small towns in the Yangtze River Delta, Song et al. divided 16 cities in the Yangtze River Delta region into four types\(^7\). However, few studies have evaluated the sustainable development of small mountainous towns in southwest China. Thus this paper develops an index system to evaluate the status of sustainable development of mountainous small towns in southwest China.

2 Framework of indicators

In order to understand the sustainable development level of small mountainous towns in southwest China, it is very important to construct a suitable index system.

Sustainable development emphasizes the coordinated development of society, economy and environment, and it pursues the harmony among human beings as well as that between mankind and nature\(^8\). And the indicator system can be designed as the framework of four dimensions of "system-target-standard-index". Since late 1980s, the Chinese government has introduced many types of sustainable urbanization schemes. Based on the different index systems established by several departments in China since the 1980s\(^9\), 24 indicators were selected to assess the status and progress of sustainable development of small mountainous towns in southwest China. The indicator system for sustainable development of small mountainous towns is shown in table 1.

<table>
<thead>
<tr>
<th>Target layer</th>
<th>Standard layer</th>
<th>index layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic (A)</td>
<td>economic structure indicator</td>
<td>the proportion of rural output value in GDP (A1.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the proportion of industrial output value in GDP</td>
</tr>
<tr>
<td>(A&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>(A&lt;sub&gt;1.2&lt;/sub&gt;)</td>
<td>the proportion of tertiary industry output value in GDP (A&lt;sub&gt;1.3&lt;/sub&gt;)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>economic increment indicator (A&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>The growth in fixed asset investment (A&lt;sub&gt;2.1&lt;/sub&gt;)</td>
<td>Fixed asset investment growth rate (A&lt;sub&gt;2.2&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>Growth speed of tertiary industry (A&lt;sub&gt;2.3&lt;/sub&gt;)</td>
<td></td>
</tr>
<tr>
<td>economic aggregate indicator (A&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>Per capita GDP (A&lt;sub&gt;3.1&lt;/sub&gt;)</td>
<td>Per capita local financial revenue (A&lt;sub&gt;3.2&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>per capita retail sales of social consumption goods (A&lt;sub&gt;3.3&lt;/sub&gt;)</td>
<td></td>
</tr>
<tr>
<td>population status indicator (B&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Resident population urbanization rate (B&lt;sub&gt;1.1&lt;/sub&gt;)</td>
<td>Density of population (B&lt;sub&gt;1.2&lt;/sub&gt;) (number / sq.km)</td>
</tr>
<tr>
<td>living standard indicator (B&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>Per capita disposable income of urban residents (B&lt;sub&gt;2.1&lt;/sub&gt;)</td>
<td>Per capita disposable income of rural residents (B&lt;sub&gt;2.2&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>The number of the tertiary industry and private enterprises per one thousand people (B&lt;sub&gt;2.3&lt;/sub&gt;)</td>
<td>Number of industrial enterprises per one thousand persons (B&lt;sub&gt;2.4&lt;/sub&gt;)</td>
</tr>
<tr>
<td>Social security indicator (B&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>The coverage of basic medical insurance programs (B&lt;sub&gt;3.1&lt;/sub&gt;)</td>
<td>The coverage rate of old-age insurance (B&lt;sub&gt;3.2&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>Gas penetration rate (B&lt;sub&gt;3.3&lt;/sub&gt;)</td>
<td>The number of high school students per thousand students (B&lt;sub&gt;3.4&lt;/sub&gt;)</td>
</tr>
<tr>
<td>environment indicator (C&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Per-person cultivated land area (C&lt;sub&gt;1.1&lt;/sub&gt;) (mu / person)</td>
<td>The forest coverage rate (C&lt;sub&gt;1.2&lt;/sub&gt;)</td>
</tr>
<tr>
<td>human settlement environment indicator (C&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>Sewage treatment rate (C&lt;sub&gt;2.1&lt;/sub&gt;)</td>
<td>Penetration rate of drinking-water (C&lt;sub&gt;2.2&lt;/sub&gt;)</td>
</tr>
<tr>
<td></td>
<td>Collection rate and decontamination rate of garbage (C&lt;sub&gt;2.3&lt;/sub&gt;)</td>
<td></td>
</tr>
</tbody>
</table>

3 AHP-Entropy theory for assessing sustainable development

The comprehensive evaluation of the index system usually adopts the analytic hierarchy process, which is often based on expert's subjective assessment and different people will give different weights\(^{[10]}\). In order to avoid the effect of subjective factors, this paper proposes a model of using the method of entropy weight to adjust the weight determined by analytic hierarchy process (AHP)
to evaluate the status of the sustainable development of small mountainous towns in southwest China\cite{11}.

3.1 construct the normalized matrix

Suppose there are \( n \) samples, and each sample has \( m \) indicators. Thus all observations consist of a matrix \( X = (x_{ij})_{n \times m}, i=1,2,...,n, j=1,2,...,m \). Since these indicators are of different measurement units, direct aggregation is not possible. The specific steps of the construction of the normalized matrix are as follows\cite{12}:

The standardization of "positive" indicator:

\[
    x'_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j};
\]

The standardization of "reverse" indicator:

\[
    x'_{ij} = \frac{\max x_j - x_{ij}}{\max x_j - \min x_j};
\]

3.2 AHP

Analytical Hierarchy Process (AHP) is the most common comprehensive evaluation method\cite{11}. The main idea is to break down the evaluation system into hierarchy structure and compare each element according to a principle, then acquire the compare matrix elements and calculate the relative weights and the overall weights\cite{13}. The weight of indicator by AHP:

\[
    \theta = \theta^{(k)} \theta^{(k-1)} \cdots \theta^{(2)}
\]

3.3 entropy method

Step1. Calculate the Entropy of each Attribute \( j \).

\[
    e_j = -k \sum_{i=1}^{m} (y'_{ij} \times \ln y_{ij})
\]

Where, \( k = \frac{1}{\ln m}, y'_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} \)

Step2. Calculate the weight \( \omega_j \) of indicator \( j \):

\[
    \omega_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)}
\]

3.4 Determination of the overall weights

This paper determines the overall weights by the following formula:
\[ \lambda_i = \frac{\theta_i \omega_j}{\sum_{j=1}^{m} \theta_i \omega_j} \]  

(6)

### 3.5 Evaluation of Sustainable Performance

The evaluation results can be obtained by the following formula:

\[ S = \sum_{j=1}^{m} \lambda_i X_j' \]  

(7)

### 4 case study

The 12 sample mountainous townships were selected for our research, and the selection of sample towns covers the direction of different industries. Based on the model established in Section 3, this section evaluates the sustainable development level of 12 sample mountainous townships in southwest China.

In this paper, 12 small towns in southwestern China such as Gasa town and Heishan town were selected as the object of study. Among them, Gasa town and Lushi town were representatives of small mountain towns in Yunnan Province, Heishan town, Yanwo town, Qiantang Town, Tiaodeng town is the representative of small mountain town in Chongqing, Fenshuiling town, Fangshan town is a representative of small mountain town in Sichuan Province, Chaole town, Yongxing town and Dalucao town is Guizhou mountain small town representative. The selection of small towns of different sizes covers the development direction of different industries, which are representative and reasonable. Through horizontal comparison of the sample towns, it is possible to evaluate the sustainable development level of different towns and different types of small towns in southwest mountainous areas.

### 4.1 data sources

This research is based on data from 2015. The data for environment used for this paper are collected during a period of over two months from February to April 2017, when the research group used a questionnaire survey to collect data related to the environment. Besides, the data for the social and economic indicators are collected from the sample towns of the report on the work of the government in 2015.

### 4.2 data analysis

Using AHP-entropy method in section 3 to calculate the weight of the subjective and objective weights respectively, and the overall weights value can be calculated which are shown in Table2.

<table>
<thead>
<tr>
<th>system</th>
<th>Target layer</th>
<th>Standard layer</th>
<th>index layer</th>
<th>Subjective weights ( \theta_i )</th>
<th>objective weights ( \omega_j )</th>
<th>overall weights ( \lambda_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>The sustainable development of small</td>
<td>0.521</td>
<td>0.064</td>
<td>A1</td>
<td>0.016</td>
<td>0.011</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>A1,1</td>
<td>A1,1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.033</td>
<td>0.030</td>
<td>0.027</td>
</tr>
</tbody>
</table>

Table 2. The subjective and objective and the overall weights
<table>
<thead>
<tr>
<th>Mountainous towns in southwest China</th>
<th>A_1.3</th>
<th>A_2.1</th>
<th>A_2.2</th>
<th>A_2.3</th>
<th>A_3.1</th>
<th>A_3.2</th>
<th>A_3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.042</td>
<td>0.106</td>
<td>0.057</td>
<td>0.078</td>
<td>0.054</td>
<td>0.029</td>
<td>0.038</td>
</tr>
<tr>
<td>B_1.3</td>
<td>0.033</td>
<td>0.015</td>
<td>0.022</td>
<td>0.023</td>
<td>0.023</td>
<td>0.020</td>
<td>0.018</td>
</tr>
<tr>
<td>B_2.1</td>
<td>0.033</td>
<td>0.015</td>
<td>0.022</td>
<td>0.023</td>
<td>0.023</td>
<td>0.020</td>
<td>0.018</td>
</tr>
<tr>
<td>B_2.2</td>
<td>0.022</td>
<td>0.041</td>
<td>0.035</td>
<td>0.084</td>
<td>0.133</td>
<td>0.013</td>
<td>0.008</td>
</tr>
<tr>
<td>B_2.3</td>
<td>0.022</td>
<td>0.041</td>
<td>0.035</td>
<td>0.084</td>
<td>0.133</td>
<td>0.013</td>
<td>0.008</td>
</tr>
<tr>
<td>B_2.4</td>
<td>0.023</td>
<td>0.035</td>
<td>0.084</td>
<td>0.133</td>
<td>0.013</td>
<td>0.008</td>
<td>0.007</td>
</tr>
<tr>
<td>B_3.1</td>
<td>0.023</td>
<td>0.035</td>
<td>0.084</td>
<td>0.133</td>
<td>0.013</td>
<td>0.008</td>
<td>0.007</td>
</tr>
<tr>
<td>B_3.2</td>
<td>0.023</td>
<td>0.035</td>
<td>0.084</td>
<td>0.133</td>
<td>0.013</td>
<td>0.008</td>
<td>0.007</td>
</tr>
<tr>
<td>B_3.3</td>
<td>0.023</td>
<td>0.035</td>
<td>0.084</td>
<td>0.133</td>
<td>0.013</td>
<td>0.008</td>
<td>0.007</td>
</tr>
<tr>
<td>B_3.4</td>
<td>0.023</td>
<td>0.035</td>
<td>0.084</td>
<td>0.133</td>
<td>0.013</td>
<td>0.008</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Finally, the comprehensive evaluation value of 12 sample towns can be obtained and sorted, which can be seen in Table 3.

**Table 3. The sustainable development evaluation results of Sample towns**

<table>
<thead>
<tr>
<th>Sample townships</th>
<th>So (B)</th>
<th>En (C)</th>
<th>Evaluation value (S)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tiaodeng</td>
<td>0.24</td>
<td>0.07</td>
<td>0.5753</td>
<td>1</td>
</tr>
<tr>
<td>Yongxing</td>
<td>0.10</td>
<td>0.13</td>
<td>0.4153</td>
<td>2</td>
</tr>
<tr>
<td>Qiantang</td>
<td>0.10</td>
<td>0.06</td>
<td>0.3300</td>
<td>3</td>
</tr>
<tr>
<td>Heishan</td>
<td>0.07</td>
<td>0.12</td>
<td>0.3275</td>
<td>4</td>
</tr>
<tr>
<td>Gasa</td>
<td>0.07</td>
<td>0.19</td>
<td>0.3265</td>
<td>5</td>
</tr>
<tr>
<td>Lushi^{1}</td>
<td>0.06</td>
<td>0.16</td>
<td>0.3187</td>
<td>6</td>
</tr>
<tr>
<td>Lushi^{2}</td>
<td>0.09</td>
<td>0.06</td>
<td>0.3008</td>
<td>7</td>
</tr>
<tr>
<td>Yanwo</td>
<td>0.07</td>
<td>0.07</td>
<td>0.2725</td>
<td>8</td>
</tr>
<tr>
<td>Fenshuiling</td>
<td>0.05</td>
<td>0.06</td>
<td>0.2722</td>
<td>9</td>
</tr>
<tr>
<td>Fangshan</td>
<td>0.06</td>
<td>0.05</td>
<td>0.2507</td>
<td>10</td>
</tr>
<tr>
<td>Dalucao</td>
<td>0.02</td>
<td>0.09</td>
<td>0.2148</td>
<td>11</td>
</tr>
</tbody>
</table>
The value of standard layer for economic evaluation can be seen in Figure 1. Figure 2 shows the value of standard layer for social evaluation. Figure 3 presents different values of standard layer for environmental evaluation.

![Figure 1. The value of standard layer for economic evaluation](image1)

![Figure 2. The value of standard layer for social evaluation](image2)

![Figure 3. The value of standard layer for environmental evaluation](image3)

### 5 Results and discussion

The sustainable development level of small towns in mountainous regions of Southwest China is low (lower than 0.5, except Tiaodeng Town) according to the analysis results of the sustainable construction of sample towns. In addition, the sustainable development level is different in
different small towns in mountainous regions of Southwest China, which can be discussed in
detail from the following three aspects combined with profiles of various sample towns:

(1) From the perspective of economy, the evaluation value of economic structure indicator
\((A_1)\) is generally low from Figure 1, in which Fenshuiling Town and Fangshan Town develops
tourism projects of agriculture and entertainment by seizing opportunities of the rapid
development of tourism, so the evaluation value is higher than the average level; while the
evaluation value is lower in Lushi\(^1\) Town, Yongxing Town and Dalucao Township due to the larger
proportion of agricultural output value in GDP. (2) There is a large degree of discretization for the
evaluation value of the economic increment indicator \((A_2)\), in which the evaluation value of
Yongxing Town is particularly prominent because the agricultural production mode and the rural
economic growth mode are changed by means of the agricultural industrialization management
strategy here, while the evaluation value of the economic increment indicator of Gasa Town,
Tiaodeng Town and Chaole Town is significantly lower than that of the remaining sample towns.
The economic growth is stabilized in Gasa Town because the tourism market has gradually formed;
the production value of cement plants has a small contribution to the economic growth of
Tiaodeng Town that is cement plant-based; the tourism industry of Chaole Town is still in the
initial stage so that its economic income mainly comes from sales of agricultural products,
resulting in the slow economic growth is. There is also a larger degree of discretization for the
evaluation value of the economic aggregate indicator, and the evaluation value is lower than the
average value except for Heishan Town, Tiaodeng Town, Fenshuiling Town and Lushi\(^2\) Town.
Among them, the evaluation value is particularly low in Lushi\(^1\) Town and Dalucao Township as
national poverty townships, so that these two sample towns should form the industry model
combing characteristic agriculture and leisure tourism based on advantageous resources to
promote the economy development.

(2) From the perspective of social progress, from Figure 2, population status indicator \((B_1)\)
is closely related to the degree of economic development of small towns. In small towns with a low
level of economic development and a slow growth rate, the employment absorption is weak so that
a large number of rural people go out to work, resulting in declined rural population and thus a
low evaluation value. There is also a larger degree of discretization for the evaluation value of the
living standard indicator, in which the evaluation value of the mining industry–based Tiaodeng
Town is obviously higher than that of traditional agriculture–based Dalucao Township. Therefore,
it is necessary to introduce suitable industries according to industry orientation for creating
employment opportunities as well as improving the income level and living standards of residents.
Social security indicator \((B_3)\) can reflect the degree of social security enjoyed by residents of small
towns. However, the evaluation value of the social security indicator is lower than the average
value in Heishan Town, Lushi Town\(^1\), Yanwo Town and Dalucao Township, so they are supposed
to continue to perfect the social security system and expand social insurance coverage.

(3) From the perspective of resource and environment, the overall evaluation value of
resource and environment in sample towns is higher. From Figure 3, the evaluation value of the
resource status indicator \((C_1)\) is higher than the average value in Gasa Town, Lushi Town\(^1\), Heishan
Town and Yongxing Town, which creates a good condition for the development of tourism scenic
spots. The evaluation value of the human settlement environment indicator \((C_2)\) is lower than the
average value in Gasa Town, Lushi Town\(^1\), Heishan Town and Yongxing Town, so the government
should increase capital investment for construction of facilities for the harmless disposal of
garbage and sewage treatment to achieve safe drinking water in small towns, so that the quality of life of residents is improved in a clean, tidy, hygienic and orderly urban and rural environment.

6 conclusion

From the perspective of the sustainable evaluation, the hierarchical entropy method is used to evaluate the sustainable construction level (especially the economic development level) of 12 small towns in mountainous regions of Southwest China in this paper. The results show that the sustainable development level of small mountain towns in the southwest is not high. Therefore, the development of sustainable economy is a key to improving the sustainable construction level, and two suggestions are proposed. First of all, the township industrial park should be vigorously developed, and industries near towns can be combined as far as possible for unified management and rational use of resources, and a number of innovative projects are planned to fight for funds for new rural construction. Secondly, eco-tourism projects need to be vigorously developed in the township, that is, rich natural landscapes in southwest region are used to open tourism and leisure projects (such as leisure fishing, farm zoo, picking, agricultural experience and so on) to expand visibility and promote the development of the entire region. The obtained results can provide decision-making reference for enhancing the sustainable construction level of small towns in mountainous regions of Southwest China. However, the number of sample towns can be improved properly for analysis and discussion to obtain more effective diagnostic results in the future because there are some limitations in the selection of sample towns.

Acknowledgements:
This study was supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant No. “15AZD025” and “15BJY038”.

Reference

SOFT SCIENCE:78-87.


Coupling analysis on the coordination between socio-economy and carbon emission: case study of Chongqing, China

Yali Huang 1*, Liyin Shen 2 and Zhenhua Huang 3

Abstract: Fast-development of socio-economy creates increasing pressure on carbon emission. An accurate evaluation of the coordination level between the socio-economy and carbon emission systems makes it possible to lead them towards sustainable development. A coupling coordination degree model (CCDM) was established for the evaluation, using the data of Chongqing from 1997 to 2014. During the evaluation process, the performance level of socio-economy and carbon emission systems was calculated by using an index system. The four primary indicators for socio-economy system are: population development, economic development, social development and space change; there are also four primary indicators for carbon emission system: energy structure, energy economy, clean energy and technological level. The results show that: (1) social development and economic development contribute most to the socio-economy system in Chongqing. And the usage of the clean energy and energy structure are the main contributors to the carbon emission system, the result stresses the importance of using clean energy and improving the structure of energy consumption for carbon emission reduction; (2) the contribution coefficients (α, β) have significant influence on the coordination level and the influence is caused by the gap in performance level between carbon emission and socio-economy systems; (3) the coupling coordination degree of Chongqing shows a S-shaped curve, tracing a shift from “slightly unbalanced development” to “barely balanced development” and finally to “superiorly balanced development”. The results of this study provide an important application to attain the coordinated development of both socio-economy and carbon emission systems.

Keywords: socio-economy; carbon emission; coupling coordination degree model; Chongqing.
1 Introduction

Carbon emission has strong interaction with socio-economy development[1]. On the one hand, social and economic development heavily relies on energy consumption, which is the main source of carbon emission. On the other hand, the control of carbon emission can affect the implementation of social and economic development. Thus, there is a need to balance and coordinate between controlling the carbon emission and promoting the socio-economy activities, which is in line with the principle of sustainable development, as appreciated widely[2, 3]. This highlights the importance of understanding adequately whether there is a coordination between carbon emission and socio-economy systems under a specific circumstance. This adequacy can only be ensured if the tool used for analysis is effective. Without an effective analysis tool, the coordination level between socio-economy and carbon emission systems cannot be accurately recognized and the sustainable forms of socio-economy development may not take effect [4]. The paper introduces coupling analysis tool for this purpose.

Previous studies have investigated the coordination between carbon emission and socio-economy systems by using the environmental Kuznets curve (EKC) theory [5], which qualitatively described the coordination phenomenon where environmental degradation was relieved when the economy grew. Others have examined the relation between environment and socio-economy development by applying quantitative method. Zhao [1] introduced a dynamic coordination coupling degree model by using coupling principle to evaluate the coordination between urbanization and eco-environment in the Yangtze River Delta. By applying coordination coupling degree model, Li [6] discovered a U-shaped curve of the coordination between urbanization and the environment by referring to the case of Lianyungang city. Wang [7] illustrated a S-shaped curve of the coordination between urbanization and the environment in the context of Beijing-Tianjin-Hebei. However, above studies present the following two limitations. (1) study areas were focused on the developed region in the eastern China but seldom developing regions in the middle-western China have been researched. (2) the coupling based model is also seldom adopted in the assessment of the coordination between socio-economy and carbon emission systems. Therefore, it is necessary to evaluate the coordination level between socio-economy and carbon emission systems, especially in mega-cities in middle-western China.

The aim of this study is to apply coupling analysis model for examining the coordination level between carbon emission and socio-economy systems in Chongqing, China. The reminder of this paper is arranged as follows: the study area and data source in part two, methods for the analysis of the coordination level between socio-economy and carbon emission systems in part three, results and discussion in part four, conclusions in part five.

2 Study area and data source

Located in the south-western mountain area of China, Chongqing is administered as a city with province-level status. There were two reasons when ascertained the study area. Carbon emission relating to socio-economy is most serious in fast-growing cities[8], and Chongqing is the representatives of this kind of cities. The GDP growth rate of Chongqing maintained high in the recent years, delivering an average growth rate of 13.9% from 2005 to 2014 (Chongqing Statistical Yearbook, 2015). So, it is significant to study the dynamical coordination level of the Chongqing.

**3 Methods for analysis of the coordination level between socio-economy and carbon emission**

The development of the coupling model includes two components. Firstly, an indicator system for evaluation of the performance level of the two systems will be presented. Secondly, a coupling coordination degree model will be established to evaluate the coordination level between the two systems.

**3.1 The indicator system for evaluation the performance level of socio-economy and carbon emission systems**

**3.1.1 Indicators selection**

Firstly, indicators were roughly selected by considering the existing academic achievements. The indicators for evaluating the performance level of socio-economy system came from the research of [9] who conducted a statistic of 688 papers relating to socio-economy indicators of Hownet Database, an authoritative database in China. As energy consumption is the main contributor of carbon emission, indicators for evaluating the performance level of carbon emission system stress on the energy sector. Indicators for evaluating the performance level of carbon emission system came from the research of [10]. Secondly, indicators were further selected by the method of expert evaluation and the principle of data availability. The index systems for socio-economy system and carbon emission system are showed in Table 1 and Table 2.

**Table 1. Index system for socio-economy**

<table>
<thead>
<tr>
<th>Primary indicators</th>
<th>Secondary indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Permanent population $a_{11}$</td>
</tr>
<tr>
<td>development $a_1$</td>
<td>Proportion of non-agricultural population (%) $a_{12}$</td>
</tr>
<tr>
<td></td>
<td>Proportion of the tertiary industry Employee (%) $a_{13}$</td>
</tr>
<tr>
<td>Economic</td>
<td>Local financial revenue per capita (yuan) $b_{11}$</td>
</tr>
<tr>
<td>development $b_1$</td>
<td>Total fixed assets investment per capita (yuan) $b_{12}$</td>
</tr>
<tr>
<td></td>
<td>Added value of the tertiary industry per capita (yuan) $b_{13}$</td>
</tr>
<tr>
<td></td>
<td>Proportion of industrial output value of gross industrial and agricultural output value (%) $b_{14}$</td>
</tr>
<tr>
<td></td>
<td>Gross industrial output value per capita (yuan) $b_{15}$</td>
</tr>
<tr>
<td></td>
<td>GDP per capita (yuan) $b_{16}$</td>
</tr>
<tr>
<td>Social</td>
<td>Retail sales per capita (yuan) $c_{11}$</td>
</tr>
<tr>
<td>development $c_1$</td>
<td>Urban living area per capita (m²) $c_{12}$</td>
</tr>
<tr>
<td></td>
<td>Number of public transport per 10,000 people $c_{13}$</td>
</tr>
<tr>
<td></td>
<td>Number of doctors per 10,000 people $c_{14}$</td>
</tr>
<tr>
<td></td>
<td>Road area ratio (m²) $c_{15}$</td>
</tr>
<tr>
<td></td>
<td>Average annual disposable income of urban residents $c_{16}$</td>
</tr>
</tbody>
</table>
Table 2. Index system for carbon emission

<table>
<thead>
<tr>
<th>Primary indicators</th>
<th>Secondary indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy structure $f_i$</td>
<td>Proportion of natural gas consumption (%) $f_{i1}$</td>
</tr>
<tr>
<td></td>
<td>Proportion of coal consumption (%) $f_{i2}$</td>
</tr>
<tr>
<td></td>
<td>Proportion of petroleum consumption (%) $f_{i3}$</td>
</tr>
<tr>
<td></td>
<td>Share of non-fossil fuels in primary energy consumption (%) $f_{i4}$</td>
</tr>
<tr>
<td>Energy economy $h_i$</td>
<td>Energy consumption per GDP (tons/yuan) $h_{i1}$</td>
</tr>
<tr>
<td></td>
<td>GDP growth rate (%) $h_{i2}$</td>
</tr>
<tr>
<td>Clean energy $m_i$</td>
<td>Clean energy consumption(tons) $m_{i1}$</td>
</tr>
<tr>
<td></td>
<td>Proportion of clean energy power generation (%) $m_{i2}$</td>
</tr>
<tr>
<td>Technological level $n_i$</td>
<td>Energy transformation efficiency (%) $n_{i1}$</td>
</tr>
</tbody>
</table>

Entropy method was applied to calculate the weight of indicators in the two systems, which is an approved effective method for the weight calculation\cite{11, 12}, the detailed steps of using the method can be seen in these two papers.

3.1.2 Establishment of weighting values between indicators

The weighting values between indicators are established by using entropy method, which is a proven effective method\cite{11}. In applying entropy method, several parameters need to be defined. $n$, the number of indicators; $m$, the number of the surveyed years; $i$, the $i$th year; $j$, the $j$th indicator; $X_{ij}$, the initial value of the indicator $j$ for the year of $i$; $\max \{X_j\}$ and $\min \{X_j\}$, the maximum and minimum values of the indicator $j$ during period of the surveyed years; $r_{ij}$, normalized value of the indicator $j$ in the $i$th year; The weighting values between indicators by applying entropy method are calculated as follows:

Weighting value of indicator $j$: $W_j = \frac{1 - E_j}{\sum_{j=1}^{m}(1 - E_j)}$  \hspace{1cm} (1)

In model (1), $E_j$ is the information entropy of the indicator $j$, which can be calculated as follows:

Information entropy of the indicator $j$: $E_j = -\frac{1}{\ln n} \sum_{i=1}^{n} P_y \times \ln P_y$  \hspace{1cm} (2)

In model (2), $P_y$ is the proportion of the indicator $j$ in year $i$, which can be calculated as follows:

The proportion of the indicator $j$ in year $i$: $P_y = r_j / \sum_{j=1}^{n} r_j$  \hspace{1cm} (3)

In model (3), $r_j$ is the normalized value of the indicator $j$ in the $i$th year, which can be calculated as follows:

Positive indicator: $r_{ij} = (X_{ij} - \min \{X_j\}) / (\max \{X_j\} - \min \{X_j\})$  \hspace{1cm} (4)

Negative indicator: \( r_{ij} = \frac{(\max\{X_j\} - X_{ij})}{(\max\{X_j\} - \min\{X_j\})} \)  \( (5) \)

### 3.1.3 The performance level of socio-economy and carbon emission systems

The performance level of socio-economy system \((U(V_i))\) in year \(i\) was determined by the equation (1) and equation (2). The performance level of carbon emission \((U(W_i))\) in year \(i\) can also be calculated by using the similar models (6)- (7).

**Evaluation of the indicator:** \( U(V_{ij}) = W_j \times r_{ij} \)  \( (6) \)

**Comprehensive level in year \(i\):** \( U(V) = \sum_{j=1}^{n} U(V_{ij}) \)  \( (7) \)

### 3.2 The coupling coordination degree model for coordination level assessment

The coupling degree model was established based on the similarity with the physics degree coupling model. Supposing there are \(n\) subsystems, \(C_n\) refers to the degree of coupling between \(n\) subsystems, \(U\) refers to the system which consists of \(n\) subsystems. And the physical coupling degree model can be described as followed [4]:

\[
C_n = \left( \frac{U_1 \times U_2 \ldots U_n}{\prod(U_1 + U_j)} \right)^{1/n}
\]  \( (8) \)

The coupling degree model between socio-economy and carbon emission subsystems can be described as followed:

\[
C = \left( \frac{(U(V) \times U(W))}{\prod[U(V) + U(W)/2]} \right)^{1/2}
\]  \( (9) \)

Where \(C\) stands for the coupling degree of socio-economy and carbon emission, \(U\) is a coupling system consisting of two subsystems: socio-economy and carbon emission. \(U(V)\) is the performance level of socio-economy subsystem and \(U(W)\) represents the performance level of carbon emission subsystem. \(C\) ranges from zero to one, and the system \(U\) is more coordinated when \(C\) is larger. However, \(C\) will equal 1 when \(U(V)\) equals \(U(W)\), which ignores the actual performance level of the two subsystems. So, the coupling degree model was further established and written as:

\[
T = \alpha U(V) + \beta U(W); \quad D = \sqrt{T \times C}
\]  \( (10) \)

Where \(D\) is the coupling coordination degree of socio-economy and carbon emission subsystems. \(\alpha\) and \(\beta\) describe the contribution of socio-economy and carbon emission subsystems to the coupling coordination degree, respectively. \(T\) comprehensively denotes the overall effect level of socio-economy and carbon emission subsystems.

In model (5), the value of \(D\) will be assured with a range of \((0,1)\). According to the similarity of previous study [4], the coupling degree between socio-economy and carbon emission subsystems was classified into four primary development stages: Seriously unbalanced development \((0 < D \ll 0.3)\), Slightly unbalanced development \((0.3 < D \ll 0.5)\), Barely balanced development \((0.5 < E \ll 0.7)\), Superior balanced development \((0.7 < E \ll 1.0)\).

### 4 Results and discussion

#### 4.1 The performance level of socio-economy and carbon emission in Chongqing

We established an indicator system to reflect the performance levels of socio-economy and carbon emission systems. Then we calculated the weight of the indicators by using the model (1) and data of Chongqing from 1997 to 2014. The outcome of the weight of each indicator for Chongqing is denoted in Table 3. As the result indicates, social development and economic development
contribute most to the level of socio-economy system in Chongqing, which is in line with the research of Zhao [1]. As for carbon emission system, the key primary indicators are energy structure and clean energy of Chongqing, which is consistent with [13].

Table 3. The indicators and its weight for Chongqing

<table>
<thead>
<tr>
<th>indicators</th>
<th>weight</th>
<th>indicators</th>
<th>weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population development (a_1)</td>
<td>0.146</td>
<td>Permanent population (a_{11})</td>
<td>0.056</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proportion of non-agricultural population (%) (a_{12})</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Employee proportion of the tertiary industry (%) (a_{13})</td>
<td>0.037</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local finance income per capita (yuan) (b_{11})</td>
<td>0.089</td>
</tr>
<tr>
<td>Economic development (b_1)</td>
<td>0.428</td>
<td>Total fixed asset investment per capita (yuan) (b_{12})</td>
<td>0.069</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Added value of the tertiary industry per capital (yuan) (b_{13})</td>
<td>0.077</td>
</tr>
<tr>
<td>Social development (c_1)</td>
<td>0.331</td>
<td>Proportion of industrial output value of industry and agriculture (%) (b_{14})</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gross industrial output value per capita(yuan) (b_{15})</td>
<td>0.078</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GDP per capita(yuan) (b_{16})</td>
<td>0.076</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retail sales per capita (yuan) (c_{11})</td>
<td>0.077</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban living area per capita(m2) (c_{12})</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of buses per 10,000 people (c_{13})</td>
<td>0.037</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Number of doctors per 10,000 people (c_{14})</td>
<td>0.061</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Road person ratio(m2) (c_{15})</td>
<td>0.047</td>
</tr>
<tr>
<td>Space change (d_1)</td>
<td>0.096</td>
<td>Average annual disposable income of urban residents (c_{16})</td>
<td>0.065</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban built-up area(m2) (d_{11})</td>
<td>0.051</td>
</tr>
<tr>
<td>Energy structure (f_1)</td>
<td>0.435</td>
<td>Population density (m2/per capita) (d_{12})</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proportion of natural gas consumption (%)(f_{11})</td>
<td>0.090</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proportion of coal consumption (%)(f_{12})</td>
<td>0.073</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Proportion of petroleum consumption (%)(f_{13})</td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Share of non-fossil fuels in primary energy consumption (%)(f_{14})</td>
<td>0.167</td>
</tr>
<tr>
<td>Energy economy (h_1)</td>
<td>0.161</td>
<td>Energy consumptions per GDP(tons/yuan) (h_{11})</td>
<td>0.088</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GDP growth rate (%) (h_{12})</td>
<td>0.073</td>
</tr>
<tr>
<td>Clean energy (m_1)</td>
<td>0.283</td>
<td>Clean energy consumption(tons) (m_{11})</td>
<td>0.181</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The proportion of clean energy power generation (%) (m_{12})</td>
<td>0.102</td>
</tr>
<tr>
<td>Technological level (n_1)</td>
<td>0.121</td>
<td>Efficiency of energy transformation (%) (n_{11})</td>
<td>0.121</td>
</tr>
</tbody>
</table>

The performance levels of the two systems are calculated by using model (6) and (7), as shown in Figure 1. The socio-economy level of Chongqing has been promoted with high speed since nearly 2005. The growth was driven by social development and economic development. However, Carbon emission system in Chongqing showed a declined trend from 2005 to 2009, when socio-economy skyrocketed, but recovered at full speed in 2013.
4.2 Coupling results of different values of contribution coefficients $\alpha$ and $\beta$

Coupling coordination degree of socio-economy and carbon emission systems was calculated with different values of $\alpha$ and $\beta$ which severally represented the contribution of socio-economy and carbon emission to the coupling coordination degree. The outcome was revealed in Figure 2. The influence of the contribution coefficients on the coupling coordination degree is caused by the gap in the performance level between the two subsystems. In other words, when the gap in the performance level between socio-economy and carbon emission of Chongqing is large, the contribution coefficients will have significant influence on the coupling coordination degree, which is the reason that the contribution coefficients have relatively large influence on the coupling coordination degree of Chongqing in the year of 2005 and 2008.

4.3 Coordination stages between socio-economy and carbon emission systems of Chongqing

The coupling coordination degree was invented to evaluate the coordination state. Figure 3 denoted the coupling coordination degree and the stages of coupling between socio-economy and carbon emission systems of Chongqing.
The carbon emission system in Chongqing showed a declined trend from 2005 to 2009 when socio-economy development with a high speed in Figure 1, which is the reason for the coupling coordination degree has been restricted from 2005 to 2009. Coupling coordination degree of Chongqing shows a S-shaped curve and there were three stages in the process of development: slightly unbalanced development, barely balanced development and superior balanced development.

5 Conclusions

This study expands the scope of the application of coupling model, and this model is applied to the carbon emission and socio-economy systems, which provides a new perspective to lead the socio-economy and carbon emission systems to coordinated development. The results show that: Social development and economic development contribute more than 65% to the socio-economy development in Chongqing. The usage of clean energy and energy structure contribute over 70% to improve the performance level of the carbon emission system, and the result stresses the importance of using clean energy and improving the structure of energy consumption for carbon emission reduction.

In addition, the coupling coordination degree of Chongqing shows a S-shaped curve during the study period, tracing a shift from “slightly unbalanced development” to “barely balanced development” and finally to “superiorly balanced development”. The unbalance development between carbon emission and socio-economy systems is accompanied with the degradation of the performance level of either socio-economy system or carbon emission system and the degradation can happen in any stage. Policy makers therefore still need to lead to socio-economy and carbon emission systems towards coordinated development in the future.

Finally, two contribution coefficients have evident influence on the coupling coordination degree of Chongqing and the influence was caused by the gap in the performance level between socio-economy and carbon emission systems. The accuracy of the model therefore needs to be improved, which will be our future works.

Acknowledgements

This research work is supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant Nos. “15AZD025” and “15BJY038”.

Reference


Life Cycle Cost Analysis on Non-Residential Green Buildings in Singapore

Li, S.P.1*, Lu, Y.J.2 and Kua, H.W.3

Abstract: The high cost is the main obstacle to develop green buildings. It is important and necessary to conduct a life cycle cost analysis of non-residential green buildings on a national basis. This paper computes and compares the Life Cycle Costs (LCC), Construction Costs (CC) and Operation Costs (OC) for a variety types of buildings such as building functions, building owners and levels of Green Mark. Data was collected from 44 non-residential buildings in Singapore constructed over the period for 1978-2013. The findings demonstrate that the annual average values of LCC, CC and OC of 44 projects in Singapore are 222.03 $/m², 91.85 $/m² and 130.18 $/m² respectively. In regression analysis, the annual LCC and OC increase 47.81 $/m² and 25.37 $/m² as Green Mark improves a level. This study contributes to expanding the application of LCC method to green building sector and helps industrial practitioners to more efficiently manage the building cost while achieving environmental sustainability.

Keywords: Construction Costs; Green buildings; Life Cycle Costs; Non-residential buildings; Operation Costs; Whole life cost index.

1*Li, S.P.
Corresponding author, School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China
E-mail: 13452920662@163.com

2 Lu, Y.J.
Department of Building, School of Design and Environment, National University of Singapore, Singapore

3 Kua, H.W.
Department of Building, School of Design and Environment, National University of Singapore, Singapore
1 Introduction

The building sector is the substantial source of greenhouse gas emissions and contributes to climate change. Residential and commercial building sectors emitted approximately 33% of total greenhouse gas emissions in developed countries (UNEP, 2009). Green building is recognized as an effective response to reduce greenhouse gas emissions [1] and has become a trend to build a pleasant and sustainable living environment. To facilitate the construction of green buildings, various green building certificates have been carried out in many countries to improve the sustainability of the building industry. The earliest rating system is the Building Research Establishment Environmental Assessment Method (BREEAM) launched in the UK in 1990[2]. Then the United States Green Building Council established the Leadership in Energy and Environmental Design (LEED) in 1998[3]. The Green Building Council of Australia launched the Green Star rating tool in 2003[4]. In Singapore, the Building and Construction Authority (BCA) promoted the Green Mark Scheme as a benchmark for evaluating green buildings in 2005[5]. From 2006 to 2014, three comprehensive Green Building Masterplans have been launched to make buildings more environmentally sustainable. For the last ten years, more than 2,700 green buildings have been built in Singapore. The percentage of green buildings in Singapore has grown exponentially from 0.5% in 2005 to more than 31% in May 2016, and it is expected to achieve 80% green buildings by 2030[6]. Data of Green Mark certified buildings is sufficient in Singapore. Additionally, Singapore is situated in the tropical region, a large amount of energy is consumed by the air-conditioning. It is necessary to choose Singapore as the research region to conduct the life cycle analysis of green buildings.

However, the development of green building faces some obstacles, especially its high initial construction costs[7]. Kats reported that green buildings cost approximately $3/sf to $9/sf more than conventional buildings[8]. Actually, the operating costs will decrease as the result of the more investment in energy-efficient technologies and components during the construction process. A study of 170 buildings showed that green buildings saved 34% energy-use compared with conventional buildings[8]. Therefore, it is necessary to create a more comprehensive view of costs of green buildings during the process of design, construction and operation, which can illustrate the relationship between initial capital costs growth in the phase of green building construction and costs reduction at the operation stage. Nevertheless, few previous literature constructs an adequate picture of operation cost performance during the whole life cycle on account of the lack of reliable data for the OC. It has become a major constraint on the implementation of LCC in the construction industry, particularly in green buildings sector[9]. Based on this knowledge gap, this study aims to analyze the whole life cycle costs of non-residential Green Mark certified building in Singapore and derive useful information for industry stakeholders to achieve better value for money. The specific objectives of this study are to compute the LCC, CC and OC of non-residential buildings, create a Whole Life Cost Database on basis of the data and apply multiple regression to analyze the correlations between the annual LCC, OC, CC of non-residential buildings and building types, building owners and Green Mark levels.

In theory, this study expands the application of LCC method to green building sector, meanwhile, it contributes to better understand green buildings in the perspective of life cycle cost. In practice, this study can be particularly useful for building owners better balance the changes of costs in each period and achieve the most economic value across the entire life cycle of buildings.
Also, this national-level empirical study will help the policymaker examine the validity of the green building certification system and related policies.

2 Methodology

2.1 The calculation of Life Cycle Costs

In this paper, Life Cycle Costs of the buildings can be calculated by these two main components, Construction Costs and Operation Costs. The framework of LCC is shown in the Table 1, the standard classification of Construction Costs, Operation Costs was developed by the internationally renowned Building Cost Information Service (BCIS) in the Britain\textsuperscript{[10]}.

Table 1 Life Cycle Costs in Detailed Categories

<table>
<thead>
<tr>
<th>Construction Costs</th>
<th>Operation Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1 Substructure</td>
<td>Occupancy</td>
</tr>
<tr>
<td>CC2 Superstructure</td>
<td>OC1 Energy</td>
</tr>
<tr>
<td>CC3 Finishes</td>
<td>OC2 Water</td>
</tr>
<tr>
<td>CC4 Fittings &amp; furnishings</td>
<td>OC3 Cleaning</td>
</tr>
<tr>
<td>CC5 Services</td>
<td>OC4 Security &amp; Health</td>
</tr>
<tr>
<td>CC6 External Works</td>
<td>OC5 Management</td>
</tr>
<tr>
<td>CC7 Others</td>
<td>OC6 Main Building</td>
</tr>
<tr>
<td>Maintenance &amp; Repair</td>
<td>OC7 Plumbing &amp; Sanitary</td>
</tr>
<tr>
<td></td>
<td>OC8 ACMV</td>
</tr>
<tr>
<td></td>
<td>OC9 Electrical Installations</td>
</tr>
<tr>
<td></td>
<td>OC10 Lift</td>
</tr>
<tr>
<td></td>
<td>OC11 Communication</td>
</tr>
<tr>
<td></td>
<td>OC12 Fire Protection</td>
</tr>
<tr>
<td></td>
<td>OC13 Replacement</td>
</tr>
</tbody>
</table>

2.1.1 Construction Costs

Construction Costs of Project M in completion year of construction (s) can be calculated as follows:

\[
CC = CC_1 + CC_2 + CC_3 + CC_4 + CC_5 + CC_6 + CC_7 \quad (1)
\]

Where \(CC_1 \cdots CC_7\) represent the 7 components of the Construction Costs, referring to the Table 1.

The annual Construction Costs (ACC) can be obtained as follows:

\[
ACC = \frac{CC}{n} \quad (2)
\]

Where \(n\) is the life span.

2.1.2 Operation Costs
Operation Costs are computed by the following three steps. In the first stage of the calculation process, OC incurring in the latest year \( t \) of Project M are selected as the Regular Operation Costs \( (OC_t) \). The formula of the Regular Operation Costs is expressed as follows:

\[
OC_t = OC_1 + OC_2 + OC_3 + \cdots + OC_{13} \quad (3)
\]

Where \( OC_1 \cdots OC_{13} \) denote the 13 specific components of Operation Costs in the latest year \( t \), referring to the Table 1.

In the second stage, the Net Present Value of Operation Costs incurred in year \( t \) \( (NPV_{OC_t}) \) can be calculated as:

\[
NPV_{OC_t} = \frac{OC_t}{(1+a)^{(t-s)} \times (1+e)^{(t-0)}} \quad (4)
\]

Where \( s \) is the construction completion year of Project M; \( n \) is the life span of Project M, \( i \) represents one year of the whole life span, \( i = s \ldots t \ldots n \); \( a \) is the Average Escalating Rate of Operation Costs, \( e \) is the discount rate.

In the third step, the Total Operation Costs \( (OC) \) can be calculated as follows:

\[
OC = \sum_{i=s}^{n} NPV_{OC_i} \quad (5)
\]

Where the \( NPV_{OC} \) is the Total Operation Costs for Project M; \( n \) is the life span of Project M.

The annual Operation Costs \( (AOC) \) can be obtained by the following formula:

\[
AOC = \frac{OC}{n} \quad (6)
\]

2.1.3 Life Cycle Costs

Overall, the Life Cycle Costs of Project M can be calculated as:

\[
LCC = CC + OC \quad (7)
\]

The annual LCC (ALCC) can be obtained as follows:

\[
ALCC = \frac{LCC}{n} \quad (8)
\]

In order to standardize the Costs of projects completed in different construction completion years, the Costs in different construction completion years can be converted into the values in the base year 2008. This will play a tremendous role in comparing the Costs of projects built in different years. The standardized values of \( CC \), \( OC \) and \( LCC \) in the base year 2008 \( (S_{CC}, S_{NPV_{OC}}, S_{LCC}) \) can be calculated by formulas (9), (10), (11), respectively.

\[
S_{CC} = \frac{CC}{(1+e)^{2008-2008}} \quad (9)
\]

\[
S_{OC} = \frac{OC}{(1+e)^{2008-2008}} \quad (10)
\]

\[
S_{LCC} = \frac{LCC}{(1+e)^{2008-2008}} \quad (11)
\]

2.2 Multiple Regression analysis
In this study, LCC, OC, CC have the correlation with the variables of Green Mark level (GM), building type (BT), building owner (BO). Multiple regression analysis is conducted to indicate the degree of independent variables (GM, BT, BO) contribute to the dependent variables (ALCC, ACC, AOC). The regression formula is established as follows:

\[ AC = \alpha GM + \beta BT1 + \mu BT2 + \gamma BO + \delta \]  

Where AC represent ALCC, ACC or AOC; the Green Mark level of Certified, Gold, Gold Plus and Platinum are represented by the values of GM =1,2,3,4; BT1 and BT2 are the dummy variables, the commercial, industrial and institutional buildings are represented by the values of BT1, BT2 = 1, 0; 0,1,0,0, respectively; public and private building owner are represented by the values of BO= 0,1, respectively.

3 Data source

3.1 Data collection

Since the launch of the BCA Green Mark scheme in 2005, the number of green buildings in Singapore had increased from 17 in 2005 to 2155 in 2014. The gross floor area (GFA) has reached about 62 million square meters, equivalent to 25% of the total built-up areas in Singapore [11]. Clearly from this, a large amount of data on green buildings can be used to conduct the life cycle cost research on a national basis. In this paper, we mainly concentrate on the non-residential buildings, which can be divided into three categories: commercial buildings, industrial buildings and institutional buildings.

We sent the invitation of survey participation to all Green Marks certified buildings in Singapore that can be found with contacts. The survey template is well designed on the basis of international standard classification, and they are distributed to corresponding building owners for collecting relevant data of Construction Costs and Operation Costs. Among them, 59 projects with relevant information were returned. After careful checking of the returned project data, 15 out of 59 projects were found either missing or having incomplete data, and thus were removed from the study. Eventually, a total of 44 projects from 13 respective owners were collected for the LCC analysis of non-residential buildings as follows.

3.2 Collection of main calculative parameters

The main calculative parameters of the life cycle calculation method defined in the methodology section can be collected as follows.

3.2.1 Annual Escalating Rate of Operation Costs

On account of the changings of occupants’ behavior and frequency of equipment usage, Operation Costs vary from year to year at the operation stage. We select 10 representative buildings with the specific data of OC from 2010 to 2012 shown in Table 2, and the calculation result of Annual Escalating Rate of Operation Costs (a ) is 4.75%.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Projects</th>
<th>Yearly escalating rate</th>
<th>Average escalating rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2011</td>
<td>2012</td>
</tr>
</tbody>
</table>
### Yearly Escalating Rate

<table>
<thead>
<tr>
<th>S/N</th>
<th>Projects</th>
<th>Yearly Escalating Rate</th>
<th>Average Escalating Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chromos</td>
<td>-0.74%</td>
<td>-15.14%</td>
</tr>
<tr>
<td>2</td>
<td>Helios</td>
<td>6.93%</td>
<td>8.53%</td>
</tr>
<tr>
<td>3</td>
<td>Centros</td>
<td>6.11%</td>
<td>2.73%</td>
</tr>
<tr>
<td>4</td>
<td>Matrix</td>
<td>9.33%</td>
<td>-7.49%</td>
</tr>
<tr>
<td>5</td>
<td>Nanos</td>
<td>7.39%</td>
<td>7.03%</td>
</tr>
<tr>
<td>6</td>
<td>Genome</td>
<td>6.10%</td>
<td>8.34%</td>
</tr>
<tr>
<td>7</td>
<td>Proteos</td>
<td>7.08%</td>
<td>22.04%</td>
</tr>
<tr>
<td>8</td>
<td>Fusionopolis</td>
<td>8.06%</td>
<td>4.72%</td>
</tr>
<tr>
<td>9</td>
<td>Environment Building</td>
<td>10.56%</td>
<td>10.06%</td>
</tr>
<tr>
<td></td>
<td>8 Jurong Town Hall Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>(JTC Summit)</td>
<td>9.93%</td>
<td>6.69%</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td></td>
<td><strong>4.75%</strong></td>
</tr>
</tbody>
</table>

#### 3.2.2 Discount rate

In view of the time value of money, the OC in different years are not comparable. Discount rate is an important parameter in NPV method to discount the future costs to the present value. All the case buildings are constructed during the period from 1987 to 2013. The discount rate (\(e\)) in model (4) can be computed by taking the average of domestic interest rates from 1987 to 2013. The rates are derived from the Money Authority of Singapore (MAS): Financial Database. The calculation result is 2.65%.

#### 3.2.3 Life span

Life span (\(n\)) is an important parameter used for calculating the LCC and OC in the life cycle cost method. The economic life spans for different types of buildings are shown in Table 3. The median values of economic life span for different building types are chosen as the life span for calculation in model (2), (5), (6), (8).

<table>
<thead>
<tr>
<th>S/N</th>
<th>Building Type</th>
<th>Type Code</th>
<th>Economic Life Span</th>
<th>Life Span for calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shopping Mall</td>
<td>SP</td>
<td>10 ~ 20 years</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>Hotel</td>
<td>HT</td>
<td>10 ~ 20 years</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Office Building</td>
<td>OF</td>
<td>20 ~ 30 years</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>Hospital</td>
<td>HP</td>
<td>20 ~ 30 years</td>
<td>25</td>
</tr>
<tr>
<td>5</td>
<td>School/College/Polytechnic/University</td>
<td>UN</td>
<td>&gt; 30 years</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>Factory</td>
<td>FA</td>
<td>20 ~ 30 years</td>
<td>25</td>
</tr>
<tr>
<td>7</td>
<td>Warehouse</td>
<td>WA</td>
<td>&gt; 30 years</td>
<td>40</td>
</tr>
<tr>
<td>8</td>
<td>Transportation Facility / Depo</td>
<td>TR</td>
<td>&gt; 30 years</td>
<td>40</td>
</tr>
<tr>
<td>9</td>
<td>Community Centre</td>
<td>CC</td>
<td>10 ~ 20 years</td>
<td>15</td>
</tr>
<tr>
<td>10</td>
<td>Scientific/Research Building / Lab</td>
<td>SC</td>
<td>10 ~ 20 years</td>
<td>15</td>
</tr>
</tbody>
</table>
4 Analysis of Results

4.1 LCC, CC and OC of 44 projects

Accordingly, the calculation results are presented in Figure 1. Annual average values of LCC, CC and OC of 44 projects are 222.03 $/m², 91.85 $/m² and 130.18 $/m², respectively. On average, Construction Costs account for about 48.61% of the Life Cycle Costs, while the average percentage of OC is 51.39%. It can be seen that the ALCC of Wide Chord Fan Blade Manufacturing Facilities is the largest one (647 $/m²) among the 44 projects, and it is 18.8 times larger than the smallest ALCC of project Gourmet East Kitchen. Discrepancies of ALCC are mainly caused by the different AOC. Meanwhile, the highest AOC is 469.76 $/m² of project Wide Chord Fan Blade Manufacturing Facilities. The lowest AOC is 11.75 $/m² of project Skytech. Except for the largest ACC of project Test Bed Facilities (409 $/m²), the ACC of other projects varies with a relatively small range from 13 $/m² to 177 $/m². Overall, the results imply that there are huge differences of ALCC between different projects, and the main contributor to the discrepancy is the AOC. The proportion of AOC becomes larger as ALCC increase.

![Figure 1 Annual Construction Costs and Operation Costs of 44 projects](image)

4.2 LCC from 1998-2013

The average ALCC from 1998 to 2013 of three building types are illustrated in Figure 2. It can be seen from this Figure that the ALCC of three building types were relatively stable before 2008, but it fluctuated significantly during the period 2008-2013. Specifically, the ALCC of commercial buildings fluctuated between 197 $/m² to 294 $/m², with a slight growing trend. Before 2010, the ALCC of industrial buildings are almost unchanged, with the value of approximately 50 $/m², and then the costs increased significantly, with 647 $/m², 400 $/m² and 200 $/m² in 2010, 2011 and 2013 respectively. The ALCC of institutional buildings fluctuated between 165 $/m² and 384 $/m².
during this period, excluding the minimum value of 70 $/m^2 in 2006.

![Figure 2 The average ALCC from 1998 to 2013 of three building types](image)

### 4.3 Comparison analysis

Table 4 shows the average values of LCC, CC and OC with different building types, Green Mark levels and building owners. The differences of OC and CC are illustrated in Figure 3 intuitively. From the perspective of three building types, the LCC, CC and OC of commercial buildings are 5822.33 $/m^2, 2407.10 $/m^2 and 3415.24 $/m^2, respectively, which are the smallest among three types. In comparing to the CC of three building types, CC of industrial buildings, including factory, office building and transportation, are the largest, with the value of 3271.02 $/m^2. This might suggest that prices of materials and components are high in the construction process of industrial buildings. With regard to the OC, the value of institutional buildings is the highest (5246.65 $/m^2). Meanwhile, the LCC of institutional buildings is the largest (7993.26 $/m^2). The institutional buildings consist of school buildings from NUS, NTU, NYP and MDIS. It might reveal that the energy consumptions of schools are high due to the laboratories with high energy use.

The 44 non-residential buildings are certificated by four levels of Green Mark in BCA individually, including Certified, Gold, Gold Plus and Platinum. The CC and LCC are associated with the Green Mark levels. Buildings with higher Green Mark level have the larger LCC and CC. The level of Gold Plus is excluded in this comparison analysis, because only one building at this level and this value is not typical. Therefore, buildings at the level of Platinum have the highest LCC and CC, with the value of 8744.36 $/m^2, 3584.45 $/m^2. As for the OC, OC of Gold (4874.34$/m^2) is higher than the value of Platinum (4659.41 $/m^2), and the smallest OC is 2093.40 $/m^2, with the buildings at the Certified level.

This study includes 13 building owners, with 4 private building owners and 9 public building owners. The CC, OC and LCC of private building owners are considerably higher than the values of public building owners. This phenomenon indicates that the governmental building owners perform well in saving costs and fulfilling the responsibility of sustainability.
Table 4 Average costs of different building types, Green Mark levels and building owners ($/m²)

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>CC</th>
<th>CC/LCC</th>
<th>OC</th>
<th>OC/LCC</th>
<th>LCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Type</td>
<td></td>
<td>$/m²</td>
<td>%</td>
<td>$/m²</td>
<td>%</td>
<td>$/m²</td>
</tr>
<tr>
<td>Commercial</td>
<td>17</td>
<td>2407.10</td>
<td>42.25</td>
<td>3415.24</td>
<td>57.75</td>
<td>5822.33</td>
</tr>
<tr>
<td>industrial</td>
<td>10</td>
<td>3271.02</td>
<td>57.78</td>
<td>3436.92</td>
<td>42.22</td>
<td>6707.94</td>
</tr>
<tr>
<td>Institutional</td>
<td>17</td>
<td>2746.60</td>
<td>49.56</td>
<td>5246.65</td>
<td>50.44</td>
<td>7993.26</td>
</tr>
<tr>
<td>Green Mark Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Certified</td>
<td>11</td>
<td>1407.35</td>
<td>60.43</td>
<td>2093.40</td>
<td>39.57</td>
<td>3500.75</td>
</tr>
<tr>
<td>Gold</td>
<td>16</td>
<td>2800.04</td>
<td>40.72</td>
<td>4874.34</td>
<td>59.28</td>
<td>7674.38</td>
</tr>
<tr>
<td>Gold Plus</td>
<td>1</td>
<td>2690.36</td>
<td>30.77</td>
<td>6054.00</td>
<td>69.23</td>
<td>8744.36</td>
</tr>
<tr>
<td>Platinum</td>
<td>16</td>
<td>3584.45</td>
<td>49.48</td>
<td>4659.41</td>
<td>50.52</td>
<td>8243.86</td>
</tr>
<tr>
<td>Building Owner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td>9</td>
<td>3365.43</td>
<td>41.18</td>
<td>4315.88</td>
<td>58.82</td>
<td>7681.31</td>
</tr>
<tr>
<td>Public</td>
<td>35</td>
<td>2572.41</td>
<td>50.52</td>
<td>4079.38</td>
<td>49.48</td>
<td>6651.79</td>
</tr>
</tbody>
</table>

Figure 3 The OC and CC of different building types, Green Mark levels and building owners

4.4 Regression analysis

Related data are analyzed in the statistics software SPSS. The results are illustrated in Table 5. It shows the standardized beta coefficient values for respective independent variables, and the values of $R^2$, Adjusted $R^2$ and F. The t test reveals that ALCC and ACC are significantly correlated with Green Mark level. As the degree of Green Mark upgrades one level, the ALCC and ACC increase 47.805 $/m²$, 25.373 $/m²$ respectively.

Table 5 Multiple regression analysis results of ALCC, AOC and ACC

<table>
<thead>
<tr>
<th>Variable</th>
<th>ALCC</th>
<th>AOC</th>
<th>ACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM</td>
<td>47.805*</td>
<td>22.432</td>
<td>25.373*</td>
</tr>
<tr>
<td>BT1</td>
<td>3.938</td>
<td>-10.764</td>
<td>14.702</td>
</tr>
</tbody>
</table>
5 Conclusions

This paper conducts a life cycle analysis of 44 non-residential green buildings in Singapore. The principal findings of this study are concluded from four aspects. Firstly, annual average values of LCC, CC and OC for 44 non-residential buildings in Singapore are 222.03 $/m², 91.85 $/m² and 130.18 $/m² respectively. Secondly, the ALCC for three building types are constructed, the values of indexes were relatively stable before 2008, but fluctuated significantly from 2008 to 2013. Thirdly, after the comparison analysis, with regard to building types, the CC of industrial buildings is the largest (3271.02$/m²) while the OC of institutional buildings is the highest (5246.65 $/m²). In the perspective of Green Mark levels, the CC and LCC are associated with the Green Mark levels, buildings with higher Green Mark level have the larger LCC and CC. As for the building owners, CC, OC and LCC of private building owners are significantly higher than the values of public building owners. Finally, in the multiple regression analysis, ALCC and ACC are significantly correlated with Green Mark level. As the Green Mark upgrades one level, the ALCC and ACC increase 47.8 $/m² and 25.4 $/m² respectively.

Theoretically, this study enriches the research contents of life cycle cost analysis on green buildings, which can provide references for future researchers in related field. Practically, this research demonstrates a visible view of Life Cycle Costs of green buildings for construction stakeholders like building owners, architects, engineers, contractors and governments, particularly in tropical climates. This will in turn help contractors to choose the economic construction modes, and help governments to make effective policies in the promotion of green buildings from the perspective of economic feasibility.

Some limitations also exist in this study. In the process of data collection, some data for Operation Costs are not available. The sample size of green buildings are not big enough to represent all green buildings in Singapore. In the future, a more integrated and accurate study can be carried out by collecting more completed Operation Cost data and enlarging the sample size and range. Especially more buildings at Gold plus level and non-Green Mark buildings can be encompassed for comparison.

Acknowledges

This research was supported by the project “Construction of a Non-Residential Whole-Life Building Cost Index for Singapore” administrated by National University of Singapore. We would like to thank the support of National Social Science Foundation of China (grant numbers 15AZD025, 15BJY038).
References


Exploring health and well-being of workers on a large multinational construction project

David Oswald¹ and Michelle Turner²

Abstract: The health and well-being of construction workers is far from ideal. Through an ethnographic approach, which adopted participant observation as they main research tool, an inductive investigation into health and well-being of construction workers was undertaken. As a participant observer, the researcher was a member of the H&S department on a large (+£500m) multinational construction project in the UK for three years. Data was collected through: H&S department meetings; having informal conversations with project employees; attending site 'walk-arounds'; and having access to project documents. Three themes emerged from thematic analysis of the data: work environment, work schedule and lifestyle. The findings reinforced previous literature that long work hours, commute time, job insecurity and work schedule all created an environment that impacted worker health and well-being. It was also found that: subcontracting created division, feelings of exclusion and a lack of self-worth amongst workers; cleanliness and layout of onsite facilities were important for worker health and well-being; and that for workers away from home, suitable accommodation was critical for making positive health choices, and for having the option to seeing family members more frequently. As the focus on health and well-being grows, it was also recognized that there was greater potential for conflict with other project goals, such as production. The findings were grounded in a social ecological framework, and suggest that factors related to industry and workplace levels, influenced worker health and well-being at family and individual levels.

Keywords: health, well-being, construction worker, ethnography

¹* Oswald, D.
Corresponding author, School of Property, Construction and Project Management, RMIT University, Australia
E-mail: david.oswald@rmit.edu.au

²* Turner, M.
School of Property, Construction and Project Management, RMIT University, Australia
1 Introduction

Health and safety are theoretically and practically very different, yet they are often managed in tandem. In their seemingly unbreakable amalgam, safety is very much the dominant partner (Sherratt, 2017), as the immediate impact of an accident has prioritised safety and neglected health in both practice and research (Skan, 2015). However, within the United Kingdom (UK) it was estimated that more construction workers suffer from a work-related illness (79,000) per year than a work-related injury (66,000), highlighting that construction worker health is still a very important area that deserves more attention (HSE, 2016). Indeed, Sherratt (2017) noted that worker health was now becoming as important as safety, with the UK construction industry making a concerted effort to improve both occupational and public worker health. The aim of the research was to improve understanding of the health and well-being of construction workers on a large multinational construction project (+£500m) in the UK.

Construction workers are a high risk group for occupational disability and poor health (Lingard & Turner, 2015). They are vulnerable to: poor occupational health through the hazards they encounter (e.g. dust and noise); poor mental health from occupational stressors such as production pressure, dangerous work and complex decision making; and the industry structure, which induces further psychosocial harm in terms of temporary work contracts, long working hours and lack of job security (Sherratt, 2017). Using a social ecological framework to frame their research, Lingard & Turner (2017) considered construction workers’ health from a multilevel system perspective inclusive of: individual, family, workplace and industry. Individual represented the workers’ personal characteristics and motivations; family and workplace characterized the workers experience and interactions with family members and in the workplace respectively; and industry signified the workers experiences of working within the construction industry. The role of theory has a critical role in generalizing lessons learned from cases (Yin, 2013). The research presented in this case study draws upon Lingard & Turner’s theoretical framework to analyse the data through a multilevel system perspective.

2 Research methods

Ethnography is a research approach that gains understanding of the social world through: involvement in the daily practice of the research participants; immersion into the context; gaining trust and rapport with agents; both hermeneutic and phenomenological interpretations; and recognition of the complexity of the social world (O’Reilly, 2012). It is reflexive towards the researcher’s role, accounts for the researcher-researched interaction, and does not attempt to reduce the complex social world into statistical or typological representations (ibid). Pink et al. (2012) argued that ethnographic approaches can provide a powerful way of providing the kinds of insights necessary for theoretically informing understanding of construction practice. However, ethnographic studies into health and safety in the construction industry are rare. The limited previous work in this area has typically focused on safety (and not health). For example, Borys (2012) investigated safe work method statements; and Oswald (2016), unsafe acts. There is no known ethnographic study that focuses purely on construction worker health (and not safety) in the construction industry; though there have been ethnographic studies in other industries, such as
Holmes (2006), who investigated the social context of migrant health amongst 130 farm workers and 30 clinicians in the United States.

In this case study, the researcher was a member of the Health and Safety (H&S) department on a large UK construction project and attended the project approximately twice a week for almost three years. The H&S advisors each had a different physical space on the site, and the researcher used the advisors as ‘gatekeepers’ on the project. Gatekeepers can ease the passage of the researcher’s entry through helping to introduce the researcher to other informants. They can also make the surroundings and contexts more visible and understandable through their explanations and interpretations of the social world (Pole and Morrison, 2003). Data was gathered through participant observation which included: attending H&S department meetings; having informal conversations with project employees throughout the hierarchy from directors to labourers; attending organised H&S ‘walk-arounds’; and having access to project documents. Initial notes in the field were later developed into more extensive fieldnotes and input into nVivo. The inputted data was analysed using a thematic analysis approach, which gives the researcher a ‘bird’s-eye view’ of emerging patterns that could be drawn out (Aronson, 1994). The data collection and analysis were a concurrent process (Silverman, 2013), and data was collected and analysed until saturation was reached.

3 Findings

The findings presented are from a wider three year study that had a total project population of approximately 1100 workers. This case study draws upon the health and well-being related themes that emerged during this period: work environment, work schedule and lifestyle. The quotations used in the findings section are representative of many other scenarios and situations which, when analysed as a whole, were able to reveal the key findings of this study. All names have been changed to protect the anonymity of the participants and the case study project itself.

3.1 Work environment

The findings revealed that the physical work environment could affect construction worker health and well-being, such as the site layout and welfare unit facilities, which typically included a canteen, toilet, drying room and office space. For example, one worker commented that the on-site facilities were inadequate for the number of workers: ‘The facilities are getting worse. Too many men, not enough facilities.’ This contributed to a lack of cleanliness and reduced the space in the drying room and canteen areas for the workers. During peak construction work, the emphasis on production could affect the quality of the welfare units: One of the H&S advisors stated: ‘The site had the bare minimum to get the guys to work. It was sent out with no running water, no chairs, soap, handtowels – we were lucky the unit had four walls. I spoke to the Head of Section and Foreman and got it sorted. But we are still having issues. The cleaner hasn’t been out in a month and the guys are living like rats. Welfare units looking like pig stys - no-one seems responsible for it. They’ve nicknamed it Ebola block.’

In terms of the site layout, one of the greatest challenges was designing appropriate smoking areas
for the workers. The management did not want to encourage or support smoking on-site, as it would promote a poor image for health and well-being and could affect production. However, it was a common habit for many workers, some of whom smoked approximately 50 cigarettes a day. There were times when workers broke the site rules, and would smoke in non-designated areas, which caused concern amongst the H&S department. For instance, one H&S advisor stated: ‘Smoking is getting ridiculous. Guys are smoking in all areas, and when operating plant. It is rife and no-one is challenging it.’ However, the workers believed that in some areas the site layout could have been improved to facilitate smokers: ‘The site is 85m long. And there is one smoking area. By the time I get back to work I want another one’. Smoking breaks could affect production rates, especially when the smoking areas were far from where the workers were operating. However, site management were resistant to potentially encouraging the frequency of smoking, by creating new smoking areas.

The findings revealed that the social work environment could also affect construction worker health and well-being. The division between the principal contractor and subcontractor’s social relationship caused concerns for both entities in relation to well-being. For example, one subcontractor foreman revealed that on a daily basis he would receive complaints from his workers that they were not being shown enough appreciation from the principal contractor, and experienced a sense of exclusion: ‘The guys haven’t even been asked out for a pint at Christmas, and everybody else is going on parties. I get this complaint every day. What can I do? We need these guys happy and on-side. They are ones building it. But sometimes we just aren’t looking after them.’ The principal contractor also had concerns around their subcontractors appropriately treating their own workers. One H&S advisor raised during a meeting that: ‘Some subcontractors are not being treated well, aren’t being paid on time, or the right amount. They are being kept late and missing breaks.’

3.2 Work schedule

Long hours and overtime is a common aspect of the construction industry. During a H&S meeting the researcher observed the H&S manager explain that in particular site areas workers were consistently doing long hours each week: ‘The guys at site Z3 are working 70+ hours week-in week-out’. Construction workers explained that the late finishes and long working hours were demanding and could affect their personal lives. One construction worker explained he thought the project had: 'long days, and no concerns for family life'. Similarly, one site supervisor explained: ‘I am working long long hours and it has had strains on my relationship, my family and my health... but I know if I don’t do the job, someone else will’. Despite the demanding working hours and overtime that could affect their personal lives, workers were still willing to undertake the long days because they wanted the work and associated income. As one H&S advisor explained: ‘Overtime is very popular amongst the guys – it is all about the money. In some of my previous jobs I have caught guys that have worked days on one site, and nights on another with a few coffees in between.’

The long daily hours were compounded by the long weeks, as some workers would do 12-day shifts followed by 2 days off. One site supervisor stated: ‘Guys are working 12 days on, 2 off.'
They finish at 6:30 and the place turns into a mad house with guys trying to get away. Some of the commuting workers are doing 17 hour days from when they leave the house to when they get back at night. We don’t think about those guys.’ The long working hours took their toll on some workers, and participants acknowledged that sometimes workers would go for a short sleep during shifts. One site supervisor explained: ‘if we are ahead of schedule or the boys have hit the targets, then I see it as only fair that they get a longer break. Some will play on their phone, drink tea or go for a sleep in the first aid room.’ In other areas of the project, site-based workers such as foreman and operatives would occasionally shift from day-shift to night-shift. After changing from Saturday nightshift to Monday dayshift, one site foreman explained that it: ‘felt like jetlag’.

Some participants questioned the efficiency of the long working hour’s schedule. For instance, one site manager suggested the productivity dropped during overtime periods: ‘They [workers] do half the work, for double the pay, on a Saturday’. The pay structure, where workers would be rewarded with double pay during overtime hours, encouraged them to stay late or work weekends; but this in turn affected their health and wellbeing, as they would be spending time away from their families and were more susceptible to fatigue.

3.3 Lifestyle

The workers lifestyle was influenced by various factors including whether they were local, commuting or working away from home. The workers that had moved for the job were from other areas of the UK, and other European countries including Romania, Spain, Portugal, Poland and the Czech Republic. Migrant workers from outside the UK were initially placed in temporary accommodation for three months. The accommodation was described by one worker as: ‘very small... [he points to welfare unit] it is around the same size as this (approximately 4m x 2m). That is for two people. And very expensive compared to home.’ Some migrant workers planned to bring their significant others with them but it was challenging to find suitable accommodation. The job status of migrant workers was also insecure as after their three month probation period, some would not have their contract renewed, due to their work quality and levels of competence. Hence the accommodation during this period was often small, cheap, temporary and lacked the levels of comfort and kitchen facilities the workers desired.

The subcontractor workers that had moved away from home explained how important it was to have good accommodation, in terms of level of comfort and kitchen facilities. One British construction worker explained that: ‘The most important thing when you go away is your digs [accommodation]. You get s**t digs, then you go out all the time, makes you eat takeaways, its pub meals, its pints.’

The use of alcohol and drugs was a health and safety (H&S) concern for senior management. For instance, one project document, an H&S alert stated: ‘It has been brought to the attention of senior management that we are experiencing persons reporting to work under the influence of drugs or alcohol, and have found empty alcoholic containers within our areas of work. This type of behaviour is putting the individual and others at risk which will not be allowed on this project site.’ Site-level management were aware of their behaviours outside work, but urged them that:
'you can do what you want in your private life, I don’t care, but don’t bring it into work’. In some cases, the workers also brought other undesirable behaviours, such as gambling, into work. One site supervisor explained that he: ‘...(I) had to ban phones. I didn’t want to but some of the guys were gambling. You can imagine what it was like when they lost. One of the lads lost big, and he was eating Easter Eggs all week ‘cause it was a few days after Easter and they were a knock-down price in the shops. That was the final straw. Had to be banned.’

The lifestyle choices of the workforce raised some concerns amongst H&S advisors, as it was observed that many workers were considered over the healthy weight range. Following a T-shirt order for the workgroup winners of a H&S award, one advisor stated: ‘3 small, 4 medium, 17 large, 17 XL, 4 XXL, 1 XXXL, and 2 XXXL. It makes you wonder about the lifestyle choices and the health is of our workforce.’

4 Discussion

The results are considered using Lingard & Turner’s (2017) framework which interprets construction workers’ health from a multilevel system perspective that involved four levels: individual, family, workplace and industry. The findings in our study suggested workplace and industry levels influenced the worker conditions and behaviors at family and individual levels. This can be illustrated in the following conceptual model, which is based on the findings in this study:

![Conceptual Model](image-url)

Figure 1: The environment created at the industry and workplace levels acted as antecedents.
Causal determinants such as fatigue, schedule demands, long work hours, and concerns about job security were highlighted in Lingard & Turner’s (2017) work. In the presented study, two other determinants emerged: subcontracting, as divisions resulted in employee exclusion and feelings of lack of self-worth; and project facilities, such as the available space and cleanliness of welfare units, which was heightened during periods of high production pressure. Sherratt (2017) highlighted that the environment in which construction workers operate in could lead workers to unhealthy behaviours as stress ‘cures’. Lingard & Turner (2017) found that some workers expressed a desire to be healthy; and in the presented study it was revealed that for construction workers away from home, one of the most important factors for improving the chances of undertaking healthy behaviours was to have good accommodation. Small or uncomfortable accommodation meant workers were more likely to undertake risk-taking behaviours such as the consumption of alcohol and drugs, and a diet consisting of takeaways and pub meals. Poor accommodation also created family-based influences on health and well-being for migrant workers, as it was difficult to find suitable accommodation for their family members. Migrant workers particularly from Eastern European countries also found the accommodation very expensive compared to their native countries, which restricted their options when searching for suitable accommodation.

For local workers, the long working hours created strains on their family life. The findings in this study questioned the efficiency of such long hours, as production rates were suggested to being less than normal during overtime periods. The workers often accepted overtime opportunities, likely because of job insecurity within the industry, and that money is a strong motivator for construction workers (Oswald et al., 2017). However, these long hours resulted in high levels of fatigue, and in some cases workers were rewarded with a short sleep during work hours when production targets were met. As construction worker health and well-being gathers focus, conflicts with other project goals, such as production, became more evident. For instance, workers desired more smoking areas, and chose to break the rules by smoking in non-designated areas; while the management acknowledged fewer smoking areas could reduce production (as workers would have further to travel), they did not want to encourage smoking through having multiple easily-accessible smoking zones.

5 Conclusion

The work environment in the construction industry, consisting of long working hours, job insecurity and schedule demands has been previously highlighted in literature as impacting worker health and well-being. The results in this study suggested these workplace and industry level influences can affect the worker conditions and behaviors at family and individual levels. Aside from the determinants highlighted in Lingard & Turner’s framework, subcontracting and project facilities were found as other determinants that can affect worker health and well-being in the presented work. As the context was a multinational construction project, with many workers away from home, suitable accommodation was also stressed as particularly important for their health and well-being. Construction worker health continues to gather importance, and by building on Lingard & Turner’s framework, the presented work provides further understanding and insight into an area that has received much less attention that its seemingly inseparable counterpart, safety.
References


Critical Risk Factors for Transnational Public-Private Partnership Projects: A Literature Review

Yu, Y. ¹, Chen, C.², Chan, A.P.C.³, and Darko, A.⁴

Abstract: The importance of Transnational Public–Private Partnership (TPPP) has accelerated over the last decade, and the critical risk factors (CRFs) for TPPP has gained increasing attention from both researchers and practitioners. However, a systematic review of the extant literature on TPPP CRFs is unavailable. This study addresses this gap by conducting a systematic review of 37 selected papers on TPPP published from 1991 to 2015. Results indicate the most frequently identified TPPP CRFs are legal risk, cooperation risk, tariff risk, financing risk and political risk. This study provides reference for researchers and practitioners to enhance their understanding of the CRFs for TPPP projects for risk management activities. The checklist of TPPP CRFs also makes this paper useful for researchers to undertake further empirical studies.

Keywords: Transnational Public-Private Partnership; Critical risk factors; Literature review.

¹ Yu, Y.
Corresponding author, Business School, Sichuan University, China
E-mail: yuyaoscu@126.com

² Chen, C.
Business School, Sichuan University, China

³ Chan, A.P.C.
Department. of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong

⁴ Darko, A.
Department. of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong
1 Introduction

Public–Private Partnership (PPP) is considered the “key vehicle” for implementing large and complex infrastructure projects in many countries and in the regions. This strategy combines competitive tendering and flexible negotiation to achieve greater efficiency and better monitoring[1], as well as to share project risks and benefits between public and private sectors[2]. Considering its potentials, many countries around the globe, such as the UK, US, Australia, and China, are increasingly adopting the PPP concept as an effective means to deliver infrastructure projects[3]. As a result of the significant development of the world economy’s globalization and integration, private sectors not only participate in local PPP projects but also seek investment opportunities in the global market. The demand for PPP infrastructure projects in developing countries is increasing, which brings opportunities for investment, construction, procurement, and other business opportunities for investors from developed countries[4].

In this study, TPPP is defined as “continuous and relatively institutionalized trans-boundary interactions between public and private actors that formally strive for the provision of collective goods, whereas private actors can be for-profit and/or civil society organizations”[5]. Risk events have been of interest to researchers working on PPP projects[6].

More so in TPPP, risk is bound to increase with foreign penetration due to unfamiliarity in the geography, the supply chain, the local legislation, and the business practices[7]. Over the past decade, numerous research studies discussed risk factors in TPPP. However, the attention given to the need to review the already published TPPP critical risk factors (CRFs) is lacking. Therefore, conducting a systematic review of previous TPPP CRF-related studies is worthwhile. This review study is conducted to answer the important research questions: What are the most frequently identified TPPP CRFs in the literature?

A total of 37 relevant papers in the area of TPPP published in peer-reviewed journals from 1991 to 2015 were identified and systematically analyzed. As a result of the developed checklist of TPPP CRFs, this paper will also be useful for researchers to undertake further empirical studies on TPPP CRFs.

2 Research Methodology

Literature review is a useful way to gain insight into a particular research topic and appreciate the existing body of knowledge about the topic[8]. Thus, this study reviewed the literature on TPPP to identify the CRFs in TPPP projects. For TPPP, when foreign investors expand their services internationally into other countries, uncertainties usually increase the risk of becoming unsuccessful. Therefore, foreign investors need to identify the risk factors in host countries and fully understand the characteristics of PPP projects overseas before making investment decisions. The 37 papers analyzed in this study examined and discussed CRFs for TPPP from different perspectives. Following a review of the 37 papers, 42 risk factors were identified and summarized in Table 1. Most of the TPPP CRFs reported in the literature are legal risk, cooperation risk between public and private sectors, tariff risk, financing risk, and political risk, identified in 19, 18, 17, 16, and 16 references, respectively. Considering the word/space limitation, only these top-five CRFs are discussed in this paper.
<table>
<thead>
<tr>
<th>No.</th>
<th>Risk factors</th>
<th>References</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Legal risk</td>
<td>[4] [6] [7] [12] [13] [15] [16] [17] [19] [21] [22] [26] [28] [29] [30] [32] [34] [36] [37]</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>Cooperation risk between public and private sectors</td>
<td>[2] [3] [4] [5] [7] [8] [9] [10] [11] [13] [18] [19] [23] [29] [30] [32] [33] [36]</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>Tariff risk</td>
<td>[2] [4] [6] [7] [11] [12] [13] [15] [17] [20] [26] [27] [30] [31] [32] [34] [37]</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>Financing risk</td>
<td>[2] [5] [6] [7] [10] [12] [13] [20] [27] [28] [29] [30] [32] [33] [34] [35]</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>Political risk</td>
<td>[5] [6] [7] [12] [13] [16] [17] [20] [22] [26] [27] [28] [29] [31] [34] [35]</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>Technology risk</td>
<td>[2] [3] [5] [7] [8] [16] [17] [19] [27] [29] [31] [34] [35] [37]</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>Corruption risk</td>
<td>[3] [4] [6] [7] [8] [13] [14] [20] [21] [23] [24] [26] [34] [36]</td>
<td>14</td>
</tr>
<tr>
<td>8</td>
<td>Administrative procedures risk</td>
<td>[4] [5] [6] [7] [12] [13] [26] [27] [29] [31] [35] [36]</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>Demand and revenue risk</td>
<td>[5] [6] [11] [13] [16] [17] [20] [29] [33] [37]</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>Credit risk</td>
<td>[3] [5] [6] [10] [12] [13] [28] [29] [36]</td>
<td>9</td>
</tr>
<tr>
<td>12</td>
<td>Worker risk</td>
<td>[1] [2] [13] [15] [17] [21] [29] [34] [36]</td>
<td>9</td>
</tr>
<tr>
<td>13</td>
<td>Construction risk</td>
<td>[5] [6] [13] [17] [24] [29] [30] [34]</td>
<td>8</td>
</tr>
<tr>
<td>14</td>
<td>Operation risk</td>
<td>[5] [6] [13] [20] [25] [29] [30] [34]</td>
<td>8</td>
</tr>
<tr>
<td>15</td>
<td>Force majeure</td>
<td>[5] [6] [13] [17] [26] [29] [30] [34]</td>
<td>8</td>
</tr>
<tr>
<td>17</td>
<td>Public opposition/resistance</td>
<td>[7] [8] [13] [28] [29] [32]</td>
<td>6</td>
</tr>
<tr>
<td>18</td>
<td>Natural condition</td>
<td>[13] [29] [32] [34] [36]</td>
<td>5</td>
</tr>
<tr>
<td>19</td>
<td>Risk in land acquisition</td>
<td>[5] [7] [13] [17] [29]</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>Competitiveness risk</td>
<td>[3] [12] [17] [19] [33]</td>
<td>5</td>
</tr>
<tr>
<td>21</td>
<td>Inability of government to manage PPP</td>
<td>[7] [13] [29] [32]</td>
<td>4</td>
</tr>
<tr>
<td>22</td>
<td>Long-term management risk</td>
<td>[1] [3] [34]</td>
<td>3</td>
</tr>
<tr>
<td>23</td>
<td>Tax risk</td>
<td>[13] [17] [29]</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Risk Factor</td>
<td>References</td>
<td>Frequency</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------</td>
<td>------------</td>
<td>-----------</td>
</tr>
<tr>
<td>24</td>
<td>Payment risk</td>
<td>[13] [17] [20]</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>Cultural impediments</td>
<td>[7] [34] [35]</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>Excessive contract variation</td>
<td>[12] [13]</td>
<td>2</td>
</tr>
<tr>
<td>27</td>
<td>Bidding method</td>
<td>[15] [32]</td>
<td>2</td>
</tr>
<tr>
<td>28</td>
<td>Restriction on import and supporting facilities</td>
<td>[13] [17]</td>
<td>2</td>
</tr>
<tr>
<td>29</td>
<td>Performance risk</td>
<td>[20] [32]</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>Conflict of national essence (capitalism/socialism)</td>
<td>[2]</td>
<td>1</td>
</tr>
<tr>
<td>31</td>
<td>Risk of business-cultural clashes</td>
<td>[3]</td>
<td>1</td>
</tr>
<tr>
<td>32</td>
<td>Restriction policy on foreign investor</td>
<td>[4]</td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>Lack of consistent dispute resolution scheme</td>
<td>[4]</td>
<td>1</td>
</tr>
<tr>
<td>34</td>
<td>Perceptions of a country or nation as high risk economy by foreign investors</td>
<td>[7]</td>
<td>1</td>
</tr>
<tr>
<td>35</td>
<td>Environment risk</td>
<td>[21]</td>
<td>1</td>
</tr>
<tr>
<td>36</td>
<td>Limited decision power for private sector</td>
<td>[10]</td>
<td>1</td>
</tr>
<tr>
<td>37</td>
<td>Prohibition of cross-border design and construction services</td>
<td>[12]</td>
<td>1</td>
</tr>
<tr>
<td>38</td>
<td>High transaction cost</td>
<td>[20]</td>
<td>1</td>
</tr>
<tr>
<td>39</td>
<td>Reliability of cooperation with local entities</td>
<td>[26]</td>
<td>1</td>
</tr>
<tr>
<td>40</td>
<td>Commercial risk</td>
<td>[31]</td>
<td>1</td>
</tr>
<tr>
<td>41</td>
<td>Language differences</td>
<td>[35]</td>
<td>1</td>
</tr>
<tr>
<td>42</td>
<td>Environmental transformations</td>
<td>[37]</td>
<td>1</td>
</tr>
</tbody>
</table>

### 3 Results and Discussions

#### 3.1 Legal Risk

Legal risk has been found to be the most significant TPPP risk factor highlighted by 19 different papers. Law is vital for private companies cooperating with local
government, as it provides a regulatory, legal, and institutional framework in which the interests of all parties are taken into account. Especially in TPPP projects, investors need to familiarize themselves with the host countries’ regulatory requirements and comply to them while carrying out business activities. Compared with domestic PPP projects, legal risk is more serious in TPPP projects. For instance, in most developing countries, sound legal basis or well-established legal frameworks are limited, which presents considerable risks to foreign investors in the implementation of PPP in those countries. Thus, weak or poor regulatory framework and enforcement are highly risky to foreign private sectors in a TPPP contract. For TPPP projects, the host country’s legal conditions might present regulatory barriers for foreign investors, even with strong political opposition/hostility. Private sectors need to adopt local policies and industry regulations and attempt to use fair negotiations to solve the policy debate conflicts.

3.2 Cooperation Risk between Public and Private Sectors

In TPPP, the partnership between public and private sectors is critical to the success of the project. A total of 18 papers emphasized that problematic cooperation between the public and private sectors is a critical risk in TPPP projects. Establishing good partnerships in host countries is fundamental to address practical needs, thereby developing capacity and long-term sustainable solutions. Considering various roles of the government in PPPs, conflicts of interests might arise. Furthermore, the inadequate distribution of responsibilities and risks, inadequate distribution of authority in partnership, differences in working method and know-how between partners, and the lack of commitment from either partner are all potential risks for cooperation. Meanwhile, in transnational cooperation, each party rarely trust each other, and local regulators might offer power limitations to newcomers, resulting in potential conflicts of interest among stakeholders. Owing to the divergent, competing, overlapping, and conflicting interests among participants, the insufficient coordination between the public and private sectors usually leads to contradiction and loss of value for money (VFM).

3.3 Tariff Risk

Tariff risk is also critical to TPPP, which is identified in 17 different papers. In PPP projects, private companies can obtain benefits in three ways, namely, government payment, user payment, and government subsidy. Regardless of which method of payment is adopted, the private sector and the government need to specify the tariff of public services on the contract to ensure that potential benefits would be forecasted and that the risk allocation strategy can be made reasonable in accordance with the payment methodology.

Tariff is a serious problem for foreign investors considering its relation to economic benefits. During the long operation period, the adjustment of the tariff must be clearly stated in the contract. Provision of the adjustment formula and renegotiation mechanism effectively respond to this risk. If a serious emergency incident occurs or the previous contract has severe flaws that affect the cost and operation of a project, both parties can renegotiate and change the payment scheme based on equal principle. Public users remain increasingly sensitive to tariff levels; thus, both parties have to be cautious in dealing with this problem.

3.4 Financing Risk

Financing risk has been identified in 16 different papers. Many TPPPs are large-scale infrastructure projects with huge investment. When investors attempt to finance infrastructure projects in another
country, they often face numerous challenges, such as difficulties in securing a credit facility from local banks, inability of local institutions to provide long-term financing or equity financing, lack of financing support and guarantee from a host country’s government, high finance costs and long financial schedule\[^{17}\]. Financing is also affected by the macroeconomic environment, including instabilities in the financial system, difficulties in macroeconomic adjustment, the limitation of long-term financing, the weak institutional capacity of domestic banking, influential economic events, capital market, the volatility of interest rates, and uncertainty over the availability of foreign exchange\[^{18}\]. The attractiveness of the project, which can be linked to the expected benefits, also influence the accessibility and availability of financing.

3.5 Political Risk

In 16 of the papers analyzed in this study, political risk is identified as a CRF for TPPP projects. In cooperation with the foreign private sector, the policies of host governments are strongly related with the investment and the success of the project. Political support is essential in the implementation of the TPPP contract. Furthermore, in TPPP, private investors do business in politically sensitive sectors with powerful governments; thus, they need sound and legal political support to ensure fairness, transparency, and long-term sustainability. In most developing countries, political instability affects infrastructure projects, leading to insufficient payment even in expropriation\[^{11}\]. The extent of political risk and governmental interference is affected by the prevailing political regimes and the importance of the project to the local economy. Political interference in the procurement process, political reneging during such long period, the withdrawal of government support network, the termination of concession by government, revocation, expropriation, sequestration, or political force majeure events are all potential political risks for TPPP projects\[^{12}\]. Based on the fair risk allocation principle, governments will benefit from retaining most of the political risks considering their ability to take on this responsibility.

4 Conclusions

Over the past decade, an increasing trend has been observed on the research interest in TPPP, resulting in numerous academic publications on this topic. However, to date, a systematic review of CRFs in TPPP projects is unavailable. Therefore, this paper aims to review and analyze papers in peer-reviewed journals with regard to CRFs in TPPP projects to contribute in addressing this research gap. The Scopus search engine was adopted to identify the 37 relevant papers, from 1991 to 2015, analyzed in this study.

Findings reveal that most reported CRFs of TPPP in the literature are legal risk, cooperation risk between public and private sector, tariff risk, financing risk, and political risk, implying that these are the most significant risk factors in TPPP projects. This finding implies that the government and other parties involved should pay attention to these risk factors and come up with appropriate strategies for managing or mitigating these risks to ensure the success of TPPP projects.

The findings of this study are expected to provide a useful reference for researchers and industry practitioners to appreciate the research trend and development on TPPP CRFs and to broaden their understanding of the CRFs in TPPP projects for risk management activities. As a result of the developed checklist of TPPP CRFs, this paper will also be useful for researchers to undertake further empirical studies on TPPP CRFs.

5 Acknowledgement
This paper is a part of an ongoing joint PhD project from The Hong Kong Polytechnic University and Sichuan University, and it is a part of an accepted paper from ASCE Journal of Infrastructure System.

References


## Appendix

Table 2. Selected Papers on TPPP Projects Used in This Research

<table>
<thead>
<tr>
<th>No.</th>
<th>Year</th>
<th>Authors</th>
<th>Journal</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1]</td>
<td>2001</td>
<td>Barchiesi, F.</td>
<td><em>Antipode</em></td>
</tr>
<tr>
<td>[2]</td>
<td>2010</td>
<td>Cocq, K., McDonald, D. A.</td>
<td><em>Antipode</em></td>
</tr>
<tr>
<td>[23]</td>
<td>2009</td>
<td>Abramov, I.</td>
<td><em>Journal of Business Ethics</em></td>
</tr>
<tr>
<td>[29]</td>
<td>2010</td>
<td>Ke, Y., Wang, S., Chan, A. P. C.</td>
<td><em>Journal of Infrastructure Systems</em></td>
</tr>
<tr>
<td>[31]</td>
<td>2003</td>
<td>Frankevych, R., Wetz, A.</td>
<td><em>Journal of International Development</em></td>
</tr>
<tr>
<td>[32]</td>
<td>2003</td>
<td>Muller, M.</td>
<td><em>Journal of International Development</em></td>
</tr>
<tr>
<td>[33]</td>
<td>2011</td>
<td>Meng, X., Zhao, Q., Shen, Q.</td>
<td><em>Journal of Management in Engineering</em></td>
</tr>
<tr>
<td>[34]</td>
<td>2012</td>
<td>Rebeiz, K. S.</td>
<td><em>Journal of Management in Engineering</em></td>
</tr>
<tr>
<td>[36]</td>
<td>1998</td>
<td>Bennett, A.</td>
<td><em>Natural Resources Forum</em></td>
</tr>
<tr>
<td>[37]</td>
<td>2014</td>
<td>Ramakrishnan, T. S.</td>
<td><em>Transportation Research Record</em></td>
</tr>
</tbody>
</table>
Driver and challenges facing leadership in adopting sustainability in the built environment: a developer’s perspective

Abstract

Sustainable development drives the sustainable built environmental campaign on the global stage, which will continue to be an increasing challenge over the next decades particularly to most developing countries. In order to meet the challenges involved, several major China property developers have initiated a “green building development” campaign. They have established a post of “Director of Sustainability” responsible for overseeing the overall development and implementation of green technologies in their projects. Decisions concerning sustainable building development are often embedded in the typical logic of a property developer’s strategy, e.g. from vision, mission and strategy to final objectives. This paper identifies and explores the drivers and challenges confronted by the leadership of real estate enterprises in adopting sustainability, and their strategies and approaches taken to reinforce sustainability in the built environment. By doing so, this highlights the great diversity of drivers and challenges facing entrepreneurs in adopting sustainability and which extends well into the built environment.

Keywords: Leadership; Sustainable built environment; Drivers and challenges.

1 Introduction

For several decades, nations, cities and stakeholders worldwide have begun to promote the construction of “green buildings”. Due to different national realities, different countries have different approaches to developing green building. In referring to the environmental performance assessment systems of developed countries, a special organization is usually established by either government or industry associations (Non-government Organizations, or NGOs) by way of the third technical certification to conduct green building reviews and evaluation. For example, the United Kingdom’s Building Research Establishment’s Environmental Assessment Method (BREEAM) (Larsson, 1998), United States’ Leadership in Energy and Environmental Design (LEED) (Crawley and Aho, 1999), Australia’s Green Star (Seo et al., 2006), the Japanese Comprehensive Assessment Scheme for Building Environmental Efficiency (CASBEE) (Japan Sustainable Building Consortium, 2006), the GBTTool designed by Canada and applied in internationally by over 20 countries (Cole, 1998) and the Hong Kong Building Environmental Assessment Method (HKBEAM) (Davies, 2001). In the USA, green buildings are promoted by NGOs, which aim to use market forces for their development. The U.S. Green Building Council for example, an NGO, established the LEED system, which is designed for market-oriented operation. Before market forces start to play their role in driving green construction projects, however, government
intervention is the primary force to encourage building green. In the USA, the federal and state governments have passed legislation concerning the energy consumption of products, mandatory minimum energy standards of equipment, and use government investment projects to demonstrate and encourage state-of-the-art building energy-saving technologies based on building energy efficiency standards. Building environmental rating systems, therefore, provide a way of showing building owners the extent to which a building has been successful in meeting the expected level of performance in terms of the various criteria involved (Buys and Hurbissoon, 2011).

It is necessary to encourage more stakeholders to be involved in initiating green buildings. Real estate developers are considered to be one of the most proactive stakeholders. With the increasing rise in environmental awareness, some pioneers in the real estate industry have gradually entered the realm of eco-friendly design and building practices in building management and taken other green initiatives (Torre, 2013). In China, green buildings are becoming increasingly demanded due to rapid urbanization pressures, low carbon city developments and public, social and private stakeholders’ willingness to pay for sustainability. Although the central government in China is committed to delivering sustainable developments, it rarely is delivered in practice once the policy is handed down to a local level. Quite why this situation exists is unknown. Of course, it is possible that it is attributable to the well-known challenges involved in green projects, such as higher initial cost.

In this context, green buildings need committed, forward-thinking leadership to drive through change. Ignoring green building issues is no longer a safe business model, as the current market demands developers to be more innovative than ever before, and it is therefore critical for real estate developers to adjust their core business model to the environmental driven market environment (Torre, 2013).

2 Definition of green building development and roles of “Director of Sustainability”

2.1 The definition of green building development

Green building, also known as ‘green construction’ or ‘sustainable building’, is a term defined by the Office of the Federal Environmental Executive. This agency defines this term as:

“the practice of (1) increasing the efficiency with which buildings and their sites use energy, water, and materials, and (2) reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal—the complete building life cycle” (Howe, 2010).

It can be traced to many origins over recent decades, being initially called “Arology” in 1960s by Paolo Soleri, an architect combining ecology and architecture (Soleri, 1969). The arrival of the oil crisis in the 1970s, in which the price of oil quadrupled
virtually overnight, alerted building providers and operators to the need for greater energy saving and that high energy consumption was unsustainable for development in general. In the 1980s, the excessive focus on energy saving resulted in severe detrimental effects on users’ physical and mental health, prompting calls for more attention to be paid to “healthy” buildings. By 1987, the United Nations’ World Commission on Environment and Development first defined sustainability as the ability of the present generation of people to meet their needs without compromising the ability of future generations to meet theirs (Yudelson, 2007). This idea was extensively promoted and applied to architecture in the form of “sustainable building”.

Since 2000, global warming has increasingly attracted the attention of the international community. The Intergovernmental Panel on Climate Change (IPCC) predicted that greenhouse gas emissions will grow by 25%-90% from 2000 to 2030 (IPCC, 2007), which will have an immeasurable influence on our living environment. Significantly, as is well-known, building construction is one of the major sources of greenhouse gas emissions, with an estimated 36% of greenhouse gases being emitted by building construction related activities (IPCC, 2001; Metz, 2001).

Today, “green building” is based on the theory of sustainability and is part of the concept of promoting sustainability (Chan et al, 2009). It has become a flagship for sustainable development in this century, with a responsibility for balancing long-term economic, environmental and social health. (Ali and Al Nsairat, 2009). According to the USGBC (1998), green buildings incorporate design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants in five broad areas of: (1) sustainable site planning; (2) safeguarding water and water efficiency; (3) energy efficiency and renewable energy; (4) conservation of materials and resources; and (5) indoor environmental quality (Council UGB, 1998). Mahsa et al (2011) define a green building as “a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner”.

The Building Services Research and Information Association (BSRIA) point out that a green building is conducive to people’s health, and its construction and management should be based on the principle of efficient resource utilization and ecological benefits. Generally, green buildings are energy efficient, water conserving, durable and non-toxic, with high-quality spaces and materials with a highly-recycled content (Yunna and Ruhang, 2013). They have both private utility and public utility. Private utility refers to safety, comfort and health as, according to the World Health Organization (WHO), green buildings can provide healthy, comfortable and safe spaces for people’s living, working and other activities. In contrast, public utility is recognized as environmental protection through saving energy and water and reducing carbon emissions, which presents a solution to resource and environmental problems.

For the purpose of reducing carbon emissions and alleviating the greenhouse effect, more and more research concerning green building is focused on “low carbon” buildings. As a result, together with energy rating systems such as LEED and Green Star now operating in several countries, green building is gradually being put into
practice. China, as a large industrial country and one of the largest energy consumers
and carbon emitters in the world, where especially residential buildings are in great
demand, has a responsibility to urgently help lead the way (Yunna and Ruhang, 2013).

2.2 Stakeholders in green building development

Whilst awareness of ‘green’ issues continues to grow, being a good steward of ‘going
green’ plays a significant role in attracting progressive businesses and new residents.
At the national level, the 2006 Five Year Plan ushered in China’s first important move
toward transparent sustainable measurement and reporting; for example, to reduce
Energy use per unit of GDP. This was further accelerated by the 12th Five Year Plan
which established the target of “reduction of carbon emissions per unit of GDP by 17
per cent by 2015 of the 2010 level” (Qu et al., 2012). At the enterprise level, initiating
a green building program allows an enterprise to demonstrate a pioneering image in
sustainability, by taking measures to save energy, reduce waste reduction and form
environmentally friendly communities. Although not usually a high priority for
investors, governors, owners or even tenants, buildings use a significant amount of
energy and are obviously a key concern with regard to global warming (Sayce, Ellison
and Smith, 2004: 226). In China, stakeholders engaged in green building development
can be categorized into primary participants and subordinate participants. Primary
participants involve mainly government departments, developers and consumers (end-
users), while subordinate participants include planning and design institutions, material
and equipment suppliers, contractors, construction supervision institutions and property
management companies (see Figure 1).

The primary participants - government, developers and consumers - follow their own
interests in pursuing green building development. For instance, government
propaganda promotes the idea of sustainable development, developers maximize profits
and consumers seek higher living standards (Lin, 2012). Different stakeholders
participate in green building development through various approaches. Local
government takes part in progressing green building mainly through examination and
approving land leasing. However, as a positive externality of green building, the
government has to enact relevant policies to encourage green building projects, such as
by supporting financial institutions in providing loans to developers preferentially or
providing credit guarantees for financing. Developers then start to conduct such
development activities as feasibility studies, planning and construction. According to
Hu and Xiao (2013), developers in China do not actually participate in construction
activities, but instead, but make profits by integrating resources, and being sponsors
and organizers of green building developments. In this context, developers usually lack
the momentum to develop green projects as it is assumed that green buildings cost much
more than traditional ones.

As for subordinate players, it is vital for designers to support green building projects.
Recently, “integrated design” is gaining increasing attention in practice. The Integrated
Design Process (IDP), developed in Canada and Europe has shown that changes in the
design process can make major contributions to the performance of buildings (Larsson, 2009). Material and equipment suppliers are responsible for providing the environmental friendly materials and equipment needed. They are followed by the contractors, translate the greening design plan into reality. In China, a supervision unit is also involved in developing green projects by supervising and controlling projects and making sure the design plans are completed. After the buildings are delivered to the owners, it is necessary to hand over the responsibility for the green operations management to property managers. As for commercial buildings, the property managers also support developers who want to make their current portfolio of properties more environmentally friendly through technical enhancements. For example, the capital costs and maintenance of facilities’ upgrades can often be covered through energy saving over the long-term life cycle.

In China, developers play a vital role in integrating stakeholders and resources to successfully produce green buildings. Developers firstly coordinate with local government to obtain access to the land. This is based on a feasibility study involving planners and architects. Once the conceptual design of the green building project is approved by the relevant government bodies, developers invite the involvement of subordinate parties. When the transfer of the property title between the developer and purchaser is endorsed and registered by the relevant government authorities, a property ownership certificate is issued to the purchaser by the government authorities and the title of the property is transferred from the developer to the purchaser (Pan, 2011). The property development process is finished at this point and the property management company then becomes responsible for undertaking the maintenance and management of the green building (see Figure 1 and Table 1).
Figure 1 Stakeholder analysis for green building development
<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Key roles and responsibilities</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real estate developers</td>
<td>Integrated resources in the value chain of green building; Adaptation to emerging market needs; Seeking for new channel for green building development</td>
<td>Zhang et al., 2011</td>
</tr>
<tr>
<td>Architect, planner and agents</td>
<td>Integrated design process; Innovative green design; Code compliance and technical due diligence</td>
<td>Summarized from interviews by the author, 2014</td>
</tr>
<tr>
<td>Financial institutions (e.g., banks)</td>
<td>Green loans for green building products; Discount in insurance premiums; Targeted green investment</td>
<td>Summarized from interviews by the author, 2014</td>
</tr>
<tr>
<td>Government department</td>
<td>Regulations with strong compliance mechanisms; To enact relevant green property tax and refund incentives policy; To encourage green building by subsidies through capital or land areas</td>
<td>Zhang et al., 2011</td>
</tr>
<tr>
<td>Owners and tenants</td>
<td>Social responsibility for built environment; Market demand for green and healthy buildings</td>
<td>Zhang et al., 2014</td>
</tr>
<tr>
<td>Suppliers</td>
<td>Train employees to be adapt to green production; Skills and professionals for green innovation</td>
<td>Summarized from interviews by the author, 2014</td>
</tr>
<tr>
<td>Property management companies</td>
<td>Maintenance of the building over the life cycle stages; Help tenants manage green property portfolios</td>
<td>Zhang et al., 2014</td>
</tr>
</tbody>
</table>

2.3 The role of the “Director of Sustainability”
The Director of Sustainability is a position that is responsible for achieving one of the corporate goals, *e.g.*, to sustain social responsibility. In general, corporate social responsibility means the organizational consideration of multiple stakeholders and global impact, beyond simply focusing on maximizing the shareholders’ wealth (Pienaar, 2010). Many companies associate the expenses involved in social responsibility and green design effort to be in accordance with the idea of integrating economic, environmental and social criteria into strategy and management to create long-term value for shareholders (Smith, 2007). These widespread CSR efforts are driven not only by ideological thinking that firms can be positive forces for social change, but also by the business returns that firms potentially reap from CSR engagement (Du, 2013). Consequentially, corporations now pay more attention to the internal status of “green building”. Hence, sustainability is becoming a vital consideration in leadership decision making, and may even lead to the birth of a new “green” position.

As it is important to engage with different stakeholders in developing green buildings, I conducted several interviews with business leaders to elicit their opinions concerning their attitudes to social responsibility or, in other words, the sustainability development views of managers.

According to CEO of Gammon Construction, Ho Corporate Social Responsibility is defined as action to promote and protect the environmental, social and economic interests of future generations, adding that, as part of the commitment to create real value in a changing world, they are determined to hold themselves accountable for the social, environmental and economic impacts of their operations and are committed to developing appropriate policies, business practices and services (Jones Lang LaSalle and LaSalle Investment Management, 2010). Mr Mao Daqing, the CEO of Vanke, one of China’s largest developers, believes that corporations will not stay in existence unless they conform to being “green”. This is echoed with China Merchants Property Deputy GM, Mr Hu Jianxin’s comment that “Real estate is in a process of green innovation that will gradually spread to all levels of the real estate industry chain. Hence, it is becoming a common mission and vision for most Chinese developers to depart from the traditional real estate development approach in favour of developing green buildings (Zhang *et al*., 2011). Although it is not necessary for a business corporation to found its own energy saving company, it must have a management team to implement requirements from top-down (Jiao, 2012).

In China, some leading real estate developer pioneers, such as China Merchant Properties, Vanke, Modern Land and Landsea real estate, have integrated their own characteristics with a burgeoning green mission since 1999. For example, China Merchants Property (CMP) proposed a “green real estate” concept directly with a guidebook published in 2004 named “The Road towards Green Real Estate”. During early 2010, a new mature green operation system first appeared within the CMP management system. Within this system, the CMP headquarters established a Planning Commission Committee and Green Real Estate Research Centre to maintain their green
property operation as well as promote new housing products. In each of their local branches, CMP nominates its technology director as a green commissioner to take responsibility for green development. CMP has also established a new position of “Green Technology Director.” As the main principal for corporate social responsibility and green real-estate development, the Green Technology Director is responsible for green strategy formulation, implementation, low-carbon green product standardization, technology development (RandD), corporation strategic platform construction and green financial expansion (Zhong, 2011). The directors of sustainability in other real estate enterprises have similar responsibilities. For example, Modern Land has established a chief energy efficiency executive officer to take care of green building and produce a complementary building energy management system that integrates a number of advanced green technologies. Landsea has also instituted a senior technology management position named “Green Chief Architect” who is responsible for reviewing all of development projects in terms of sustainability criteria (see Table 2).

Table 2 Director of Sustainability in three real estate enterprises

<table>
<thead>
<tr>
<th>Corporation</th>
<th>Position</th>
<th>Director responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>China Merchants Property</td>
<td>Green Technology Director</td>
<td>(1) Develop, implement and promote corporate green strategies.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) Standardise product, research and develop specific technologies.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3) Review regional green building projects.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4) Coordinate the relationship between government and corporation financed green subsidies.</td>
</tr>
<tr>
<td>Modern Land</td>
<td>Chief Energy Efficiency Executive Officer</td>
<td>(1) Complete the energy saving technology system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) Provide a comfortable and energy-efficient residential product.</td>
</tr>
<tr>
<td>Landsea</td>
<td>Green Chief Architect</td>
<td>(1) Responsible for green building technology counselling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2) Review all green building projects.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3) Continue designing environmental friendly residences.</td>
</tr>
</tbody>
</table>

3 Leadership in promoting green building development: the status-quo

3.1 Performance in engaging with green building

Leadership is the capacity for leaders to be engaged with their subordinates and relevant stakeholders, including the interactions among them (Zhang, 2007). The influence of leadership is significant throughout the process of green estate development,
particularly the leaders’ perceptions of green buildings, green marketing, and green management. Nevertheless, developers perceive the development of green buildings in different ways, which has a direct impact on their marketing strategy, e.g., to prioritise green projects as core products. In a market survey conducted by the China Real Estate in 2011, 36% of the property developers agreed that the green building industry in China is in a ‘germination’ (initial) or transition stage (from of ‘demonstration to rapid development’), while 22% thought it had already passed into the ‘demonstration stage.’

Distinctive cognition differences have led to particular preferences in green buildings. Proactive business leaders tend to take the initiative in developing green buildings and promoting real estate projects that comply with green guidelines. In this way, entrepreneurial behaviour driven by green leadership can change a property developers’ core strategy, technology system, supporting mechanism and development goal to one that is devoted to green real estate.

Furthermore, the leader’s perception of the green building development can also influence the formulation and transformation of consumer perception in ‘going green’ through real estate products and marketing campaigns. Therefore, when developers promote their products in the market, they are also contributing to publicising and popularizing green building development. In fact, there are insufficient intellectual resources available for green building in China. In this context, a proactive leadership of the sustainability mission and vision not only has a significant impact on recruiting the intellectual resources needed for green building, but also in personnel training and establishing a green strategic map, which would eventually lead to a greater core competence to compete in the real estate market. Recently, several real estate enterprises have successfully transformed themselves from the traditional approach to green building development and established their own green real estate research teams. For example, the China Merchants Property Development Company has started a “Green, R and D and Application Centre” with the purpose for achieving the goal of “building green homes and promoting social progress.” Landsea has also recruited more than 200 domestic and foreign senior researchers committed to the development of green building technologies.

3.2 Leadership styles for green building

Entrepreneurial leadership can be classified into two types – transformational leadership and transactional leadership - which perform differently in promoting green building development. Specifically, transformational leadership plays a more positive role in delivering green buildings due to consideration of social responsibilities and the interests of secondary stakeholders (Du et al.2013), entrepreneurial spirit. The acceptance of social responsibility is one of the initial moves of housing developers in delivering green real estate. Environmental protection and energy saving are important aspect of company social liability. As a leading property developer, one of the primary goals of the Vanke Group has always been to undertake social responsibilities. Since 2008, the Vanke Group has added “becoming an outstanding green enterprise” to its developing vision. In 2013, its total Green Building Certification Area reached 596.4
million square metres, while the area with “Green 3-stars” reached 172.7 million square metres (Vanke CSR Report, 2013). China Merchants Property Development Co, a developer ranked second only to Vanke, defines its core values as “Humanism, Responsibility, Outstanding and Co-prosperity”. Its leaders believe the company can only create more social values by bonding together social responsibility and their own competitive advantage. In order to listen to the voices of all stakeholders, a complete CSR system has been established that provides a stage for the stakeholders to express their opinions concerning green building development.

Another impetus from transformational leadership in green building development is generated by entrepreneurship - the spirit to grab opportunities, confront challenges and take risks even in an uncertain environment. Entrepreneurship also inspires creative and innovative approaches. Corporate innovation is revealed in a spirit of adventure through ‘first-mover strategies’ (Das et al.1998). As a new venture, green building faces higher costs, more technical difficulty, greater market risk and other developmental problems compared with traditional building. For this reason, many companies tend to stay with traditional building. But entrepreneurial companies choose to seize the opportunity and encourage staff to develop green building in creative ways. In fact, companies that have made a successful green transformation always focus on innovation. For example, ‘green gold’ is a new concept indicating the high rewards that can be obtained from investing in green building technology, and has already been adopted by major real estate companies such as Vanke, Landsea, and Vantone.

Compared with transformational leadership, transactional leaders are inclined to focus on the pursuit of self-interest rather than the interests of secondary stakeholders (Das et al., 1998). They usually lack a spirit of adventure and innovation. Therefore, transactional leaders are not willing to invest in the green real estate market because of the high risk and high-cost. In China, small and medium-sized real estate enterprises pay less attention to green buildings than to the traditional market, which leads them to behave as transactional leaders. Henda Property Enterprises is a representative case of the transactional style of leadership. As the second largest real estate enterprise in China, the Hengda Real Estate Group has invested less in green building over the years. Its business leaders have placed their emphasis on hard-work and a fighting spirit instead of the change and innovation needed in ‘going green’.

At present, there are a total of 112 mature and professional real estate enterprises in China, 27 of which are in a process of green transformation. These enterprises regard green real estate as a corporate strategy. Of the top 10 green real estate enterprises, 6 have written social responsibility and a spirit of innovation into their enterprise vision and business goals. The leadership of these enterprises not only bring their own approach to better development in the green real estate market, but also promote customer awareness and acceptance of green building. In addition, the leadership promotes the development of green building technology and improvement in laws and regulations. For example, the green image imposed on the public promotes the developer’s brand and reputation, which can enhance the developer’s intangible value
and improve overall competitiveness accordingly. In this aspect, the China Merchant Property (CMP) enterprise and one of the top ten developers in the Chinese real estate development industry, provides a good example. According to an interview with one manager in CMP:

“A leader does not only lead in performance and capability, but also accepts greater social responsibilities and has a mission to lead the industry to a healthier development. CMP is always committed to external environmental protection so as to secure the long-term value among shareholders and stakeholders. In this way, CMP is on the way towards making a green and social responsible difference of our own future.”

Consistent with its mission, China Merchant Property has been promoting the responsibilities of corporate citizenship and green property brand within the Chinese real estate industry, and has gained the trust and respect of society, which in turn has provided the firm with greater opportunities for further development.

4 Drivers of change

4.1 Incentives for green building projects

As the “green building” movement gains momentum, many business leaders of key stakeholders, such as developers, governors, and designers, are anxious to understand the use of green building metrics to make the case for a sustainable future. Through a comprehensive literature review, a list of 16 incentive factors has been compiled as optional factors driving the implementation of green buildings. These factors can be classified into three groups in accordance with the guidelines in the extant literature.

1) Financial incentives

Many previous studies agree that financial incentives provide both efficient and effective tools for improving the building energy consumption and environmental protection situation (Jaffe et al., 2002; Dennis, 2006; Qian and Chan, 2007b, 2008b). As green projects can offer reduced operating costs while providing an improved working or living environment such as by natural daylight and better indoor air quality, it is therefore considered by many business sectors that the value of buildings designed by sustainable principles is more than that of conventional buildings – the reduced operating costs being a welcome bonus. In this way, the market demand for green buildings could be met (Baldwin et al, 1998; Clark, 2003). The investment needed during the construction period to develop green buildings is 1%-4% more than that of conventional buildings - substantially lower than is commonly perceived (Kats et al., 2008; Zhang et al., 2011). However, the economic returns due to increased property rents, the energy and water savings, reduced waste and lower operation and maintenance costs during the sales and post-sales period are much higher than the increased construction costs (Kats, 2003; Bradshaw et al., 2005; Johnson, 2005;
Braham, 2006; Qiu, 2010). Taylor (2009) and Baek (2008) also include incentive money from utility energy efficiency programs, in terms of structural, mechanical, appliances, lighting, and alternative/renewable energy. In order to acquire the expected financial benefit, it is necessary for owners to understand which incentive programs are available to them, the specific details of each program and the products involved. Income tax credit is another important financial incentive (MTETM, 2007; Hawken et al., 1999). For example, a landfill tax was introduced in 1996 at a cost of £7 per tonne of active waste and £2 per tonne of inactive waste (The Sustainability Construction Task Group, 2002). For the installation of new renewable energy equipment, the tax credit has been increased from 15% to 40% of the expenses; and for high-efficiency insulators, a tax credit of 25% of the investment cost (MTETM, 2007). Green building tax credit is also available to corporate and residential taxpayers who construct a new green building or undertake the green rehabilitation of an existing building (USGBC, 2011). In the case of New York, for example, six different tax credit projects are available, which comprise the whole building credit, base building credit, tenant space credit, fuel cell credit, photovoltaic module credit and green refrigerant credit. In addition, many USA municipalities have already offered tax credits and abatements as a means of advancing specific policy agendas to improve green building development.

2) Policy incentives of government-related bodies

Recently, government regulations and incentives have led many construction projects to pursue sustainable outcomes (Rahman and Sadeghpour, 2010). For example, the EU Energy Performance of Building Directive requires energy performance certificates for all property bought, sold or rented in the commercial and residential sectors (Strong, 2005). In 2002, Germany passed additional energy saving regulations known as EnEV) which set new minimum and mandatory standards for all new residential and almost all new non-residential buildings (Power and Zulauf, 2011). In France, a subsidy of not more than 20% of the construction costs is granted for the general renovation of private dwellings, and grants as well as subsidies are given for renovations to improve energy performance (Baek, 2008). Many studies have explored the best way for the government to motivate the increased development of green buildings (Varone and Aebischer, 2001; Atsusaka and LeVan, 2003; Qian and Chan, 2007). The Density Bonuses Policy offered by the U.S. government could provide an opportunity for municipalities to tie incentives to specific local public policy priorities. For example a higher percentage increase in Floor Area Ratio (FAR) can be offered to clients after green building certification (Hawkins & Wang, 2013).

The access to relevant policies and preferential loans/loan funds is considered as another effective policy incentive (Power and Zulauf, 2011). It is considered favourable for the public sector to offer low interest loans from a large fund to those seeking to build or renovate to verifiable green building standards. In this way, the concerns over the initial costs of a green building retrofit could be eased to a certain extent. Other forms of government policy incentives exist, such as partially or fully refunded development fees (Circo, 2009). As Nolan (2008) reports, for example, because few
municipalities and land use agencies in the USA can afford to relinquish revenues, reduced fees and rebates can only provide meaningful savings to developers if some alternative source replaces the lost revenue involved. One alternative solution, named a “cost-shifting strategy”, aims to increase the fees paid by traditional projects by an amount sufficient to offset the costs of the green building program. However, this cost-shifting strategy depends on local circumstances, as expedited review and development bonuses have relatively high value to developers.

“Priority permit processing/reduce the difficulty of the project approval” is another policy incentive (Prum, 2009; Deng, 2012). For example, for developers who adopt specified green building standards several government programs, some aspects of the development permit application are processed more quickly than those submitted by traditional developers (Circo, 2009).

3) Corporate-based incentives

Many previous studies agree that corporate-based incentives are both efficient and effective tools to improve the development of green buildings (McMurdy, 1991; Gallarotti, 1996; Warren, 2010). As one of the stakeholders in sustainable development, real estate developers’ incentives include: positive benefits for corporate business performance (McMurdy, 1991; Castleman, 1987); strengthening of corporate environmental performance (Carroll et al., 1990); establishment of ‘green brands’ in the industry (Gallarotti, 1996); green project awards (Tinker and Burt, 2004; AIA, 2006); meeting various shareholder requirement and benefits (Smart, 1992; Ken and Ratnayaka, 1992); philosophy to build green (internally) (Gallarotti, 1996); added value to the property (Warren, 2010); and Marketing/Good Publicity/Awards (Clark, 2003). In many cases, the mere presence of green buildings provides much publicity, which can make it easier for developers to attract new tenants or purchasers – especially where energy savings are involved. In this case, the value of faster sales and higher occupancy rates can substantially improve short run business performance (Clark, 2003).

<table>
<thead>
<tr>
<th>Code</th>
<th>Incentives</th>
<th>Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI₁</td>
<td>Incentive money from a utility energy efficiency program</td>
<td>Zhang et al., 2011</td>
</tr>
<tr>
<td>CI₂</td>
<td>Access to relevant policies and preferential loans</td>
<td>Prum, 2009</td>
</tr>
<tr>
<td>CI₃</td>
<td>Income tax credit</td>
<td>Prum, 2009</td>
</tr>
<tr>
<td>CI₄</td>
<td>Marketing/Good Publicity/Awards</td>
<td>Zhang et al., 2011</td>
</tr>
<tr>
<td>CI₅</td>
<td>Seek for green project awards</td>
<td>Kats et al., 2008; Zhang et al., 2011</td>
</tr>
<tr>
<td>CI₆</td>
<td>Density Bonuses (Higher FAR)</td>
<td>Zhang et al., 2014</td>
</tr>
<tr>
<td>CI₇</td>
<td>Development Fees Partially or Fully Refunded</td>
<td>Braham, 2006; Zhang et al., 2011</td>
</tr>
<tr>
<td>CI₈</td>
<td>Priority Permit Processing/Reduce the difficulty</td>
<td>Qiu, 2010; Zhang et al.,</td>
</tr>
</tbody>
</table>
5 Conceptual challenges in ‘going green’

Green building development still faces challenges in market penetration (Chan et al., 2009). Business leaders are also faced with challenges and risks before they make the ‘go green’ decision - failing to meet the required level of certification for example. This risk may be significant where a large number of projects need to meet sustainability standards (Hancock, 2010).

Developers are one of the key participants in green building. From the developer’s perspective, there are both ideological and operational challenges to be addressed during the decision-making and delivery processes involved. Ideological challenges include a cognitive bias towards green building development from inside and outside the organization. Internal misunderstanding occurs mainly from the leadership and the corporate culture. As discussed in the previous section, transformational leadership is more willing to adopt green building development than transactional leadership as the former has more sense of social responsibility and is more proactive in embracing challenges and taking risks. Moreover, the attitude of the leadership towards green building development has a profound influence on the choice of development approach for integrating the ‘green’ concept into the enterprise’s personnel management and cultural development. Taking Vanke and Landsea as examples. Landsea values green building development more than Vanke, due to its cultural characteristics since its establishment. Due to its investment in ‘green’ technology, Landsea has been engaged in a variety of green projects since the early stage of its formation. It provides comfortable, energy-efficient, environmentally friendly residential products with highly cost-effective products in the housing market and it continues to expand its growth in green technology. On the other hand, unlike Landsea, Vanke places less emphasise on green building, giving priority instead to its traditional value of ‘high speed of capital recycling’ and adherence to the Wal-Mart model of development, which
features the production of standardized residential developments around the city outskirts to specifically targeted groups of consumers (Guang, 2009). This external cognitive bias is associated with the public awareness and acceptance of green buildings. Even though the concept of green building has been widely accepted, progress in its adoption is very slow. Newly constructed green buildings are always located in suburbs, such as in a high-tech development zone, which is distant from well-developed public services facilities, such as renowned hospitals and schools. Green buildings are also more expensive in the research and development stages. Consumers may be fond of the advantages of the green building but might not be ready to pay the costs involved.

From the developers’ viewpoint, a major issue also concerns the perceived costs involved. From an operational perspective, the challenges confronted by developers include the cost throughout the building life-cycle. The cost of building includes construction costs and operating costs, which specifically refers to the research and development expenses (R&D) incurred with green techniques, manufacturing installation costs, and operating and maintenance costs. R&D for green techniques can lead to a significant cost difference between traditional building and green building (Jerry, 2007, and many others), leading to the general perception that green buildings are too expensive and not worth the extra cost (Kats, 2003). Indeed, Bartlett and Howard’s (2000) research indicates that UK quantity surveyors believe that energy efficient and environmentally friendly buildings cost between 5% and 15% more to build from the outset (Bartlett and Howard 2000).

A particular issue concerns the difficulties involved in estimating costs over the lengthy building life-cycle, with uncertainty surrounding future developments and absence of reliable information and associated risks being a major problem (Cole and Sterner, 2000). On one hand, the R&D costs for green technology increase the initial cost of green building. On the other hand, uncertainty of the application of green techniques increases the risks. For example, green building in China must be tested and may fail in the evaluation, which means that if the building does not reach the Evaluation Standard for Green Building (GB/T 50378-2006), then it cannot be classified as a “green building”, so that all the effort in the use of green techniques is wasted. The risks can also be defined as opportunity costs. Hence, R&D expenses and opportunity costs both increase the cost of green buildings, and therefore present great challenges for their large-scale adoption. This is reflected in an interview with a developer CEO in talking about the barriers to going green: “It made sense to me to go green. However, there is still a lack of cost analysis and measurement tools in going green due to the initial development stage. For most of the cases, I need to equip myself and the managerial team with ‘green’ and ‘social responsibility’ roles, however, when we get down to the cost analysis and measurement tools, we got stuck there.”

Other perceived challenges to limit the development of green buildings, as shown below (Larsson, 2009):

- lack of simple funding mechanisms to pay for incremental performance;
difficulty in measuring environmental performance in an objective and reliable way;
increasing requirements for specialized skills and knowledge in the design and construction process;
skill deficits in small design firms and contractors;
lack of suppliers to provide green construction materials and equipment

There are great challenges, therefore, in converting green building intentions into reality. Ultimately, though, it is our responsibility to adhere to sustainable development and it is imperative that green building is implemented, and developing a mechanism for bringing this about is an important mission.

6 The ways ahead

Global trends are hitting faster, harder, and wider, with results that can be both exhilarating and devastating for companies, industries, and entire regions, and the winners of tomorrow will be those organizations with strong leaders who enthusiastically anticipate change, maximize talent, embrace social responsibility, and demonstrate authenticity (PWC, 2008). As for green building, the leadership will possibly light the way ahead so that the green value is achieved with the following recommendations:

• **Model the way and inspire a shared vision**
Leaders in built environment should clarify green value by finding voices and affirming shared ideals. Green building will evolve to be not only a way to generate less carbon emissions, but a continuous process for creating local communities with a more healthy, regenerative and economically viable environment. The leaders can set an example by aligning actions with shared values (Herbst and Conradie, 2011), envision the future by imagining, exciting and ennobling possibilities and enlist others in a common vision by appealing to shared aspirations (Hauer, 2010).

• **Challenge the process and enable others to act**
They should also search for opportunities by seizing the initiative and looking outwards for innovative ways to improve green buildings by either experimenting or taking risks to learn from experience and test best practice principles (Kouzes and Posner, 2012). Furthermore, being leading practitioners, leaders are able to foster collaboration, build trust and facilitate relationships that can produce a dominant inter-organisational culture to promote green building development.

• **Managerial, political and community support**
Acknowledging that growing government and public sector activity in support of green building throughout China we argue that leaders should seek managerial, political, and community support to increase self-determination and develop competencies for themselves and the whole industry. These supports are the fundamental needs in
pushing for accelerated, continuous uptake, and improvements in green building. Meanwhile, leaders can provide their own support to others. Showing appreciation for excellence, recognising the contribution, and celebrating shared values and victories will create a green spirit for continual improvements in the sector and society.

In section 5, we examined the ideological and operational challenges confronted by developers. High cost premiums, unequal distribution of benefits, complex legislation, and lack of awareness are major obstacles in green building project management (Hwang and Tan, 2012). In this section, we discuss possible solutions through intergovernmental cooperation in the context of mainland China.

1) Government can play a pivotal role in driving green building development. On one hand, preferred-purchasing policies in the construction, buying, leasing or renovating of buildings will help to provide market pull by creating demand for new products and services (The Commission for Environmental Cooperation, 2008). On the other hand, government can provide financial instruments, e.g. tax exemptions, support funds, project subsidies, interest-free, or discount government loan etc., to enhance supply (Lin et al., 2013).

2) The market also can be used to promote green building development by financial product innovation. For example, the study by Lee et al. (2013) suggests an option model for facilitating green building projects with a governmental guarantee based on Certified Emission Reduction (CER).

3) Notwithstanding the challenges of purely public solutions and the weaknesses of private business systems, it is necessary to explore the potential for collaboration between government and private businesses for green buildings. Research should be carried out to provide a deeper understanding to enable the development of institutions for government and business collaboration in the future.

- Engagement of a greater stakeholder perspective.

Organizations consider meeting stakeholders’ demands to be a strategic investment, requiring commitments beyond the minimum resource thresholds, and it has been revealed that pressures from different stakeholders are determining factors in organizations becoming green oriented (Lin et al., 2013). More stakeholders need to be involved in pushing forward the green building agenda. For example, as the main stakeholder, consumers are becoming increasingly important due to a raised awareness of environmentally friendly products, including buildings. The notion of health is appealing to all, as consumers are willing to pay for an unpolluted environment and for non-toxic construction materials used in buildings in good locations (Hu et al., 2014). These demands are concurrent with the fast economic growth in China.

Being a source of “green capabilities”, suppliers should provide a list of available resources to the industry, including recycled materials and green building features. The incessant exogenous changes from suppliers also provide sufficient incentives to spur green behaviours (Lin et al., 2013). Storage arrangements for the relevant materials and features can significantly influence awareness in the industry of material availability, transportation costs and the required time involved before designing green buildings.
In addition to consumers, supplies and other stakeholders, such as competitors, media, communities etc., should be seriously considered during the whole lifecycle of green buildings. The avenues to the future also include both academics and practitioners.

7 Conclusions

This paper has attempted to articulate an alternative view of sustainability in built environment as seen through the eyes of the business leaders of real estate developers. In doing so, it highlights a much greater diversity of drivers and challenges for business leaders in promoting green buildings which extend well into the China built environment. By introducing the primary and subordinate stakeholders into the process of green building development, a new set of roles and responsibilities becomes apparent. The paper has emphasised, through the description of the differentiated role of “Director of Sustainability”, how the entrepreneurships intend to exploit proactive missions, visions, strategies and solutions at the early stage, which are often more challenging and difficult to make decisions for going green. The judicious decision made by these leaders of real estate developers increasingly deployed by managers and staff can help in addressing both the challenges and intractable barriers that may hinder the development of green building on a wider scale.

The unprecedented pace of urbanisation in China has created a sense of urgency to address the negative externalities of environmental haze pollution, particularly those involving construction related carbon emissions. Policy makers in both public and private sectors in China can learn from the challenges, drivers and opportunities inherent in initiating their pioneering activities. By acknowledging these, we argue that business leaders should seek political, legal, managerial and community support to maintain their self-determination and cultivate the “social responsibility” and “going green” culture at the enterprise level among their employees and the whole building industry. It is encouraging to see that the Chinese central government have allocated targets in national FYPs to subnational levels through negotiations. Once the effectiveness of binding targets is guaranteed by personnel appointment and removal, the targets will be used as a threshold. If they fail to achieve the targets, it will result in the removal of the local government’s leading officials. Although challenging times are ahead, it is expected that positive drivers will also appear.

References

Atsusaka, N., and LeVan, S. (2003). Growing the green building industry in Lane County: a report for the Lane County sustainable business and jobs project, available at website: https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/2365/Lane_Green.pdf?sequence=1


China Merchants Property Development Co.Ltd.2013. CMPD CSR Report.


Jerry, 2007,


Johnson, B.T. (2005), Barriers to certification for LEED registered projects, PhD thesis, Colorado State University, Fort Collins, CO.


Kats, G., James, M., Apfelbaum, S., Darden, T., Farr, D. and Fox, R. et al. (2008), Greening Buildings and Communities: Costs and Benefits, Good Energies, New York, NY.


Nolan 2008)


Prum D. A. (2009). Creating state incentives for commercial green buildings: did the nevada experience set an example or alter the approach of other jurisdictions? 34 Wm. and Mary Envtl. L. and Pol'y Rev.171,
http://scholarship.law.wm.edu/wmelpr/vol34/iss1/5

PWC (2008). How leadership must change to meet the future. Available at website:


Rahman, F., & Sadeghpour, F. (2010). Canadian industry practitioners' perception on LEED credits. In Construction Research Congress (pp. 1547-56). University of Alberta and the Construction Institute of the American Society of Civil Engineers.


Vanke CSR Report, 2013. Available at website:


The Synergy between New Urbanization and Land Use Efficiency—A Case Study of Dingzhou City in Hebei Province

Wang, Y.S.¹, Li, G.J.²*, Huang, D.H.³ and Li, Y.L.⁴

Abstract: Land is the material base for new urbanization and how to use the limited land efficiently is a practical problem worthy of discussion. This paper selects Dingzhou City (a county-level city in North China) as the study object and concentrates on its land use situation under the backdrop of rapid urbanization and both agricultural and industrial development being of great importance in the city. The study yields the following findings: first, economic indicators are the key impetus to the evolution of the complex system and ecological & environmental systems also make great contributions. Second, the entropy of the complex system in the observation period is between 0.5 and 0.6, which can be classified into “reluctantly coordinated”. Third, rapid changes in economic indicators and slow changes in social indicators accounts for the fluctuations of the system’s coordination level. To improve the efficiency of land use, greater importance should be attached to social and environmental benefits in the process of urbanization.

Keywords: Urbanization; Land Use Efficiency; Synergy

¹ Wang, Y.S.
School of Management Science and Engineering, Central University of Finance and Economics, China.

²* Li, G.J.
Corresponding author, School of Management Science and Engineering, Central University of Finance and Economics, China.
E-mail: ligj@cufe.edu.cn

³ Huang, D.H.
School of Management Science and Engineering, Central University of Finance and Economics, China.

⁴ Li, Y.L.
School of Management Science and Engineering, Central University of Finance and Economics, China.
1 Introduction

Land is the material basis for the survival and development of mankind. The acceleration of urbanization process in China triggers a large demand for land resources. However, the blind expansion of urban space has not only caused the inefficient use of land, but also intensified the conflicts between people and land. To address the problems such as the inefficiency and irrational use of land in the process of urban expansion, the National Plan for New Urbanization (2014-2020) proposed that the most stringent “Arable Land Protection System” and “Efficient Use of Land System” should be implemented to optimize land use structure and improve land use efficiency in a bid to meet the needs of land in the development of urbanization [1].

Previous studies focus the land use efficiency in the process of urbanization mainly on three aspects. Some researchers explore the reasons or the influencing factors for the improvement of land use efficiency, such as built-up area expansion [2] and advancement in technology [3], in an effort to answer the question of “why”; Some investigate the relationship between urbanization and land use efficiency from the perspective of sustainable development, including dynamic evolution [4,5] and coupling and coordination development [6,7,8], so as to answer the question of “what”; Others put forward the methods and solutions to make effective use of urban land [9], as well as the concept of future urban development, such as shrewd growth [10] and low-carbon city [11,12], with the aim to answer the question of “how”.

Although these studies carry out in-depth analysis on land use efficiency and its laws in the process of urbanization, they are far from comprehensive when taking into account the national conditions of China. First of all, previous studies focus on urban space and ignore the fact that the land expansion in the city often starts from the surrounding suburbs or villages and that urbanization is concerned about the combination of urban and rural continuity instead of the city alone. Moreover, previous researches concentrate on large and “typical” cities or the cities that have a special location with few scholars touching upon the vast majority of county-level cities.

This paper continues the discussion on the synergy between urbanization and land use efficiency and chooses Dingzhou City, a county-level city in North China Plain that attaches equal importance to the development of agriculture and industry, as an example. The author holds that land use system and urbanization development system influence and support each other. On the one hand, the land provides construction area, agricultural products and other material support for the development of urbanization [13]. On the other hand, the rational development of urbanization can change the way of using land, improve the economic benefits of unit land and accelerate the integration of urban and rural areas. In 2015, the urbanization rate of Dingzhou City in Hebei Province reached 41.6%. However, as a city in traditional agricultural province, Dingzhou is faced with land resources shortage and its conflicts with the rapid development of urbanization. Therefore, how to efficiently and rationally use land resources to promote the development of urbanization become a major issue in the city.

2 Research Design

2.1 Introduction of Study Area

Dingzhou City is one of the first batches of pilot cities that carry out the system reform of
provincial direct management in Hebei Province and administers 25 townships and 530 villages, with a total area of 1283 square kilometers and the total population of 1.3 million. The urban planning region takes up 100 square kilometers, with 38.5 square kilometers have been completed. The population of residents is 360,000. In 2014, the gross domestic product (GDP) in Dingzhou reached 27.742 billion Yuan and the fiscal revenue was 2.78 billion Yuan, making it being approved as a pilot city for the new urbanization.

Dingzhou not only has a long history and rich culture, but also has exceptional advantage in transportation. Located in the strategic hinterland for the cooperative development of Beijing, Tianjin and Hebei, it is an important city on the axis between Beijing and Shijiazhuang, with Beijing-Guangzhou Railway, Beijing-HongKong-Macau Expressway and 107 National Road crossing the area. Furthermore, it also earns an edge in industrial and agricultural development. In terms of the former, the planning area of Dingzhou Economic Development Zone is about 52 square kilometers, with 13.85 square kilometers having been completed. The automobile industries, coal-chemical industry annually produce 400,000 cars, 3.7 million tons of coke, 350,000 tons of formaldehyde respectively. The power plant (600 MW) is the first one to achieve zero emissions in Beijing and Tianjin. So far, an industrial cluster that amounts to over five billion Yuan and three industrial clusters that worthy of over 3 billion Yuan have form. With respect to agriculture, Dingzhou has a solid agricultural foundation and forms three industries: vegetables, breeding and flowers. It is also the demonstration base for the processing of agricultural products in Hebei Province and a big producer for grain, pig and oil in China.

2.2 Indicator System and the Source of Data

Land use efficiency and the new urbanization are complicated systems composed of multiple subsystems. On the basis of the index system adopted by previous researches\cite{14,15,16} and taking into account the actual situation of the development of urbanization in Dingzhou, the author designs a set of index system that reflects the features of the two systems (Table 1). The establishment of land use efficiency system takes 14 evaluation indicators into consideration, including economic benefits(X1-X7), social benefits(X8-X10), ecological benefits(X11-X12) and environmental benefits (X13-X14). New urbanization can be divided into four layers, including the population urbanization (Y1-X4), economy urbanization (Y5-X11), society urbanization (Y12-X15) and space urbanization (Y16-X17) with 17 evaluation indicators.

Table 1 The Construction of Index System

<table>
<thead>
<tr>
<th>System</th>
<th>Sub-system</th>
<th>Order parameters of each sub-system</th>
<th>Unit</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land use</td>
<td>Economic benefits</td>
<td>X1:Gross National Product</td>
<td>Yuan/km²</td>
<td>0.140439</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X2:Investment in social fixed assets</td>
<td>Yuan/km²</td>
<td>0.092252</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X3:Total industrial output</td>
<td>Yuan/km²</td>
<td>0.194120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X4:Fiscal revenue</td>
<td>Yuan/km²</td>
<td>0.028865</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X5:Grain yield per mu</td>
<td>t/Mu</td>
<td>0.065454</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X6:Industrial output for per unit of land</td>
<td>Yuan/km²</td>
<td>0.017649</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X7:Agricultural output for per unit of land</td>
<td>Yuan/km²</td>
<td>0.017648</td>
</tr>
<tr>
<td>benefit</td>
<td>Social benefits</td>
<td>X8:Population density</td>
<td>person/km²</td>
<td>0.0177716</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X9:Road area per capita</td>
<td>m²/person</td>
<td>0.017647</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X10:Housing area per capita</td>
<td>m²/person</td>
<td>0.017648</td>
</tr>
<tr>
<td></td>
<td>Ecological benefits</td>
<td>X11:Green coverage</td>
<td>%</td>
<td>0.017649</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X12:Public green area per capita</td>
<td>m²/person</td>
<td>0.017648</td>
</tr>
<tr>
<td></td>
<td>Environmental</td>
<td>X13:Sewage discharge</td>
<td>t/km²</td>
<td>0.017648</td>
</tr>
<tr>
<td></td>
<td>benefits</td>
<td>X14:The use of pesticide and fertilizer</td>
<td>t</td>
<td>0.017648</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X15:Effective irrigation area</td>
<td>hectare</td>
<td>0.017648</td>
</tr>
</tbody>
</table>

Urbanization

| Population   | Y1:Urbanization rate | %    | 0.017649  |
According to the above indicators, the data of this paper are mainly taken from the “Statistical Yearbook of Dingzhou City from 2006 to 2015” and “The Yearbook of Hebei’s Economy”. Some of the data are collected from “The Yearbook of China’s Urban Economy” and “The Yearbook of the Statistics of China’s Urban Construction”.

3 Methodology

3.1 Standardization of Data

Because the nature, calculation unit and the numerical size of the data collected and calculated are different, the original data needs to be standardized. First, different types of data are classified and analyzed. Then the data are non-dimensionalized and normalized with the data interval being fixed in the interval [0, 1]. Since this article adopts the entropy method to evaluate the index system, the author normalizes the original data to standardize the range: 

Suppose $X_{\min}(j)$ or $X_{\max}(j)$ is the minimum or maximum value of $I$, $p(i, j)$ is the indicator that has been standardized, which can be divided into Positive correlation indicator and Negative correlation indicator the formula is:

Positive correlation indicator: $x(i,j) = \frac{x(l(j)\text{-}x_{\min}(j))}{x_{\max}(j)\text{-}x_{\min}(j)} = 1,2,\ldots,n; j=1,2,\ldots,m$

Negative correlation indicator: $x(i,j) = \frac{x_{\max}(j)\text{-}x(l(j))}{x_{\max}(j)\text{-}x_{\min}(j)} = 1,2,\ldots,n; j=1,2,\ldots,m$

3.2 The Calculation of Weight

Entropy is employed to measure how chaotic the object is while information is employed to evaluate the how the system is orderly organized. Entropy method determines the weight on the basis of how much information the index conveys. The smaller the entropy, the more the amount of information, the greater the weight of the index is, and vice versa. The weight of $j$ in the year
of $i$ is $P_{ij}$

\[ P_{ij} = X_{ij} / \sum_{i=1}^{n} X_{ij} \]

Calculation index of information entropy $E_j$:

\[ E_j = -K \sum_{j=1}^{n} P_{ij} \ln(P_{ij}) \quad 0 \leq P_{ij} \leq 1 \]

Information redundancy $F_j$:

\[ F_j = 1 - E_j \]

Weight of Indicator $W_j$:

\[ W_j = F_j / \sum_{j=1}^{m} F_j \]

Overall evaluation score: \[ S_{ij} = W_j \cdot P_{ij} \] \( S_{ij} \) is the evaluation value of $j$ in the year of $i$.

\[ S_j = \sum_{j=1}^{m} S_{ij} \]

$S_j$ is the overall evaluation value of new urbanization and land use efficiency.

### 4 The Evaluation of Land Use Efficiency

#### 4.1 Measurement of the contribution of indicators

To evaluate the contribution of each index to the evolution of the system, this paper use Principal Component Analysis to obtain their corresponding scores and contributions (Table 2).

<table>
<thead>
<tr>
<th>System</th>
<th>Indicator</th>
<th>Score</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic benefits</td>
<td>X1</td>
<td>0.9920</td>
<td>0.0399</td>
</tr>
<tr>
<td></td>
<td>X2</td>
<td>0.9597</td>
<td>0.0386</td>
</tr>
<tr>
<td></td>
<td>X3</td>
<td>0.8644</td>
<td>0.0348</td>
</tr>
<tr>
<td></td>
<td>X4</td>
<td>0.9862</td>
<td>0.0397</td>
</tr>
<tr>
<td></td>
<td>X5</td>
<td>0.7452</td>
<td>0.0300</td>
</tr>
<tr>
<td></td>
<td>X6</td>
<td>0.4371</td>
<td>0.0176</td>
</tr>
<tr>
<td></td>
<td>X7</td>
<td>0.9775</td>
<td>0.0393</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td>0.8517</td>
<td>0.0343</td>
</tr>
<tr>
<td>Social benefits</td>
<td>X8</td>
<td>0.9399</td>
<td>0.0378</td>
</tr>
<tr>
<td></td>
<td>X9</td>
<td>0.7352</td>
<td>0.0296</td>
</tr>
<tr>
<td></td>
<td>X10</td>
<td>0.8264</td>
<td>0.0333</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td>0.8339</td>
<td>0.0336</td>
</tr>
<tr>
<td>Ecological benefits</td>
<td>X11</td>
<td>0.9308</td>
<td>0.0375</td>
</tr>
<tr>
<td></td>
<td>X12</td>
<td>0.8231</td>
<td>0.0331</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td>0.8700</td>
<td>0.0353</td>
</tr>
<tr>
<td>Environmental benefits</td>
<td>X13</td>
<td>0.9302</td>
<td>0.0374</td>
</tr>
<tr>
<td></td>
<td>X14</td>
<td>0.9219</td>
<td>0.0371</td>
</tr>
<tr>
<td></td>
<td>X15</td>
<td>0.9345</td>
<td>0.0376</td>
</tr>
<tr>
<td></td>
<td><strong>Average</strong></td>
<td>0.9289</td>
<td>0.0374</td>
</tr>
<tr>
<td><strong>——</strong></td>
<td><strong>——</strong></td>
<td><strong>——</strong></td>
<td><strong>——</strong></td>
</tr>
</tbody>
</table>

As for the system, environmental benefits (0.0374) and economy urbanization (0.0376) make the greatest contribution to the two sub-systems. The former means that small changes in
environmental conditions will lead to great changes in land use efficiency at the same direction. For example, the increase in sewage emissions and the use of pesticides and fertilizers will lead to soil pollution, thereby reducing the direct output of land and its potential values. Similarly, the latter means that the improvement of economic indicators will significantly facilitate the development of urbanization. For instance, an increase in GDP per capita and income per capita, and the restructuring and upgrading of industry will promote the development of urbanization. With regard to the order parameters of each subsystem, total retail sales of social consumer goods (0.04), GDP per capita (0.04), GNP (0.0399), and fiscal revenue (0.0397), all of which belong to economic indicators, make the greatest contribution to the system. In other words, economic variables are the main driving forces for the dynamic change of the complex land use efficiency and urbanization system. However, not all economic variables have obvious effects, as in the case of industrial output (0.0176). Other indicators that make little contribution include road area per capita (0.0296), grain yield per unit (0.03) and rural social endowment insurance (0.0306).

4.2 Evaluation of the Coordination between Systems

Apart from determining the weight of the indicator, the entropy can also serve as a tool to measure the coordination of the system. According to entropy theory, we conducts a details analysis of the evolution status of land use efficiency system, urbanization system and the coordination between the two complex systems. This paper chooses the data for 10 years from 2005 to 2014. To improve the accuracy of the model, the author needs to set a certain degree of information loss. Based on the calculation and optimization, it is found that 4 years are the best degree of information loss, so the figure (Figure 1) shows the data of six years from 2009 to 2014.

![Figure 1. The Coordination between of Land Use Efficiency System and Urbanization System](image)

It can be seen from the figure that the three systems are in unstable fluctuation and basically have the same trend, with the entropy interval being basically between 0.5 and 0.6. It can be classified into “reluctantly coordinated” according to the level of coordination. Land use system and the complex system change almost simultaneously, the entropy of the two follow the steps of “decrease, increase, rise to the peak between 2012 and 2013, and decrease”. As for the urbanization system, it is slightly different from the other two systems, especially in 2011 and 2012.

Although the grain yield is relatively small, the majority of the indicators maintain the momentum of increase, account for the peak of the entropy of the land use efficiency system,
particularly the road area per capita and living area per capita, which turn from stagnant to substantial increase. The reason for the low entropy of the urbanization system is that the natural population growth rate has risen greatly from -0.4% in the previous year to 0.84%, and the growth of population (mainly the rural population) hinders the development of urbanization. Since the indicators that make great contributions keep growing at the same time, so the entropy of the composite system is also relatively high.

The entropy of the three systems dropped significantly in 2014 for the following reasons. First of all, the fixed assets investment and industrial output in land use efficiency system grow at a rate of more than 10% while the growth rate of grain yield per unit, land area per capita and living space per capita, green land area per capita is negative. Excessive investment means have been adopted to drive economic output, with the quality and coordination of the development being ignored. Moreover, in the urbanization system, the number of employees in the secondary and tertiary industry and the proportion of people that engaged in non-agricultural activities in rural areas declines, which means that an increasing number of workers go back to the countryside from the city. The natural growth rate of the population continues to remain high (0.62%) this year, but the number of health technicians, the number of beds in the hospital per thousand people are in decrease, which means that public service fails to meet the needs of the increasing population. Lastly, the coordination of complex land use-urbanization system of also decline substantially, which indicates that there is a lack of stable interaction mechanism between land use efficiency and urbanization in Dingzhou City.

5 Summary

This paper mainly discuss the land use efficiency of a county-level city (Dingzhou City) in North China, which is in the stage of rapid urbanization. Firstly, we established a set of index reflecting land use-urbanization system and calculated the contribution of each indicator to the development of complex system. And then, the entropy method was adopted to analysis the evolution status of land use efficiency system, urbanization system and the coordination between the two systems. The analysis of period data indicated that economic subsystem/indicators are key impetus influencing the evolution of the complex system. This finding is generally accordance with the conclusion of previous studies, but the only difference lies in environmental benefits and social development indicators are also of great importance to the system. It implies that the land use efficiency in China’s new urbanization is now dominated by economic drive, but the importance of environmental and social factors is increasingly obvious. Finally, there are still has some points need to further discuss, like the validity of local statistics and the completeness of environmental data. Though statistics department of China have attached importance to it, all this will have a strong effect on the accuracy of analysis result.

References

Sustainability, 9(3), 410.


Risk Identification and Assessment for Construction and Commissioning Stages of Building Energy Retrofit Projects

Alam, M.¹*, Phung, V.M.², Zou, P. X. W³, and Sanjayan J.

Abstract: Buildings account for 32% of total energy use and result in 19% of total energy-related greenhouse gas (GHG) emissions globally [1]. These figures may double by mid-century due to population growth, development of cities, and increasing levels of lifestyle [1]. This significant energy consumption and corresponding GHG emissions are contributing to global warming and urge immediate actions to prevent catastrophic climate change related events in future. Retrofitting existing buildings to be energy efficient has the potential to reduce energy consumption and GHG emission significantly [2]. However, the industry is increasingly aware that energy performance gap (the mismatch in energy consumption between the predicted and actual in the retrofitted building) is a significant problem as it can make the retrofitted buildings performing poorly, not as intended. The energy performance gap is accumulated throughout a project delivery process, from design to operation. The construction and commissioning stages contribute around 25%-60% to the mismatch between predicted and actual consumption. Therefore, this research aims at minimising the performance gap by identifying and analysing risk factors pertaining to construction and commissioning stages of a building retrofitting project. Based on a literature review, this paper developed a comprehensive list of the concerned risk factors and categorised them into six groups: material and equipment, knowledge and skills, construction management process, procurement, design input and client-related risks. Then, a quantitative risk assessment method based on Fuzzy Bayesian Belief Network (FBBN) have been proposed to analyse the probability of the risks. This research has provided an insight into the causes of energy performance gap and is the first step towards the development of a quantitative risk assessment method. Future research directions have been described.

Keywords: Energy performance gap, building retrofit, energy efficiency, risk identification, risk assessment

---

¹* Alam, Morshed
Corresponding author, Faculty of Science, Environment and Technology, Swinburne University of Technology, Australia
E-mail: mmalam@swin.edu.au

² Phung, V.M.
Faculty of Science, Environment and Technology, Swinburne University of Technology, Australia

³ Zou, Patrick X.W
Faculty of Science, Environment and Technology, Swinburne University of Technology, Australia
Email: pwzou@swin.edu.au

4. Sanjayan, J.
Faculty of Science, Environment and Technology, Swinburne University of Technology, Australia
Email: jsanjayan@swin.edu.au
1 Introduction

Buildings are responsible for a substantial proportion of energy-related greenhouse gas (GHG) emission, which is considered as the main cause of global warming. In 2010, total final energy use in buildings was 117 Exajoules (EJ) (accounting for 32% of total final energy use) and resulted in 9.18 GtCO₂e emissions (sharing 19% of total energy-related GHG emissions) globally [1]. In most developed countries, the building sector consists of more than 98% of existing buildings [3], and most of them were built before the introduction of energy-efficiency benchmarks and are energy-inefficient [4]. Retrofitting existing buildings to be energy-efficient has the potential to reduce energy consumption and GHG emission significantly. In Australia, if appropriate actions are taken, buildings may offer a reduction of 23% of overall GHG emission nationally (around 30 MtCO₂-e) by 2030 and 50% by 2050 [5]. However, one of the main challenges towards achieving these savings targets is the energy performance gap between the predicted and the actual energy performance of the retrofitted building.

Energy performance gap is the discrepancy between the actual energy consumption and the predicted consumption in an energy retrofit project. The performance gap can appear in any building retrofitting projects with different functionality and magnitude of the gap can be quite significant. Buildings can use as much as 2.5 times more energy during actual operation compared to prediction [6]. The performance gap results in reduced confidence amongst the building owners and third-party investors in making retrofitting investment. Also, in Energy Performance Contracting (EPC) procurement method where the Energy Service Companies (ESCOs) are paid from the savings achieved, this sort of performance gap results in financial loss for the ESCOs [7]. Therefore, urgent actions are required to solve this significant problem in order to ensure that energy savings targets are achieved and ESCOs have confidence on return on their investment.

As shown in Figure 1, the actual energy consumption can be close to double of predicted consumptions [8]. Another case is the Council House 2 building in Melbourne, Australia. It was the first building in the country that was designed to incorporate state of the art sustainability features [9]. However, an energy audit conducted in 2012 showed that the actual energy performance was just 3.24-star NABERS which is far below than the expectation and is well below the current industry standard for good performance [9]. NABERS stands for National...
Australian Built Environment Rating System, which measures the environmental performance of Australian buildings, tenancies and homes in terms of energy efficiency, water efficiency, waste management and indoor air quality [10].

The causes of the energy performance gap spread out at various stages of a project lifecycle: issues pertained in the design stage, causes related to the construction and commissioning stages and problems occurred in the operation stage [11]. Figure 2 shows several factors associated with each stage. As can be seen from this figure, the energy performance gap could arise from the actual construction processes and can be transferred to clients. The Green Construction Board [6] states that construction and commissioning stage contributes from 25% to 60% more energy consumption in retrofitted buildings, due to the mismatch between building quality and pre-defined specifications, or incomplete commissioning of installed components. Inaccurate design subsequently by the careless installation of components result in underperformance of thermal resistant value up to 50% [11]. Construction failures may or may not be corrected before the building is handed over, and they contribute to shortfalls in performance once the building is operational [12]. In brief, the construction and commissioning problems impact severely on the energy performance, and hence successfully assessing these problems can help to minimise the energy performance gap considerably.

![Figure 2. Energy performance gap throughout a building lifecycle (Adopted from [6])](image)

Therefore, this research focuses on addressing energy performance gap from construction and commissioning stages using risk management approach. The problems pertaining to construction and commissioning stages can contribute from 25% to 60% to the gap [6] and therefore need to be identified, analysed and managed. The literature review showed several studies on risk assessment for new builds but there is a dearth of study on risks in building retrofitting projects, particularly for construction and commissioning stage. These stages in building retrofits face some constraints that are unique to retrofitting projects such as work hour constraint, workspace constraint, material and equipment transportation constraint, surrounding environment constraint, technology and equipment constraint, and policy and regulation constraint [4]. These constraints may change the significance of certain risks to contractors compared to those in conventional building projects. Therefore, risk assessment methods for new building construction is not applicable for retrofitting projects and there is a need to develop a new risk assessment framework.

As a first step towards the development of retrofitting risk assessment framework for construction and commissioning stages, this paper focuses on risk identification. Risk
identification is an important step in risk assessment because risks that have not been identified cannot be analysed and evaluated, and their occurrence may produce adverse consequences [13]. Based on an extensive literature review, this paper compiled a comprehensive list of the associated risks in construction and commissioning stages of retrofithing project. It was then followed by a systematic discussion of future research work regarding the development of a risk assessment framework.

It is expected that the developed risk assessment framework will not only help to minimise the performance gap but also will assist the project team to assess the overall risk rating of the project. This knowledge of risk rating of a retrofit project will facilitate the selection of best procurement model (e.g. EPC, design and install etc.) for the retrofit project. Nowadays, the retrofitting industry is considering to use risk-based procurement method that considers a number of projects related risk factors to determine the project risk level instead of only project value [14]. For example, traditionally EPC procurement method is preferred if the project cost is higher than a threshold value. However, use of EPC is expensive, complex and time-consuming. Therefore, in the case of retrofitting projects where the cost is higher but the risk is relatively low (e.g. lighting), the traditional practice selects EPC as procurement method and incurs additional cost to the clients. Use of an alternative procurement model instead of EPC in those projects could save the client a lot of money. The comprehensive risk assessment framework, as discussed in this study, would be helpful in this regard.

2 Risk identification

Risks are identified based on the literature review. From the review, the concerned risk factors are categorised into six groups: (1) material and equipment; (2) knowledge and working skills; (3) construction management process; (4) procurement process; (5) design input; and (6) client-related risks. The risk factors under each category are presented in Figure 3.

The first group contains all issues relating to materials and equipment that will be used in a retrofithing project. For instance, materials and products used can deteriorate (e.g. with degraded insulation and air tightness), not as intended [15], [16]. New materials' performance and technologies are not tested over the years, so they do not conform to specification or do not perform in-situ as expected [17]–[19]. Thus, build quality may not be up to required specification. In addition, in some instances, value engineering process and change orders due to cost-cutting can lead to substitutions of building service equipment or materials. If they are not checked carefully against original specification, the changes may impact on performance criteria [11], [15], [16], [18], [19]. Further, suitable construction equipment is needed for completing works. Inappropriate use of them on-site can lead to poor working quality [20].

Variables associated with energy-efficient knowledge and working skills are in the second group. Lack of working skills is one of the common problems [11], [18], [19]. Poor working skills may lead to the poor quality installation of retrofit measures in buildings [17]. Often, building fabric is constructed incorrectly, reducing the actual performance of the thermal envelope. Improper installation and poorly commissioned building services result in reduced system efficiency and compromise the air tightness and ventilation strategies. Furthermore, lack of
understanding of the procurement and construction team regarding energy-performance related criteria result in the poor installation or commissioning of services, short-term fixes and improvisations on-site without an understanding of long-term impact [19].

The next group is *procurement* variables. If tenders were high, cost savings may be necessary. Cost cuts often affect thermal characteristics, building services and controls. If procurement teams do not prioritise energy related skills when selecting contractors, it can lead to the selection of contractors having limited knowledge on energy efficiency retrofits. It should be noted that lack of qualified contractors/suppliers and skilled workers are the current difficulties in green projects [8], [17]. In addition, tender documentations are not containing up-to-date requirements or trade specifications, resulting wrong products to be installed on-site [18], [19], [21].

*Construction management process* concerns with poor communication. It is a common issue either in conventional projects or in energy-efficient projects [18], [19]. There is also a lack of collaborative working such as lack of designer input on site if issues arise, construction teams not sufficiently involved at the design stage, poor communication, and full design information or installation guidance produced but not available on-site [18], [19]. In addition, there is no adequate *quality assurance plan*, i.e. existing quality checks were limited and did not focus strongly enough on energy-related performance [19]. This lack of quality assurance plan can result in incomplete commissioning of installed products [15], [16], [19].

Retrofitting projects are normally running simultaneously with normal commercial businesses. Hence project teams will face a challenge of remaining occupancy during the project process. The difficulty is to keep the project on schedule without reducing tenants’ satisfaction. It is noted that failure to keep the project on time leads to adverse consequences, especially the quality of works [22]. Poor working quality results in a poor energy performance in retrofitted buildings.

Most studies on energy performance gap agree that *contractor-design elements* are a big concern in building energy retrofits [11], [15], [16], [18], [19]. It is argued that incomplete design or design changes can result in construction details may not be specified correctly [11], [15], [16], [18], [19]. Details are left unspecified and for the contractor to define, with potential risks for the creation of thermal bridges. Contractor-designed elements may not end up as originally envisaged, changing the overall performance of buildings.

The last group of is *client-related* variables such as not engaging green building practices [17], lack of construction management experience in green projects [17], or unclear requirements [22]. Some owners commence a retrofitting project with an inexperienced team [17]. This can make management process more challenging to the owner. Yet, building retrofits may introduce a new process, modern technology and unfamiliar environment [17]. Lack of understanding of any aspects increases the possibility of a poor project performance.
3 Risk Assessment

This section discusses the development of a risk assessment methodology for assessing those identified risks in a building retrofitting project. The proposed method will help to identify what are the most critical risks that lead to energy performance gap if they occur. Traditional risk analysis (i.e. risk rating) is not fit-for-purpose. It is subjective and imprecise [23]. The use of Fuzzy Set Theory (FST) helps to solve these shortcomings, improving the accuracy of expert judgement. However, there remains a shortcoming of failing to capture the interactions between risks. Risks do not act alone to lead to a consequence (e.g. energy performance gap), but they interact with each other. A risk occurred can trigger the occurrence of others and the cumulative impact of a chain of risks may be greater than the sum of their individual impacts [24]. Risk analysts may miss some significant risks if using traditional risk assessment method. Therefore, considering the relationships between risks is a comprehensive approach for analysing risks [23] [25].

This research aims at proposing a quantitative risk assessment method that can capture the interrelation between risks and can help to analyse risk factors resulting in energy performance gap. To achieve the objectives, Fuzzy Bayesian Belief Network (FBBN) can be used. The method is an integration of Fuzzy set theory (FST) and Bayesian Belief Network (BBN). FST help to solve the subjectivity and uncertainty in experts’ judgement. BBN has some advantages such as flexible analysis of top-down inference (observation of a cause leading to an effect) or bottom-up (diagnosis causes) [26], provision of insight into relationships among variables of the process through graphical display [27], calculation of conditional probability of occurrence of events (i.e. a dependence of a risk on the others), updating probability, diagnosis and prediction after the introduction of new evidence [27]. Therefore, the combination between the two has a potential for quantifying energy performance risk in building energy retrofits. The overall process of FBBN is shown in Figure 4.
As can be seen in Figure 4, preliminary relationships between risk factors identified in the previous step are conducted. Then, a diagram is constructed to describe the relationships. An example of such diagram is shown in Figure 5. After this risk path model is confirmed with experts, a BBN model is developed. Based on this model, energy performance gap can be quantified given the probability of impacted risk factors. The probability of risks is obtained from expert judgement using linguistic terms. By using fuzzy inference, these terms are converted into crisp values that can be used to calculate the conditional probability. Conditional probability is the probability of occurrence of a risk (a child node) given the occurrence of another (a parent node). BBN relies on Bayes theorem to aggregate the conditional probability of the child nodes. Thus, the probability of energy performance gap based on the probability of its parent “risks” can be achieved.
4 Concluding remarks

The issue of energy performance gap poses a significant threat towards achieving energy savings target in building retrofit projects. Based on the literature review, this paper has identified a number of risk factors from construction and commissioning stages that contribute to the energy performance gap in a retrofitting project. Overall, the risk factors associated with the construction and commissioning process of a building energy retrofitting project can be divided into six groups: material and equipment, knowledge and skills, construction management process, procurement, design input and client-related problems.

A preliminary framework for risk assessment has been proposed based on FBBN method. The method has some advantages over traditional risk assessment such as reducing subjectivity and ambiguity in human judgement using Fuzzy set theory; BBN describes the relationships between risks graphically and allows calculating the conditional probability of energy performance gap based on the probability of impacted risk factors. As such, the results of FBBN will help to identify what are the most significant risk factors that result in energy performance gap. This knowledge would help project team to propose risk mitigation actions to effectively manage the risks, reducing the energy performance gap significantly.

References


Trends in Housing Offsite Manufacturing Supply Chain Management (HOSCM) Research

Masood, R.1*, Gonzalez, V.2, Lim, J.B.P.2, and Cabrera, G.3

Abstract: Offsite Manufacturing (OSM) has evolved over the years as an innovative solution to address housing problems at a global scale. However, the poor performance of supply chain management has been identified as a pivotal reason for low uptake of OSM. We believe that there are no significant reports on research that addresses the theoretical development of Housing-Offsite Manufacturing-Supply Chain Management (HOSCM). A Systematic Literature Review (SLR) was carried out to identify the critical issues related to supply chain management in HOSCM research. Around 39 journal articles spanning from 1996 to 2017 (as of October), addressing HOSCM research, were selected. Around eighty-two issues were identified after an in-depth content analysis with reference to principal component bodies of Supply Chain Management (SCM), entity of analysis, level of analysis, elements of exchange and OSM type. Identified issues were clustered under similar themes named as HOSCM constructs as weak demand, product customization, inappropriate strategy setting, stakeholder repositioning, lack of customer focus, dynamic relationships, varied stakeholder engagement, slow organizational learning, imbalance risk distribution, local environment adaptation, lack of knowledge sharing, poor communication, lack of technology utilization, financial fragility, lack of logistic integration, and inadequate performance measurement. This study provides a theoretical foundation to understand the implementation of HOSCM and identified areas for performance improvement.

Keywords: Housing, Offsite manufacturing, Supply Chain Management, Review, Issues, Constructs

1* Masood, R.
Corresponding author, Department of Civil & Environmental Engineering, The University of Auckland, Auckland, New Zealand
E-mail: rmas769@aucklanduni.ac.nz

2 Vicente, G. and Lim, J.B.P.
Department of Civil & Environmental Engineering, The University of Auckland, Auckland, New Zealand

3 Cabrera, G.
School of Ingenieria Informatica, Pontificia Universidad Catolica de Valparaiso, Valparaiso, Chile
1 Introduction

Modern methods of construction, such as OSM, have great potential to address the challenges of affordability, quality and sustainability in the housing industry [1]. However, adoption of OSM is limited because of sociological, economic and political constraints [2]. Further, appropriateness of OSM strategies and technologies is contextual and relates to resources, program, and local conditions. Poor understanding of OSM causes a lack of motivation by stakeholders [3], as the share of traditional approaches is huge in the housing market [4]. Nevertheless, the exploitation of the full benefits of OSM is still in its transition phase [5].

One of the main reasons for low uptake of OSM in the housing industry is poor performance of supply chain management [6]. OSM implementation by stakeholders (designer, manufacturer and constructor) in isolation has minimal impact on the overall performance of the industry due to interrelated and interdependent links of supply chain [7]. However, the lack of value perspective, in relation to supply chain and inter-firm organisation, is critical for the adoption of OSM [8]. Engagement of all the supply chain members is essential in offsite construction [9], to familiarize with supply chain dynamics for synchronized efforts and shared values amongst the various stakeholders [10]. Nevertheless, SCM remains a critical challenge for key stakeholders in the offsite housing industry.

SCM research in construction is still relatively new [11]. There is little clarity on the theory and practice, thus creating the space for conceptual theory development, based on abstract concepts and their relationships [12]. To benchmark, the research trends provide a clear picture of the body of knowledge and its dynamics. It is very important to analyse, synthesize and criticize the existing literature on a regular basis especially on growing research domains, such as house building supply chain management [13], particularly offsite manufactured.

HOSCM refers to supply chain management aspects in the context of housing manufactured offsite (from pre-fabricated components to modular buildings) [3, 14]. A possible justification is that SCM concepts focus on information, material and capital flow of building components, which are mainly designed and manufactured offsite and supply to the site for installation or placement [15-16]. So HOSCM is defined in line with SCM philosophy [17] and industry perspective as, “A set of organizations linked together at an operational, tactical and strategic level to provide prefabricated components to complete modular building to fulfil housing needs”.

HOSCM is a relatively new area of research [18]. There are a few relevant research studies that have addressed the theoretical development for supply chain management in OSM research [19-22]. However, there is no significant theoretical research focusing on overlapping dimensions of housing-offsite manufacturing-supply chain management. The purpose is to understand key research trends in the context of critical issues addressed in HOSCM research (Fig. 1).

2 Review of Literature

Systematic Literature Review (SLR) is a robust review method with well defined process for identifying and selecting studies, further analyzing and synthesizing the content to report the existing research and gaps [23]. This study followed the well adopted guidelines provided by [24].

The search started from the fields of title, abstract and keyword with the keywords related to supply chain management (refer to Fig.1). The search was limited to articles published in peer-reviewed journals in English between 1996 and 2017 (as of August). Databases and online library services such as Web of Science, Scopus, Engineering Village (Compendex, Inspec,
Knovel), ScienceDirect and Proquest were selected for this research as they have the most comprehensive academic resources. Chosen key areas or disciplines for this review were engineering or Civil Engineering; Construction and Building Industry; Operation Research, Business, Management & Accounting; Computer Sciences; Decision Sciences; and Environmental Sciences.

![Figure 1. The objective of Systematic literature review](image)

For screening, during meta-search on search engines, Scopus retrieved the maximum articles on HOSCM research (i.e. 593). We were left with only 187 research articles after elimination of duplication and non-relevancy to the subject matter. Next, abstract analysis was performed by careful reading of the title, abstract, and keywords, which reduced the list of articles considered for this SLR further to 108. Eight articles were added after a snowball approach to trace the relevant articles in the forward and backwards search. Because of overlapping HOSCM research, a total of 39 journal articles were identified for full-text analysis. A spreadsheet has been developed to compile the information after detailed content analysis (Appendix – A). For sources of articles, refer to Appendix – B.

3 Trends in HOSCM research

3.1 Descriptive analysis

Most common methods used in HOSCM research are conceptual (3), survey/interview (7), case study (14) and mixed (15). Countries of focus in HOSCM research are Sweden (11), UK (6), USA (5), Australia (3), Japan (2), Netherlands (2), Hong Kong (2), Germany (2), China (2), Denmark (1), Mexico (1), Turkey (1), Singapore (1) and Italy (1). Distribution of 40 articles over the span of years is such that 1996 (1), 2001 (2), 2003 (3), 2005 (5), 2006 (3), 2009 (4), 2010 (1), 2011 (3), 2012 (3), 2013 (1), 2014 (2), 2015 (4), 2016 (1) and 2017 (7).

3.2 Principal components bodies (PCB)

To identify the recurring focal issues, content analysis of each article was thoroughly read by authors for validation of identification and PCB assignment process. The classification scheme of PCB in SCM literature by [25] is used to find out the PCB under which the focal issues are related. Most of the issues in HOSCM research fall under Strategic Management (STM) followed by Logistics (LOG), and then Best Practices (BST) and Relationships (REP). Marketing (MKT) is least covered.
3.3 Significant issues

Issues of HOSCM are the foundations of constructs for theory development. During content analysis, various issues were classified based on the focus of the paper such as low, medium and high. Most significant issues in STM are related to product development (use of design-production technology and mass customization in product design), supply chain configuration, process integration in supply chain and implementation of lean thinking; for BST, performance measurement and production planning; for LOG integration of information and material flow; for REP, relationship management (mainly supplier-manufacturer), collaboration, and supplier management (such as involvement, evaluation, and retention of suppliers); for ORB, organizational learning; and for MKT, customer focus (i.e. customer satisfaction). Least addressed issues are STM (capacity development, strategic planning, power and governance, sustainability, cash flow analysis), BST (material resource planning, RFID, system thinking, reverse supply chain), LOG (postponement, order policies, demand management, information sharing, visibility, distribution channel management, capacity planning, production scheduling), REP (supply/distribution base integration, supplier development, trust, supply chain efficiency, outsourcing, merger and acquisition), ORB (organizational structure, joint venture, power in relationships, HR development) and MKT (sales management).

3.4 Entity and level of analysis

The entity of analysis is identified by tracing out which member of the supply chain is under investigation in HOSCM research. 68% of the papers had considered more than one supply chain members (i.e. in combination) and 20% of the papers had considered all supply chain members. Key members are designer, supplier, manufacturer, contractor, subcontractors, retailer, vendor, distributor and customer.

There are three levels of analysis in SCM research i.e. dyadic, chain and network [25]. In HOSCM research, network (19) followed by dyadic (12) and then chain (8) are main level of analysis. Articles on intra-supply chain were excluded as SCM concept cuts across the physical, functional and legal boundaries of firms [26].

3.5 Elements of exchange

Element of exchange by members in supply chain are assets, information, knowledge and relationship [25]. In HOSCM research the most common element of exchange among supply chain members was information, followed by asset, relationship and then knowledge. Mostly, the elements of exchange were found in combination. Only in six articles, all elements of exchange were found together.

Table 1: Critical issues in HOSCM research in context of OSM Type
3.6 Maturity in context of OSM type

HOSCM maturity is defined based on OSM type such as component, non-volumetric, volumetric and modular building. HOSCM maturity scaled differently regarding each OSM type [20]. Component type was intra-firm supply chain and rest follows supply chain network (Table 1).

3.7 HOSCM constructs

Identified issues, through SLR, were clustered under similar themes (constructs or critical elements) to develop understanding of HOSCM theory.

Table 2: HOSCM constructs description

<table>
<thead>
<tr>
<th>Construct</th>
<th>Brief description</th>
<th>Source (Appendix B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak demand</td>
<td>Inconsistency in demand due to order variation and fluctuation</td>
<td>1,7,12,15,18,20,38</td>
</tr>
<tr>
<td>Product customization</td>
<td>Recurring OSM product design and development with mass customization</td>
<td>1,8,15,25,27,30,31,37</td>
</tr>
<tr>
<td>Inappropriate strategy setting</td>
<td>Changing customer order decoupling point requires product and process alignment</td>
<td>14,15,24,25,30,35</td>
</tr>
<tr>
<td>Stakeholder repositioning</td>
<td>Switching roles and responsibilities in context of involvement in offsite industry</td>
<td>1,13,14,18,30,37</td>
</tr>
<tr>
<td>Lack of customer focus</td>
<td>Variation in customer focus with different value and satisfaction perceptions</td>
<td>1,5,12,15,27,31</td>
</tr>
<tr>
<td>Dynamic relationships</td>
<td>Intense adversarial relations with changing businesses and market situations</td>
<td>3,8,11,15,16,17,18,24,26,33,34,38</td>
</tr>
<tr>
<td>Varied stakeholder engagement</td>
<td>Lack of supplier involvement (based on degree of offsite work in OSM initiatives)</td>
<td>3,15,19,26</td>
</tr>
<tr>
<td>Slow organizational learning</td>
<td>Slow pace of organizational changes and cross impact on business for OSM</td>
<td>1,10,13,21,24,27,29,33</td>
</tr>
<tr>
<td>Imbalance risk distribution</td>
<td>Low understanding of risk and lack of appropriate strategies to avoid or mitigate</td>
<td>2,5,14,15,30</td>
</tr>
<tr>
<td>Local environment adaptation</td>
<td>Different working practices for OSM in context of local environment</td>
<td>1,5,8,14,16,18,22,24</td>
</tr>
<tr>
<td>Lack of knowledge sharing</td>
<td>Lack of experience and knowledge sharing related to OSM techniques &amp; technologies</td>
<td>1,2,6,15,22,26,29</td>
</tr>
<tr>
<td>Poor communication</td>
<td>Poor quality of information and weak exchange channels</td>
<td>1,7,12,14,16,24,33</td>
</tr>
<tr>
<td>Loss of technology utilization</td>
<td>Lack of utilizing supporting technologies to enhance work flow</td>
<td>7,13,17,28,36</td>
</tr>
<tr>
<td>Financial fragility</td>
<td>High up-front investment, poor mechanisms for payments and imbalance cash flow</td>
<td>1,12,16,17,23,24,33</td>
</tr>
<tr>
<td>Lack of logistic integration</td>
<td>Lack of quick, smooth and on time delivery of OSM products</td>
<td>3,5,6,23,39</td>
</tr>
<tr>
<td>Inadequate performance measurement</td>
<td>Performance interdependence and ineffective performance evaluation approaches</td>
<td>1,3,5,6,7,10,12,15,17,21,22,27,31,33</td>
</tr>
</tbody>
</table>

4. Conclusion

This study is a pioneer effort to get insight (latest trends) on the supply chain management perspective within peer-reviewed articles in the context of offsite manufacturing for housing projects through systematic literature review. SCM perspective of the offsite housing industry evolves as an emerging area of research having short-term developments due to the influx of OSM technologies. Strategic management aspects are mostly covered in the literature, but less attention has been given to improvement measures (i.e. best practices), relationships, organization behaviour and marketing. The research orientation revolves around ‘manufacturer(s)’ having upstream or downstream network relations. Relationship and knowledge are the least covered elements of exchange. For HOSCM maturity, fewer issues were addressed in non-volumetric and volumetric OSM types. Eighty-two issues were identified based on PCB of SCM and further clustered to sixteen HOSCM constructs. This study provides grounds for the theoretical foundation to understand HOSCM implementation and areas for performance improvement.

5. References


APPENDIX – A: Content analysis of HOSCM Research

<table>
<thead>
<tr>
<th>PCB</th>
<th>Strategic management (27)</th>
<th>Best practices (14)</th>
<th>Logistics (16)</th>
<th>Relationships (14)</th>
<th>Org. Behaviour (8)</th>
<th>MKT (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Product development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Frequency: 5 10 15 20 30 50 100

Low [ ] Medium [ ] High [ ]
771

APPENDIX – B: Selected papers for systematic literature review
S#

Source

1


S#
21

2

Management and Economics, 19(3), 295-300. 10.1080/01446190010020417

22
23

6

10.1080/09613210302003
Management and Economics, 21(6), 593-602.
sector. Construction Management and Economics, 21(2), 137-146. 10.1080/0144619032000049674

7


27

3
4
5

8
9
10

Bergstrom, M., & Stehn, L. (2005). Matching industrialised timber frame housing needs and enterprise resource
10.1016/j.ijpe.2004.06.052
Bergström, M., & Stehn, L. (2005). Benefits and disadvantages of ERP in industrialised timber frame housing in
Sweden. Construction Management and Economics, 23(8), 831-838. 10.1080/01446190500184097

24
25
26

28
29
30
31

13

industry.
Journal
of
Urban
Planning
and
Development,
132(4),
217-225.

14


34

15

house-building industry. Building Research & Information, 37(1), 31-42. 10.1080/09613210802628003

35

16

housing construction. Construction Innovation, 9(1), 22-41. 10.1108/14714170910931516

36

17

Motawa, I., & Kaka, A. (2009). Modelling payment mechanisms for supply chain in construction. Engineering,
Construction and Architectural Management, 16(4), 325-336.

37

11
12

18
19
20

of companies in the timber housing industry. Construction Management and Economics, 28(10), 1071-1083.
10.1080/01446193.2010.494680
10.1108/13664381111116106
Management and Economics, 29(1), 25-35. 10.1080/01446193.2010.531027

32
33

38
39

Source
11(1), 77-91. 10.1108/14714171111104646
Cariaga, I., & El-Diraby, T. (2012). Assessing the Market Potential for Housing Construction Products in
Mexico.
Journal
of
Construction
Engineering
and
Management,
139(6),
717-725.
10.1061/(ASCE)CO.1943-7862.0000637
Demiralp, G., Guven, G., & Ergen, E. (2012). Analyzing the benefits of RFID technology for cost sharing in
construction supply chains: A case study on prefabricated precast components. Automation in Construction, 24,
120-129. http://dx.doi.org/10.1016/j.autcon.2012.02.005
10.1061/(asce)co.1943-7862.0000544
Bildsten, L. (2014). Buyer-supplier relationships in industrialized building. Construction Management and
Economics, 32(1-2), 146-159. 10.1080/01446193.2013.812228
10.1080/01446193.2013.812226
a precast manufacturer. Construction Innovation, 15(1), 84-106. 10.1108/CI-04-2014-0023
http://dx.doi.org/10.1016/j.ijpe.2015.05.011
housing production in Hong Kong: a social network analysis. Journal of Cleaner Production
http://dx.doi.org/10.1016/j.jclepro.2016.02.123
conceptualization of collaboration in industrialized building housing construction. Construction Management
and Economics, 1-25. 10.1080/01446193.2017.1339361
behaviour on off-site manufacturing performance in Australia. Architectural Engineering and Design
Management, 1-19. 10.1080/17452007.2017.1301367
Chain–Management System in Construction. Journal of Construction Engineering and Management, 143(3)
10.1061/(ASCE)CO.1943-7862.0001232
http://doi.org/10.1016/j.ijpe.2016.10.015
Teng, Y., Mao, C., Liu, G., & Wang, X. (2017). Analysis of stakeholder relationships in the industry chain of
building
in
China.
Journal
of
Cleaner
Production,
152,
387-398.
industrialized
http://doi.org/10.1016/j.jclepro.2017.03.094
Chain. Journal of Computing in Civil Engineering, 31(4) 10.1061/(ASCE)CP.1943-5487.0000667


Comparative Study of Crew Performance Measurement
Methods: Case Study of Steel Fixers

Farooq, Hassan¹, and Moon, Sungkon²*

Abstract: This research covers the importance of performance measurement in the construction industry and discusses different performance measurement methods. After reviewing the literatures, a gap in knowledge is observed regarding comparisons between performance measurement methods that form the basis of the research. From the literatures, three models were selected 1) Continuous Time Study 2) Work Sampling and 3) Five-Minute Rating, among which the comparisons are drawn. It was found out that each method is preferred over the others under specific conditions. Work Sampling provides the physiognomies of delays and is cost-effective, accurate and consumes less time. Unlike Work Sampling, Continuous Time Study is applicable in most conditions and provides more accurate results, which is due to less limitations and continuous observations, respectively. It was observed that a minimum of 21.25% error was detected between the Work Sampling and Continuous Time Study results obtained from the sampling of two steel fixers, but this was down to very less number of observations, which is the limitation of this paper. It is suggested that if the number of observations made for work sampling are according to the standard practices, the results obtained will be much more accurate making work sampling a better method for performance measurement.

Keywords: Performance Measurement, Comparative Study, Reinforcement Works, Continuous Time Study, Work Sampling, Five-minute Rating

1. BACKGROUND AND INTRODUCTION

The construction industry has been greatly criticized over the past few decades regarding underperformance (Lee et al., 2000). This, combined with the rapid globalization and ever so increasing competitiveness nature in every industry, has led to the deduction that performance measurement is critical to the success (Lee et al., 2000). (Neely, 1999), stated that 3,615 articles were published between the years 1994 and 1996 on performance measurement while in the USA alone a new book regarding the subject came out every two weeks during 1996. He goes on to mention that a UK based company, Business Intelligence, held 23 conferences between the years

¹ Farooq, Hassan
Department of Civil and Construction Engineering, Swinburne University of Technology, Melbourne, VIC 3122, Australia,

²* Moon, Sungkon
Corresponding author, Department of Civil and Construction Engineering; and Centre for Sustainable Infrastructure, Swinburne University of Technology, Melbourne, VIC 3122, Australia,
Email: sungkon.moon@gmail.com
1994 to 1999 focusing on performance measurement and its importance. According to (Lin and Shen, 2007), this rapid increase in the publications on performance measurement in construction is a result of: 1) Performance measurement methods being adopted by other industrial sectors; 2) Continuous increase in the difficulty of construction projects; and 3) Management and technology development in the industry.

According to Yang et al. (2010), performance measurement in construction has been conducted on the three following levels: Project, Organizational, and Stakeholder levels. For the scope of this paper, only the project level was considered where the performance measurement of a reinforcement works crew will be carried out. As already mentioned, a lot of work has been carried out in this area with different techniques of performance measurement, but there is a gap in knowledge regarding the employment of these methods based on their physiognomies.

The purpose of this paper is to perform a comparative study between some of the crew performance measurement methods: 1) Continuous Time Study 2) Work Sampling 3) Five-minute and identify the key aspects that are highlighted by each method to better understand the workings of each method which will aid future researchers in selecting the methods based on their requirements. This will be done by observing the reinforcement works at a construction site, gathering necessary data and interpreting the results for each of the aforementioned methods that will enable us to undertake our study.

### 2. RESEARCH METHODOLOGY

After reviewing the literature, the three methods of performance measurement selected were 1) Continuous Time Study 2) Work Sampling 3) Five-Minute Rating. The explanations of each along with their general procedures have already been discussed in the previous section. However, as already established, every construction project is unique and presents a different challenge during its construction process and needs to be observed accordingly. For this research, a steel fixing crew consisting of two workers and a supervisor was observed for a total of 97 mins. The data was collected in two forms; digital recording and real time observations. Continuous Time Study was conducted with the help of the recorded data as the other two methods were conducted in real time. The video recording will also serve as a source of re-checking the observations taken for Work Sampling and Five-minute Rating.

The data collected will be analyzed in terms of percentages of work done in each category. These percentages will then be compared among the three methods that will provide an insight to the characteristics of each, which is the essence of the research. As the Continuous Time Study is done over the entire length of the observation interval, it will be the most accurate and set as a benchmark to find the percentage of error in the accuracy of the other two methods. Other aspects such as time, cost and ease of implementation of these methods will also be assessed to generate a comparison between their strengths and weaknesses.

#### 2.1 Construction Site for Case Study

The project site chosen for the performance measurement of Iron/steel workers is a mid-rise residential building by the name of “Essence Apartments”. The organization responsible for
construction was “MERKON Constructions” and developed by “Salta Properties”. It is located at 35 Wilson St, South Yarra, Victoria, 6 kms from Melbourne CBD. This building stands 28.1 m tall, having a floor count of 9 with a proposed housing capacity of 92 apartments. It is bound by the rules under the Stonnington Local Government Authority. Particularly the upper most level of this building, level 8 was examined for this research and the subsequent study was conducted. Table 1 lists the summary of steel reinforcement bars and ligatures used in the site.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Diameter (mm)</th>
<th>Spacing (mm)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>16</td>
<td>100</td>
<td>Reinforcement</td>
</tr>
<tr>
<td>2.</td>
<td>12</td>
<td>200</td>
<td>Ligature</td>
</tr>
<tr>
<td>3.</td>
<td>12</td>
<td>250</td>
<td>Reinforcement</td>
</tr>
<tr>
<td>4.</td>
<td>12</td>
<td>300</td>
<td>Reinforcement</td>
</tr>
<tr>
<td>5.</td>
<td>12</td>
<td>400</td>
<td>Ligature</td>
</tr>
<tr>
<td>6.</td>
<td>12</td>
<td>1000</td>
<td>Ligature</td>
</tr>
</tbody>
</table>

Table 1: Reinforcement Details

2.2 Data Collection

Data was collected in two forms; digital recording and real-time observations. For Continuous Time Study, the medium for data collection was a video recorder installed on a tripod and strategically placed in an attempt to cover the entire work area without causing any inconvenience to the workers. The video was recorded throughout the length of the observation period from the same spot. This raw data (recorded video) was then transferred to a computer for storage and analyzed by viewing the whole recorded video and categorizing the work based on the framework shown in Table 2.

2.3 Categorization of Work

In order to process the data through different measurement methods, a framework was developed to help categorize the work done by a worker at specific observation intervals. The table shows the contents constituting each work category. The contents are numbered to help specify, if needed, the detail of the work being carried out at each observation. This table will be used for the “continuous time study” and “work sampling” methods only as the five-minute rating only considers value added work and categorizes the rest as ineffective work.

<table>
<thead>
<tr>
<th>Category</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value Added Work</td>
<td>1. Direct works that are directly contributing towards the completion of the work, e.g placing, aligning and tie works</td>
</tr>
<tr>
<td>Contributory Work</td>
<td>2. Carrying materials and tools within the working area that are essential for the completion of the work to be done. These include reinforcement tie wires, torches, sledges, wire cutters etc.</td>
</tr>
<tr>
<td></td>
<td>3. Marking and measuring according to the layout, moving scaffolding, clearing area for work cutting wires etc</td>
</tr>
<tr>
<td></td>
<td>4. Studying drawings, discussing with supervisor or getting instructions.</td>
</tr>
<tr>
<td>Ineffective Work</td>
<td>5. Materials and tools that are carried over a distance of 35 ft</td>
</tr>
</tbody>
</table>
6. Walking empty handed
7. Going out or staying within the staging area in search for material or tools or clearing area for work

<table>
<thead>
<tr>
<th>Unproductive Work</th>
<th>8. Waiting to be instructed or other crafts to clear out</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9. Redoing of work (if incorrect or changed)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Personal</th>
<th>10. Going for or taking a break or idling without reason</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11. Talking on phone or about things unrelated to the work</td>
</tr>
<tr>
<td></td>
<td>12. Not being observable</td>
</tr>
</tbody>
</table>

Table 2: Categorization of Work

3. PERFORMANCE MEASUREMENTS

The comparative study was carried out among three different measurement methods. All of the methods follow their basic principles as described in the literature review with adjustments made to suite the purpose of the study. It is to be noted that for the purpose of this study was to perform a comparative study, hence the focus was finding out comparisons between them instead of accuracy of the results that were generated.

3.1 Continuous Time Study

As the name suggests, this study involved the continuous observation of the workers. The activities of each worker was observed separately and categorized for the whole length of the 95min video based on the categorization framework. After each second has been accounted for and placed into its respective category, a figure was generated showing the progress of each worker.

Figure 1: Continuous Time Study of Two Workers

The Fig 1 shows the visual representation of the total work done by two workers throughout the length of the observation interval. A total of 5,719 seconds were observed, which were divided into time blocks representing their respective work category. Each block represents the time spent by the worker doing that category of work. The blocks representing value added work have been denoted with their times for explanation purposes, for example the total value added work done by worker A was 12.3% of the total work while for worker B it was 31.75%. Table 3 shows the percentages of work done by each worker:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Work Category</th>
<th>Time Spent in Each Category</th>
<th>Percentage of Work done</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Worker A</td>
<td>Worker B</td>
<td>Worker A</td>
</tr>
<tr>
<td>-----</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>1</td>
<td>Value added</td>
<td>708</td>
<td>1816</td>
</tr>
<tr>
<td>2</td>
<td>Contributory</td>
<td>2615</td>
<td>1422</td>
</tr>
<tr>
<td>3</td>
<td>Inefficient</td>
<td>639</td>
<td>1051</td>
</tr>
<tr>
<td>4</td>
<td>Unproductive</td>
<td>797</td>
<td>865</td>
</tr>
<tr>
<td>5</td>
<td>Personal</td>
<td>960</td>
<td>565</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>5719</td>
<td>5719</td>
</tr>
</tbody>
</table>

Table 3: Percentage of Work Done in Each Category

### 3.2 Work Sampling

As the goal was to draw a comparison, the number of observations to be taken were greatly reduced. Instead of using the usual values for confidence level, limit of error and unobservable probability in the following formula (Bernold and AbouRizk, 2010a)

\[
N = k^2 x p(1-p) + s^2
\]

- \(N = \text{No. of observations}\)
- \(K = \text{Standard Deviations for given confidence limit}\)
- \(s = \text{absolute limit of error}\)
- \(p = \text{unobservable probability (decimal)}\)

The confidence level was taken to be 90% instead of 95%, while the limit of error was changed to 10% from 5%. The most significant change made was the unobservable probability value, which was reduced from 0.5 to 0.2 because of the relatively repetitive tasks which meant that the opportunity to observe all the tasks in the work cycle was higher in this case. This gave the following

<table>
<thead>
<tr>
<th>Confidence level</th>
<th>C.L</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>z-score</td>
<td>Z</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>No. of SD for confidence level</td>
<td>k value</td>
<td>-1.644854</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.644854</td>
</tr>
<tr>
<td>Chance that element might not be visible</td>
<td>p</td>
<td>0.2</td>
</tr>
<tr>
<td>Absolute level of error</td>
<td>s</td>
<td>0.1</td>
</tr>
<tr>
<td>No. of observations</td>
<td>N</td>
<td>43</td>
</tr>
</tbody>
</table>

Table 4: Calculation of No. of Observations

The z-score comes from the concept of normal distribution, while k value is the standard deviation for the confidence level. The k- value is obtained in excel by using the formula =NORM.S.INV(Z-score). The number of observation was for the whole measurement, so it was divided by two which gives approximately 20 observations for each worker.
After figuring out the observations required, 20 random times were selected for making the observations. Again, this was done in Excel using the random command. This was then converted to random times at which the observations were supposed to carry out. The observations were carried out by marking an “x” in the column that fit the category of work being done at the random times that were generated. Work sampling allows you to be more specific within the category of work by entering the digit against the work that is being carried out. For example, if the worker A is doing contributory work during an observation, and the value in the “content no” column is 4 then, from the categorization of work “table 2”, we know that the worker was studying drawings. After all the observations are done, summation of “x” in each category is divided by the total number of observations and multiplied by 100 to give the percentages of each category of work done.

Worker B has more value added work with 25% compared to worker A who has 20%. Similarly, worker A has more contributory work with 45% to worker B’s 45%. Both of them spent 35% of their times doing work that is not related to work progress. The observations were taken simultaneously for both the workers which is an advantage over the continuous time study.

The best attribute of Work Sampling is that each category of work column is sub-divided into two columns; one for selecting the work category and the other is inserted with a digit representing the reason behind the selection of that particular category which is in correspondence with table 2. For example, the 10th observation for worker A suggests that work done during this observation is contributory work and the reason is represented by the digit 2. Referring to Table 2, it shows that the reason for selecting contributory work is “Carrying materials and tools within the working area that are essential for the completion of the work to be done. These include reinforcement tie wires, torches, sledges, wire cutters etc”. This reason of obtaining extensive information gives Work Sampling its recognition.

3.3 Five-Minute Rating

Five-Minute technique does not employ any complicated statistical analysis, nor there is any need of coming up with a framework to categorize the work. For this method, a simple table was generated to measure the work done by each worker, with time in one column and workers in the other. The total observation time was five minutes, during that interval both workers was observed for 30 seconds simultaneously. An “x” was marked if the workers were doing value added work during half of this duration and left empty otherwise. This step was repeated for consecutive 30sec intervals over five -minutes. At the end of the observation, the sum of “x” is divide by the number of observations and multiplied by 100 to give the percentage of effective or value added work that was done. The method was repeated 8 times and the mean was calculated to give the average percentage of effective work during the entire observation interval.

<table>
<thead>
<tr>
<th>Time</th>
<th>Worker A</th>
<th>Worker B</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:20</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>10:20:30</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>10:21:00</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
Table 6 is the combined efficiency of the two steel fixers which means a single steel fixer has approximately done $55/2 \approx 25.25\%$ of effective work, while the rest of it is considered ineffective. The result for value added work obtained here is almost the same as from work sampling. This method does not consider contributory work, just focuses on the percentage of value added/effective work being done, which helps in recognizing whether there is problem or not. This method may be used as an initial check before implementing other more accurate and detailed performance measurement techniques.

<table>
<thead>
<tr>
<th>Study Number</th>
<th>Crew Efficiency as Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80.00%</td>
</tr>
<tr>
<td>2</td>
<td>60.00%</td>
</tr>
<tr>
<td>3</td>
<td>90.00%</td>
</tr>
<tr>
<td>4</td>
<td>45.00%</td>
</tr>
<tr>
<td>5</td>
<td>70.00%</td>
</tr>
<tr>
<td>6</td>
<td>10.00%</td>
</tr>
<tr>
<td>7</td>
<td>70.00%</td>
</tr>
<tr>
<td>8</td>
<td>20.00%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>55.63%</strong></td>
</tr>
</tbody>
</table>

Table 6: Mean Percentage of 8 Observations for the Whole Crew

4. CONCLUSION

Over the past few decades, recognition of importance for performance measurement has resulted in the development of several different methods. However, little work has been done in regards to comparisons between different methods. This paper addresses these issues by drawing comparisons among three methods selected by reviewing the literature. Although the data obtained is limited and not enough to confirm the results, it may be picked up from here by future researchers. The results obtained, even with the limitations, give us an idea of how these methods work and the conditions they are best suited for.

The Five-Minute Rating is most effective when immediate and simple delay magnitude is required and is the easiest to implement, but is relatively inaccurate. Work Sampling is employed
to get to the root cause of the delays and uses empirical relations to find the number of observations which is directly proportional to the accuracy of the results. The limitation for Work Sampling is that the work to be observed must not be repetitive. Continuous Time Study is the most accurate of the three and is applicable for almost every work type although it consumes the most amount of time and is the most expensive.

REFERENCES:

Analysis of the Feature Small-town Origins and Scope in the Period of Transition

TIAN, Min.1* and PENG, Liu.2

Abstract: Feature small towns have different perspectives and locations in the period of urbanization development in China. Through analyzing the characteristics of small towns in terms of their connotations and scopes, this study finds that the feature small towns have industry support, industrial and spatial harmonious development. It is town forms of the basis of the system. Along with the spatial and temporal development of small cities and towns, there are more and more prominent of the balance of production, living and ecological space appearance. Zhejiang characteristic small town is a bench mark, it has the feature, as a platform for innovation and entrepreneurship. But the development of small cities and towns all over the country had a great imbalance. Construction of small towns cannot be the same model through thousands of town. Feature town at different stages, there are different meaning and scope. Resources advantage, industrial characteristics, integrated technical and economic conditions are different, so there are different ways in the road of these small towns development.

Key words: space-time reversal; characteristic; adaptation

Fund projects: This study was supported by the National Social Science Fund Project and Chunhui Project in the Ministry of Education, 2017 “Study on the construction of the win-win model of urban and rural ecological difference and economic development”; Sichuan Provincial Department of human resources and social security project "Research for the construction of feather small town's "Internet plus" new economic development platform" (Sichuan people's social letter[2017]No.436); Soft Science Project of Sichuan Science and Technology Department in 2015(2015ZR0165); 2017 Sichuan social science research project “Research on the classification and government of local conditions in the construction of characteristic small towns”.

1* TIAN, Min.
Corresponding author, School of Management, Xihu University, China
E-mail: mt83163.com

2 PENG, Liu.
School of Management, Xihu University, China
1 Introduction

Transforming to green urban is the main content of China's economic and social transformation. And the construction of feature small towns is the key to the development of urban transformation. In terms of the construction processes of foreign small towns, there are some types about the towns: (1) The headquarters of enterprise. This type of towns is characterized by a pleasant environment, lower land prices, and fully-equipped infrastructure. For instance, Redmond town, located in Seattle of the United States, where the Internet Company is headquartered, is an innovative R & D center which is a perfect combination of production, living and ecological as a whole. (2) Industry-supported feature small towns. They promote local economic development mainly by virtue of their own feature resources, geographical advantages, or a certain type of leading industry. For example, the Greenwich Town in the southwest of Connecticut, United States, known as the "hedge fund capital", now has gathered more than 500 hedge fund companies, by virtue of Coastal geographical location, closeness to the submarine cable, network speed advantage and closeness to the financial center of New York. (3) Livable towns. Since the Second World War, many cities in the United States has been suburbanized in a very short time, which led to a large number of negative effects on the suburbanized land, such as the natural environment damage, as well as the homogenization within the community housing, people long-distance commuters, traffic congestion, lack of opportunities for leisure and walking, air and water pollution, high consumption of infrastructure, loss of community and so on. In response to this urban problem, since the mid-1980s, many architects and planners in the United States have begun to advocate a new urbanism movement, the essence of which is to follow the principles of the new urbanism design, and advocate the return to the "American towns" before the Second World War, which stress style of small neighborhoods, appropriate scale streets, convenient traffic and closeness to the service facilities of community. They emphasized the intensification of urban growth and the diversified integration of community social groups to improve the quality of life, to improve the urban and community environment and to perform the smart growth model for the US community. Based on the analysis of the ways of development of foreign small towns, they could be classified into two categories: First, relying on the government to plan and construct the small towns. The most typical example was the "Metro movement" launched by Britain after the World War II. The British government promulgated the "New Town Act", in 1946, 1965 and 1981, respectively. The main purpose was to decentralize the surplus population of large cities such as London, Birmingham and Liverpool through the development and construction of small towns. With the development of the movement, the increase of private cars ownership and the improvement of traffic conditions, the region gradually extended from the towns closer to center city to the farther places. Second, under the control of economic and social development, small towns gradually grew because of the favor of enterprises and residents, while the Government only bore the assist role. The prosperity of such towns was the result of the natural selection and agglomeration of the population as well as the enterprises. In our country, the development of feature towns has its own origins and characteristics. In our study, through analyzing the characteristics of small towns in terms of their background, types, connotations and scopes, this study finds that there are different perspectives and positioning on the feature towns in the different development periods, regions and even departments. There are great imbalances of
small towns because of the unbalanced development of economic. The development of small towns should be different according to the resources advantages, industrial characteristics and the integrated conditions of technology and economy.

2 The construction of small town under the perspective of new urbanization

According to the relevant documents, such as the Report of the 18th National Congress of the Communist Party of China, the Decision of the CPC Central Committee on Deepening the Reform of Several Major Issues, the Spirit of the Central Urbanization Work Conference, the Twelfth Five-Year Plan for the National Economic and Social Development of the People's Republic of China, and the National Main Functional Area Planning, in accordance with new requirements of the new characteristics of urbanization in China and comprehensive improvement of the quality of urbanization, the State Council clearly put forward a plan to promote the core of the new urbanization in the 2014’s government work report, focusing on the problem for "three hundred million people". In March 2014, the CPC Central Committee and the State Council issued a national new urbanization plan (2014-2020). They proposed to focus on the development of small towns, promote to combine the development of small towns with easing the functions of the city center, developing characteristic industries, and solving the issues of agriculture.

Under the new urbanization perspective, the small towns have a systematic characteristic of "town", which are based on the urban agglomeration and are the basic form of the urban system. In term of the macro layout for the construction of small towns, the urban agglomeration is the main pattern. There are reasonable divisions of labor, complementary functions and coordinated development between cities and small towns.
As is shown in Figure 1, at this time the layout of small towns mainly relies on the division of urban system. Different urban systems have different industrial undertake and support. Small towns mainly undertake the backward production capacity from central city. The government is mainly responsible for management, operation and exploration of construction model. This layout aims at the function of life.

3 Feature small towns in Zhejiang Province as the benchmark in the economic transition period

The introduction of feature small towns, was first seen in the August 21, 2014, in "Several Opinions of the State Council on Promoting the Reform and Development of Tourism", the paper mentioned, "we are supposed to combine the rural tourism with new urbanization, properly using the ethnic villages and the ancient towns to develop the tourist towns within historical memory, regional characteristics and native features, and construct a number of famous villages and towns within scenic tourism." Subsequent theory and practice about feature small towns have been consummated progressively from the State Council to the Ministries, from the policy to the funds and from the government to the enterprises.

In January 2015, the authority of Zhejiang Province proposed to create feature small towns.
Relatively independent to the urban areas, the feature small towns possessed obvious industrial positioning, cultural connotation, tourism resources and space platform for community functions. They were different from the administrative divisions and Industry Parks. At this time, the towns hold the model of "town + new economy". The highlight of this model is that, different from administrative divisions and Industry Parks, the feature towns possessed innovation and entrepreneurship platform and space platform, where accumulated feature and emerging industries, and development elements. At this time, the feature towns, which didn’t belong to any administrative sections, cover a small area. The towns hold the industrial structure with gathering seven major industries and historical industries, closely integrating the Industry and Services. The enterprises are mainly responsible for management, operation and exploring construction model, while it combines “production, living and ecology”. Table 1 shows the characteristics of feature small towns, traditional towns, Industrial parks and economic development zones.

Table 1. Comparison of feature small towns, traditional towns, industrial parks and economic development zones

<table>
<thead>
<tr>
<th>Type</th>
<th>Administrative divisions</th>
<th>Industrial Structure</th>
<th>Subject of management and operation</th>
<th>Mode of development and construction</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional towns</td>
<td>Belong to the administrative sections, cover a larger area</td>
<td>Tertiary Industry besides the function areas</td>
<td>Government</td>
<td>Government-guide</td>
<td>Living</td>
</tr>
<tr>
<td>Feature small towns</td>
<td>Non - administrative sections, cross-administrative, smaller area</td>
<td>Gathered seven industries and some historical classic industries, agriculture, industry and service industry integrated</td>
<td>Enterprises</td>
<td>Enterprise-led</td>
<td>Production + living + ecological</td>
</tr>
<tr>
<td>Industrial parks</td>
<td>Within a single administrative section, larger or smaller area</td>
<td>Industrial manufacturing</td>
<td>Park Management Committees</td>
<td>Government-guide</td>
<td>Production</td>
</tr>
<tr>
<td>Economic development zones</td>
<td>Semi-administrative section, government departments, larger area</td>
<td>Industry and service industry. Generally high-tech and other industrial clusters areas</td>
<td>Management committees, investment companies</td>
<td>Government-guide</td>
<td>Production and living</td>
</tr>
</tbody>
</table>
have the feature leisure tourism, trade logistics, information industry, advanced manufacturing, folk culture heritages, or science and technology education, to promote agricultural modernization and urbanization. In March 2016, "the Thirteenth Five-year Plan" indicated to cultivate small and medium-sized cities and feature small towns actively. In July 2016, the MOHURD, the NDRC and the MOF jointly issued "the Notice on Cultivating Feature Small Towns" (Construction Village [2016] No. 147), which planned to cultivate 1,000 feature small towns approximately by 2020. In August 2016, the MOHURD issued “the Notice on Recommending Feature Small Towns in 2016"(Construction Village [2016] No. 71). In October 2016, the MOHURD officially published the first list of 127 feature small towns. In October 2016, the Central Leading Group on Financial and Economic Affairs, the NDRC and the MOHURD jointly held a conference to share experience about feature small towns. On December 2, 2016, "the State Council on Publishing the Notice of Poverty alleviation Plan in the Period of the Thirteenth Five-year" proposed to actively develop the feature cultural tourism, create a number of scenic areas and feature towns which can promote the employment of poor people, implement the project to protect and develop the ethnic villages, the traditional towns and the historical cultural towns. On December 5, 2016, "the State Council on Publishing the Notice of Ecologic Protection Plan in the Period of the Thirteenth Five-year" proposed to develop forest cities, garden cities and forest towns. Obviously, different departments have different requirements for the functional positioning and industrial support of the feature small towns.

Table 2. The Examples of Hangzhou feature small towns

<table>
<thead>
<tr>
<th>city</th>
<th>feature small towns</th>
<th>Industry types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hangzhou</td>
<td>Fund town in mountain YuHuang</td>
<td>Financial</td>
</tr>
<tr>
<td></td>
<td>Wisdom town in JiangGandinglan</td>
<td>Information economy</td>
</tr>
<tr>
<td></td>
<td>Yunqi town in West Lake</td>
<td>Information economy</td>
</tr>
<tr>
<td></td>
<td>Dream town in YuHang</td>
<td>Information economy and Financial</td>
</tr>
<tr>
<td></td>
<td>Fashion town in YuHang</td>
<td>Fashion</td>
</tr>
<tr>
<td></td>
<td>Silicon Valley town in FuYang</td>
<td>Information economy</td>
</tr>
<tr>
<td></td>
<td>Health town in TongLu</td>
<td>Health</td>
</tr>
<tr>
<td></td>
<td>Cloud manufacturing town in LinAn</td>
<td>Information economy</td>
</tr>
</tbody>
</table>

Source: According to the list of feature small towns.

As is shown in Table 2, we can see the feature towns are reflected in feature industry, feature ecology, feature culture and feature function etc. The industry positioning is "One Town One Industry", "One Town One Feature", which highlights "Feature and Strong." "Feature" refers to that each feature town must cultivate and develop local support industry to highlight the feature industry, according to the advantages of industry, information technology, high-end equipment, new materials, biological, new energy, eco-environment, digital creativity and other strategic emerging industries. "Strong" refers to that the towns must closely link to industrial restructuring and upgrading, aim at high-end industries, and attract innovation and entrepreneurship talent such as industry leader teams, growing enterprises, college graduates, senior executives, scientific and technical personnel and the returnees from foreign. The towns are also supposed to cultivate industrial leader enterprises, build industrial innovation areas, strengthen the high-end lead, and aim to be a new economic growth point. For instance, the manufacturing town, whose functional positioning is advanced equipment, needs to focus on new materials, new energy, robots, intelligent equipment, aerospace and other. The healthy town needs to concentrate on medical and
health, large medical equipment construction. In addition, the eco-environmental town should focus on energy and environmental protection, in order to lead the industrial transformation and upgrading and then make a demonstration.

Table 3. Subject of feature small towns and Examples of platform for innovation and entrepreneurship

<table>
<thead>
<tr>
<th>Towns</th>
<th>Platform for innovation and entrepreneurship</th>
<th>Subject</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yunqi town</td>
<td>Co-built by Government and enterprises</td>
<td>Entrepreneurs - highlight creativity, innovation, creativity</td>
<td>Government-guide and enterprises-led</td>
</tr>
<tr>
<td>Fund town</td>
<td>Government - hardware environment and policy services; Fund industry representative institutions - cultivate funds and new formats</td>
<td>Professional and high-level fund talents</td>
<td></td>
</tr>
<tr>
<td>Dream town</td>
<td>Information platform for dream; Government provide a model and public support Platform co-created by Government and enterprises</td>
<td>the colleges such as Zhejiang University, the talents such as Ali senior, the returnees such as &quot;thousand people plan&quot;, the businessmen such as the new generation</td>
<td>Government-guide and enterprises-led</td>
</tr>
</tbody>
</table>

Source: According to relevant data.

As is shown in Table 3, in the operation of feature small towns in Zhejiang Province, the government and enterprises are equals the two subjects, both of which can participate in the projects of towns. They can have longer time to cooperate, and also have more symmetrical information. On the innovation and entrepreneurship platform which the government and enterprises co-build, the creativity and innovation from entrepreneur can be stimulated. The two subjects jointly attract and support talents. This model not only shortens the entrepreneur’s time and costs, but also makes the entrepreneurs the most dynamic and the most creative subject. And thus, the model of "Government-guide, enterprises-lead, entrepreneurs as the subject" plays a key role in the feature small towns in Zhejiang Province as the benchmark.

4 The NDRC proposed the feature small (cities) towns include two types, feature small towns and feature small cities

In October 2016, the NDRC issued the "Opinion on constructing the beautiful feature small (cities) towns" (development planning [2016] No. 2125), proposed the feature small (cities) towns include two types, feature small towns and feature small cities. Among them, the feature small towns mainly refer to those which possessed innovation and entrepreneurship platform, as well as focusing on feature and emerging industries, gathering development elements, differing from administrative divisions and Industry Parks. The feature small cities refer to the traditional administrative divisions as a unit, with distinctive industry, a certain population and economic scale. Small towns and small cities complement with each other, supported by each other. The opinion also pointed out that the construction of feature small(cities) towns should formulate different policies according to different conditions, and every regions need to sum up and popularize the experience of feature small towns in Zhejiang Province, also explore new paths to develop cities through combining with local environmental resources. On December 27, 2016,
"the State Council on Publishing the Notice of National Information Plan in the Period of the Thirteenth Five-year" pointed out that according to the new urbanization and some strategic deployment like the Beijing-Tianjin-Hebei coordinated development or the Yangtze River Economic Development, and also according to the urban functions, geographical locations, economic levels and living standards, government should strengthen the classification of guidance, take different measures, and co-ordinate all kinds of pilot demonstration. Promote the development of wisdom towns, feature towns, to achieve the characteristic and differentiated development.

From the reality of the development conditions in China, many small towns in the eastern areas have the platform functions of innovation and entrepreneurship. However, the majority of towns in the western region developed very slowly. The small towns in the west are suffering from the fact that the technical and economic conditions cannot (completely) support the platform and social environment. It can be objectively said that such towns should be in a transition to the platform of innovation and entrepreneurship. Therefore, in addition to the support of feature industries and the space layout within trinity "production + living + ecology", towns in the western region which have not yet hold an innovation and entrepreneurship platform., need a transitional period. Based on the balance of ecological protection and economic development, this kind of towns should set up the goal like "Realizing the Innovation and Entrepreneurship platform", and make the key elements as constraints. Explore the main reasons to affect innovation, in order to seek the growth paths and supporting policies for feather small towns based on the conditions of resources in the western region, to break through the bottleneck of how to enhance the economy, to cultivate and develop the feather towns according to local conditions. At the same time, it is closely integrated with the realistic background of the era of large data, and plays the role of in formatization in the construction of the data platform for wisdom small towns, to enhance the comprehensive construction and management level of the towns.

5 Forest livable towns transformed after resource depletion and industrial recession

On November 16, 2016, "Opinions of the State Council on the deepening of the implementation of a new round of the revitalization of the Northeast strategy to accelerate the Northeast region to stabilize the important measures to stabilize the weak" proposed to support the transformation of resource depletion and industrial recession areas. The state-owned forest in northeastern would be all in to the national key ecological function area. Support the comprehensive ecological compensation and ecological migration pilot, and implement related support policies of stopping commercially removing natural forest. It’s also proposed to support the forest economy in the forest areas. Combined with the layout of the forest to optimize and adjust, there would construct a number of livable towns. What’s more, comprehensively promote the relocation of the urban old industrial areas and independent mining areas. Support the reform of the low-efficiency urban land and industrial waste disposal. It is proposed for green transformation urban, aimed at the reform of the supply front and industrial structure transformation and upgrading. That is, the construction of forest livable towns.
6 Feather villages and towns under the perspective of agricultural transformation and upgrading

On December 28, 2016, "Opinions of the General Office of the State Council on the Further Development of Agricultural Products Processing Industry", proposed the park as the main basis to create the industrial clusters and integration development Pilot areas, which gather a set of standardized raw material base, intensive processing and facilitation of service networks, to speed up the construction of feature small towns of agricultural products processing, to achieve the integration of industries and towns. On December 20, 2016, according to "the Several Views of the State Council on promoting the reform of the supply front of agriculture to speed up cultivating the new energy of agriculture and rural" ([2017] No. 1), cultivate livable feature villages and towns based on promoting the reform of the supply front of agriculture. This is the feature villages and towns under the perspective of agricultural transformation and upgrading, which are upgrade based on past "one village to one product".

In the construction of feature villages and towns, on the one hand, the villages can play some roles such as the base for agricultural production, the supplier for logistics and distribution products, the order performers for agricultural, rural leisure, health, pension center and so on. On the other hand, as a constraint to crack separation on time and space of supply and demand in agriculture, the feature villages and towns take a role of platform of fresh electricity business. It can increase the service and supply from rural fresh products to urban customers. For example, the villages can provide seasonal fruits and vegetables for customers through the e-business. At the same time, relying on agricultural multi-level industry system, it can develop the rural products in multi-levels, to create agricultural service complex. For instance, we can use the fresh air and natural scenery in rural areas to develop leisure experience agriculture and rural tourism projects. We can also establish the rural pension community to meet the demand of urban health. And gradually cultivate and develop the feather villages and towns based on the feather farm and products.

7 Conclusions

There are different perspective and different location for feature small towns in different periods, regions and departments of urbanization development in China. Through analyzing the characteristics of small towns in terms of their connotations, background and scopes, this study finds that the feature small towns have industry support, industrial and spatial harmonious development. They can also perform a basic pattern of urban system. Along with the spatial and temporal development of towns, the balance of production, living and ecological space appearance should be stressed. Feature small towns have their own function as a platform for innovation and entrepreneurship.

(1) The small towns under the new urbanization perspective have a systematic characteristic of "town", which are based on the urban agglomeration, and are the basic form of the urban system.
(2) Feature small towns in Zhejiang Province, as the benchmark in the economic transition period, hold the model of the "town + new economy". Relatively independent to the urban, the feature small towns possessed obvious industrial positioning, cultural connotation, tourism resources and space platform for community functions. They were different from the administrative divisions and Industry Parks.

(3) In October 2016, the NDRC proposed the feature small (cities) towns including two types, feature small towns and feature small cities. Among them, the feature small towns mainly refer to those which possessed innovation and entrepreneurship platform, as well as focusing on feature and emerging industries, gathering development elements, differing from administrative divisions and Industry Parks. Small towns and small cities complement with each other, supported by each other.

(4) Forest livable towns transformed after resource depletion and industrial recession.

(5) The feature villages and towns under the perspective of agricultural transformation and upgrading proposed in the paper of [2017] No. 1, are upgraded based on past "one village to one product".

Feature small towns at different stages, there are different meanings and scopes. And the development of small towns all over the country had a great imbalance. The majority towns in the western region developed very slowly. In where the technical and economic conditions cannot (completely) support the platform and social environment. They should be in a transition to the platform of innovation and entrepreneurship. The development of small towns should be different according to the resources advantages, industrial characteristics and the integrated conditions of technical and economic. Seek the growth paths and supporting policies for feather small towns based on the conditions of resources in the western region, and break through the bottleneck of how to enhance the economy.

References


Technical Review of Automated Monitoring System for Concrete Curing

Bhatia, Angat Pal Singh¹ and Moon, Sungkon²*

Abstract: Real time monitoring of concrete with non-destructive technology is the demand of today’s industry. Non-destructive techniques ensure the quality and safety of concrete. During the process mainly moisture content, concrete strength development and cracks are monitored, but monitoring moisture content in concrete is promising because it reflects the concrete uniformity. Moisture content has correlation with both concrete strength and crack formation. In the paper through literature review it is analysed that techniques such as Inductor-capacitor (LC) resonant circuit and Humidity and temperature digital combined sensor that are used to monitor moisture content in concrete at the time of curing are still expensive, lacked in accuracy and have quality issues. This research paper with an aim to overcome the problems in concrete moisture monitoring at the time of curing, provides an overview on combined RFID and optical fibre innovative system. To improve moisture monitoring process and to show system's productivity, the experimental work will be done in future.

Keywords: Concrete; Real time monitoring; Non-destructive technologies; Moisture content; Curing; Radio-frequency identification (RFID); Optical fibre.

1 Background and Introduction

Real time monitoring of concrete is the continuous monitoring of concrete characteristics such as moisture content, concrete strength development and cracks with the help of sensors (Newell, Goggins et al. 2016). Real time monitoring of concrete is promising in terms of preventing the life and property loss due to failure of structures (Tseng and Wang 2004). Out of moisture content, concrete strength development and crack, real time monitoring of moisture content is essential because it reflects the concrete uniformity (Hu and Zhang 2003).

The need to develop the techniques that can be used for concrete curing real time monitoring was required because conventional methods such as gravimetric method, compressive loading test and many more which are used to estimate the concrete moisture and strength were destructive and not efficient for instantaneous measurement (Bois, Benally et al. 1998).

The techniques that are non-destructive such as RFID (radio frequency identification technology), optical fibre, MEMS (microelectromechanical systems), microwaves, passive embedded sensor, and humidity and temperature digital combined sensor are important for real time monitoring of concrete (Loupos and Amditis 2017). Concrete quality and safety will be ensured if non-destructive techniques are used because there is no significant impact in the form of creep deflection which forms after applying heavy loads on concrete which is premature (Gu, Song et al. 2006).

In comparison to all the existing non-destructive technologies, RFID and Optical fibre are the emerging wireless technologies (Leng and Asundi 2003),(Amin, Kanth et al. 2013). RFID (radio frequency identification) technology in 1979 became usable product when Mario Cardullo's device was patented in 1973 (Niver 2010). The technology works on the principle where it uses radio waves so that data can be transferred (reader- electronic tag) and object can be monitored and tracked. In
the research done by Moon et al. (2016) a relationship was developed between water content / concrete strength and RFID tags readability to get the information about the moisture/water in concrete. RFID tags readability increases with decrease in moisture/water content (Moon et al. 2016). The two main types of RFID are passive (no use of battery) and active (use of battery) (Lesthaeghe, Frishman et al. 2013). In 1960 optical fibre was proposed as a medium to carry information. Fibre Bragg gratings (FBG’s) are one of the most widely use sensors for monitoring purposes (Mendez 2007) and were described by Giaccari et al. (2001) in his experiment.

The research aim is to analyse the combining work of RFID and optical fibre. The objectives defined to achieve the overall research aim: (1) to increase in accuracy by using RFID (Radio frequency identification technology) and Optical fibre technology, (2) life time monitoring, (3) to fulfil the requirement of cost effective system.

The structure of the paper is as follows: In Section 1, there is a discussion about the background information, why there is a need to do the research and what the objectives are. In section 2 literature review related to various technologies used for real time monitoring of ‘Moisture Content in Concrete’ with their limitations are analysed and their comparative analysis is done before stating the problems and research hypothesis in section 3. Finally, an overview in section 4 about how RFID and optical fibre combined system will be used in future to fill the limitations of previous technologies.

2 Literature review

2.1 Different methods to monitor moisture content in concrete

Evaluate water content in concrete which proved to be a hazardous factor, as it deteriorate the construction materials is important (Md, Alam et al. 2015). In monitoring water content various technologies such as microelectromechanical systems (MEMS), passive embedded sensor (inductor-capacitor (LC) resonant circuit), microwaves and many more were involved to analyse the concrete so that structures reliability and effectiveness can be maintained (Md, Alam et al. 2015).

Table 1. Basic components- Moisture content monitoring in concrete

<table>
<thead>
<tr>
<th>Non Destructive Techniques</th>
<th>Basic components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity and temperature digital combined sensor</td>
<td>• Normal and High strength concrete sample.</td>
</tr>
<tr>
<td></td>
<td>• Plastic sheet.</td>
</tr>
<tr>
<td></td>
<td>• Polystyrene board.</td>
</tr>
<tr>
<td></td>
<td>• Humidity and temperature digital combined sensor.</td>
</tr>
<tr>
<td></td>
<td>• Mathematical model.</td>
</tr>
<tr>
<td>Inductor- capacitor (LC) resonant circuit.</td>
<td>• Inductor-capacitor (LC) resonant circuit.</td>
</tr>
<tr>
<td></td>
<td>• Capacitor as the sensor component.</td>
</tr>
<tr>
<td></td>
<td>• Moisture-sensing layer.</td>
</tr>
<tr>
<td></td>
<td>• Concrete specimens.</td>
</tr>
<tr>
<td></td>
<td>• Container (13.3*13.3 cm²).</td>
</tr>
</tbody>
</table>

2.1.1 Real Time Monitoring of water in concrete by wireless sensor.

In concrete materials large number of failures are due to water content and it is important to detect it so that structures reliability and effectiveness will be maintained (Md, Alam et al. 2015). In previous researches microwave energy and microelectromechanical systems were used to monitor the moisture, but the cost to setup was very high as well as complicated and certain issues such as concrete field tracking, communication and data storage were there. So, a wireless sensor was applied by B. Ong and Mills-Beale (2008) to avoid the problems.

A. Passive embedded sensor.

It was based on wireless inductor-capacitor (LC) resonant circuit. The system had certain advantages such as low maintenance and installation cost, lightweight and reliable. The capacitor which was used as the sensor component to monitor water content was coated by moisture-sensing
layers. As the water was absorbed by coating material, there was an increase in its dielectric constant because water had high dielectric constant as compared to the coating materials (Shin, Qureshi et al. 2008). The capacitor capacitance was varied because of the shift in dielectric constant, thus changed the resonant frequency and water contents were tracked. Inductor was combined with sensor component (capacitor), so that information can be transferred by LC sensor as the resonant frequency changes. The LC sensor based system locate the water within the concrete. The detection of water inside the concrete has proved to be advantageous as it will improve the life span (Ong, You et al. 2008).

To determine the resonant frequency of sensor, detection coil impedance was measured which was placed near the sensor. The resonant frequency was denoted by $f_0$ and $f_z$ was the zero-reactance frequency. The $f_0$ and $f_z$ were related to inductor, capacitor and resistor. Capacitor and resistor were parallel to show capacitive loss. The capacitor capacitance was increased due to the increase in the water content, which reduced the resonant frequency of sensors and the increase in capacitive loss also reduced the resistor value, but the inductance was constant and this shows the dependency of sensors resonant frequency on capacitance (Shin, Qureshi et al. 2008).

\[ f_0 = \frac{1}{2\pi\sqrt{LC}} \]
\[ f_z = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{1}{R^2C^2}} \]

To monitor the content of water in concrete, mortar mix of 800 g and 200Ml was combined and placed in the container (13.3*13.3 cm$^2$). The length of inductor was 2.5cm (Inner length) and 4 cm (Outer length). The length of electrode in the capacitor was 2cm. In the concrete mixture, sensor was embedded and the sample was left for curing and at the same time sensor readings were taken. After the process of curing the sample was removed and for 10 minutes it was soaked in the water. The concrete sample was kept to dry and later placed on the detection coil in the plastic container and the detection coil impedance was measured. A close loop was formed by joining the capacitor and inductor. The upward (increasing) trend for sensor resonant frequency was noted down at the time of curing of mixture. At the time when the concrete sample was pre-soaked, sensor resonant frequency was noted down and it shows the change.

From the result it was clear that sensor had the capability to retain its sensitivity against the water and was good enough to withstand at the time of curing. On various points the reading of sensor resonant frequency and water in concrete were compared. It was found that sensor resonant frequency was linearly proportional to both measured water and dielectric constant of concrete sample. Response of sensor was compared with actual measurements to determine the ratio of water to concrete. Less than 10% error was noted down between the readings of sensor response and actual measurements.

2.1.2 Monitoring moisture in early age concrete by humidity and temperature digital combined sensor.

The objective was to monitor moisture content by measuring the interior humidity of concrete in relation with time during early age. Normal (40 MPa) and high (80 MPa) strength concrete were the two types of concrete that was used with surface of specimen as with and without a cover of plastic sheet (Zhang, Qi et al. 2009), (Zhang, Huang et al. 2011).

Normal (40 MPa) and high (80 MPa) strength concrete interior humidity was measured. To prevent the loss of moisture, plastic sheet was used to cover the mould inner surface. Polystyrene board was used to cover the outer surface so that heat loss can be prevented. To measure humidity and temperature digital combined sensor (five sensors) was applied by Zhang and Qi (Zhang, Huang et al. 2011). The length – location relationship was developed in concrete. Four sensors were placed at the different depths to measure humidity and temperature. The function of one sensor was to measure the environment humidity and temperature. The results were recorded in the computer at the interval of 10 minutes.

To describe the interior humidity variation in concrete during early age the saturation of water vapour in stage 1 where relative humidity was 100% and stage 2 where relative humidity decreased with time were used. The plastic sheet that covered the surface of specimen was effective to influence the RH when it was near the surface. The depth of concrete influenced the length where the humidity will be developed and depth mainly depends on concrete strength. More concrete
strength caused less influencing depth. Moisture from environment can be easily penetrated into the concrete, which resulted into faster degradation process (Pavlík, Tydlitat et al. 2003).

A mathematical model was used to predict moisture distribution. The two factors which played important role in the increase of relative humidity with time in concrete were considered 1) Initial water present in the pore after casting of concrete. 2) Rate at which water lost. The voids size depends on water- cement ratio and higher the ratio more is the pore size(Zhang, Qi et al. 2009). So, initial water present in the pore was a function of water- cement ratio as well as location because more the pores close to the casting area, more the content of water.

In stage 2, the water content varies due to hydration of cement and water diffused, so water diffused can be defined as the variation of water content – cement hydration in relation to time and location (Pavlík, Tydlitat et al. 2003). Relation between defined humidity and water content was related with desorption isotherms which was defined as:

\[
\frac{\partial (H-H_S)}{\partial t} = \frac{\partial}{\partial x} * \left( D \frac{\partial (H-H_S)}{\partial x} \right) + K \frac{\partial T}{\partial t}
\]

\[D = \text{Moisture diffusion coefficient}, H_s = \text{Humidity reduction}\]

The results were:
1) Interior humidity of concrete decreases as the time increases and from the experiments it was resulted that internal humidity reduced more in high strength (69%) as compared to the normal strength (89%) of concrete.
2) Diffusion of water was more in normal strength (10 cm) as compared to high strength (2.5 cm) of concrete.
3) Hydration of cement and water evaporation causes change in water distribution with time.
4) Humidity decreases as the temperature increases.
5) Humidity and water content were linear function, means defined humidity was a linear function of water present.

Table 2. Comparative Analysis- Monitoring Moisture in Concrete by various technologies.

<table>
<thead>
<tr>
<th>Number</th>
<th>Monitoring Moisture by Various technologies.</th>
<th>Key features</th>
<th>Drawbacks</th>
<th>Cost</th>
</tr>
</thead>
</table>
| 1      | Humidity and temperature digital combined sensor | •Non-destructive.  
•Measured the interior humidity of concrete at early age to reduce the degradation processes in concrete.  
•Used mathematical model to predict moisture distribution based on hydration of cement and water diffused from concrete. | •Extensive wiring made it difficult to work with on construction site and in places where there are difficult working environment conditions.  
•The system would be expensive if used in infrastructures based on large scale. | High |
| 2      | Passive embedded sensor (inductor-capacitor (LC) resonant circuit) | •Non-destructive.  
•Low maintenance cost, low installation cost, lightweight and reliable. | •No tracking of zero-reactance frequency, which could improve the accuracy of measurement.  
•The coating of paraffin wax, which was done to make the circuit safe from short circuiting, reduced the | Cheap |
3 Problem statement and Research hypothesis

Moisture present in concrete affects the strength and develops crack within concrete, which reduces the life of structure (Shin, Qureshi et al. 2008). Existing technologies such as Inductor-capacitor (LC) resonant circuit and Humidity and Temperature digital combined sensor are expensive, not able to track and locate, lacked in accuracy, have quality issues and difficult to install due to wiring problem. Such type of technologies are ineffective as well inconvenient to work with at the construction site.

In order to achieve the objectives of increase in accuracy, low price and life time monitoring, this research paper will describe how the combination of RFID and Optical fibre will work to monitor concrete curing in real time. Hypothesis 1: Optical fibre will be combined with RFID to increase the accuracy. Hypothesis 2: Optical fibre and RFID will be cost effective. Hypothesis 3: Life time monitoring of structure by using optical fibre and RFID.

This research paper will establish three hypothesis to find the solutions of the problems. To test the first hypothesis (increase in accuracy) three concrete cylindrical samples will be made. In first sample RFID tags and optical fibre will be added, second sample will be embedded with RFID tag only and third sample will contain only optical fibre. The accuracy of the first sample (RFID and optical fibre) will be compared with the accuracy of sample 2 (only RFID) and sample 3 (optical fibre only). Inexpensive equipment’s such as RFID tags and optical fibre sensor in which there is no need of wiring will be used to prove the cost effectiveness of the system. Hypothesis third (Life time monitoring) will be established by monitoring the concrete cylindrical samples in the interval of 1-7-14-28 days. RFID will be used to locate the concrete position and optical fibre will monitor cracks and strain after 28 days.

In RFID system a wireless communication between RFID reader (transceiver and an antenna) and RFID tag (transponder) will be formed with the help of electromagnetic field generated by antenna. The reader will detect the code (uniform identification code) on RFID tag and the location about the concrete sample in which the tag is embed will display on the readers screen. Ultra high frequency tags will be used in concrete samples with UHF readers (800-900 MHz). The information about the moisture/water in concrete at the time of curing will be analysed by RFID tags readability, which increases with decrease in moisture/water content like in the research done by Sungkon Moon, but with that Optical fibre will be embedded with RFID tags in the concrete samples to increase the accuracy. Through the optical fibre a light will pass, which affect the mechanical state of concrete due to change in its intensity and real time concrete information will be evaluated.

4 Summary and Future Works

RFID and optical fibre has the potential to fulfil the requirements such as non-destructive, low price, increase in accuracy and life time monitoring. The contribution of combined RFID and optical fibre innovative system will be established in next semester. The paper will present the effective use of RFID tags to analyse moisture/water in concrete. On the other hand to increase the accuracy lightweight optical fibre with small dimensions will be used without affecting the properties of concrete and to test this concrete cylindrical samples embedded with RFID and optical fibre will be made. Prof Chon who is a physics professor in Swinburne University of Technology will provide
his valuable knowledge to get more understanding about the optic fibre inspection. The combination of both RFID & Optical fibre has the potential to prove to be a cheap and productive system.

References


DEA-based Efficiency Analysis For Industrial Land Use: A Case Study of Chinese Development Zones

Shan J.M.¹, Liu X.N², Wu Y.Z.³*Zhang X.L.⁴

Abstract: Improving the efficiency of industrial land use in development zones has vital significance for promoting industrial upgrading, keeping a sustained rapid economic growth and dealing with the middle income trap risk. The paper takes 11 development zones in Shaoxing city, Zhejiang Province, as the research objects, using Data Envelopment Analysis (DEA) method to measure the efficiency of industrial land use in these zones. The research indicates that: Improving the efficiency of industrial land use requires effective policy intervention; The industrial land use efficiency and the degree of industrial concentration both have strong positive correlation with the level of research and development, while the increase of land use costs may constrain the efficiency of industrial land use; The level of development zones and the efficiency of industrial land use are not very relevant; The benefit of scale economies and the scale of land have no correlation. On this foundation, policy proposals are offered mainly from these aspects: strengthening the planning and regulation of development zones, implementing industrial land supply sort management, perfecting the evaluation system of the development zones’ upgrading and expansion.

Key words: Development zone; Industrial land; Efficiency; Middle income trap

¹ Shan, J.M.
School of public affairs, Zhejiang University, China

² Liu, X.N.
College of public administration, Nanjing Agricultural University, China

³* Wu, Y.Z.
Corresponding author, School of public affairs, Zhejiang University, China
E-mail: wuyuzhe@zju.edu.cn

⁴ Zhang, X.L.
Department of public policy, City University of Hong Kong
1 Introduction

In accordance with the World Bank standards, China has entered the ranks of middle-income countries. In this stage of development, if the economy continues to slow down and cannot effectively respond to the challenge, it is likely for China to fall into the “middle income trap”\[^1\]. In recent years, economic downward pressure and a continuous decline in economic growth rate increase the people's concern about this risk\[^2\]. Land is known as the basic element of industrial production, the use efficiency of which is able to intuitively reflect the quality of industrial development, and has a potentially significant impact on the sustainable growth of the economy. At present, Industrial land use has become one of the most dominant forms of land use in China today\[^3\], but at the same time industrial land efficiency is low\[^4\], to some extent leads to the low-end industrial structure and growth is difficult to sustain. As a regional industrial land gathering area and industrial agglomeration area, the development zone plays a key role in regional economic growth. It is of great significance to study the industrial land efficiency in the development zone. At present, the study of land use in the development zone focuses on the intensive use of land\[^5\]–\[^10\]. The research on the efficiency of industrial land in the development zone and its related policies needs further system and in-depth\[^11\].

This study takes 11 development zones in Shaoxing city, Zhejiang Province, as the research objects, using Data Envelopment Analysis (DEA) method\[^1\] to measure the efficiency of industrial land use from 2010 to 2014. By analyzing the characteristics of the change, the differences between the development zones and the possible reasons for the differences are made, and then the relevant policy suggestions for optimizing the efficiency of industrial land and promoting the sustainable development of the development zones are put forward.

2 Objects selection and research methods

2.1 Research area and object overview

Shaoxing City is located in the north and south of Zhejiang, the Yangtze River Delta south wing, covers an area of 8279km\(^2\), the resident population is 4.96 million. Shaoxing achieved a total domestic value 446.7 billion yuan in 2015, the total fiscal revenue 60.2 billion yuan, above-scale industrial added value 1588 Billion, industrial investment 125.2 billion yuan. The 6 counties (cities, districts) under the jurisdiction of Shaoxing are all the top 100 counties in china. In recent years, Shaoxing actively explore the industrial land use management, is the top ten land and resources conservation model city. Shaoxing has been a pilot city for redevelopment of inefficient land use in cities and towns determined by the Ministry of land and resources and the Zhejiang provincial government. At present the city has a total of 12 provincial-level and national-level development zones (parks). Among them, Shaoxing Hi-tech Development Zone, Paojiang Economic and Technological Development Zone, Keqiao Economic and Technological Development Zone and Hangzhou Bay Shangyu Economic and Technological Development Zone are national-level development zones. Due to the lack of data in some parts of the provincial concentration area Shaoxing Binhai New Town, this paper takes the remaining 11 provincial development zones as the object of study.
2.2 Index selection and data sources

The evaluation of land use efficiency involves three aspects of economic, social and ecological factors, the industrial land use efficiency evaluation often choose the economic aspects of the multi-index analysis, which can be multi-input multi-output variable indicator combination. Based on the relevance and representativeness of the reference index and considering the availability of the data, this study chooses the land and the asset investment as the input factor, the output value and the profit as the output factor, and the area, industrial investment and industrial output value, total industrial profits of industrial enterprises above designated size in each Development Zone to characterize and analyze the efficiency of industrial land.

Because of the main business income of the industrial enterprises above designated size statistical caliber has been transferred from 5 million yuan to 20 million yuan from 2010, taking the comparability of data into account, the time limit for this study is 2010 and the study time dimension is 2010-2014. The research data used in this study mainly come from the statistical yearbook of Shaoxing over the years and the annual statistical data of the development zones provided by the Shaoxing Commerce Bureau.

2.3 Research methods

In this study, the comprehensive efficiency of industrial land in 11 development zones is calculated by DEA method, and the industrial land use efficiency and its change structural characteristics are evaluated.

2.3.1 Data Envelopment Analysis (DEA)

The DEA model maps the input and output of decision-making unit (DMU) to the space for a linear combination to build an envelope frontline through the mathematical process of linear programming, so as to measure the relative efficiency of each decision-making unit. Compared to the research methods of index evaluation and production function, the DEA method, a nonparametric estimation method, boasts obvious advantages. Based on the concept of relative efficiency, the DEA method is not affected by the input and output complex variables and is provided with defined index weight, which effectively eliminates the interference of subjective factors. The basic form of the DEA model is the CCR (Charnes & Cooper & Rhodes) model that measures the overall efficiency supposing the DMU returns to scale is constant. When the returns to scale changes, it can be applied to the BCC (Banker & Charnes & Coopers) model developed by Banker. The basic formula for the DEA method is as follows:\(^{[13]}\):

\[
\begin{align*}
\min \theta &= v_D \\
\text{s.t.} \sum_{j=1}^{n} x_j \lambda_j + s^- &= \theta x_0 \\
\sum_{j=1}^{n} y_j \lambda_j - s^+ &= y_0 \\
\delta \sum_{j=1}^{n} \lambda_j &= \delta \\
s^- &\geq 0, s^+ \geq 0, \lambda_j \geq 0, j = 1, 2, \cdots, n
\end{align*}
\]

When \( \delta = 0 \), the formula can be expressed as the CCR model where the returns to scale is
assumed to be constant; when $\delta = 1$, it can be expressed as the BCC model where the returns to scale is assumed to be variable. In the formula, $\theta$ represents the relative efficiency of the decision-making unit (DMU); $x$ represents the input variable and $y$ represents the output variable; $s^-$ and $s^+$ represent the input and output slack variable respectively; $\lambda_j$ represents the proportion of the $j$-th DMU combination when a valid DMU combination is reconstructed based on $DMU_j$.

The value of $\theta$ is between 0 and 1. The larger the value is, the more efficient the decision unit is. When $\theta = 1$, the input-output reaches its optimal result. In this paper, we consider each of the development areas as a multi-input and multi-output decision-making unit. They are in different stages of development and show significant differences in returns to scale. Therefore, the BCC model with variable returns to scale is chosen in this paper to better reflect the use efficiency of industrial lands in different development areas.

3 Results analysis

3.1 Overall status of industrial land use efficiency

Using DEAP2.1 software, the annual industrial land efficiency and its average efficiency in 5 years in 11 development zones in Shaoxing from 2010 to 2014 are calculated.

Table 1. Industrial land use efficiency in development zones in 2010-2014.

<table>
<thead>
<tr>
<th>Name of development zone</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaoxing Hi-tech Development Zone</td>
<td>0.354</td>
<td>0.38</td>
<td>0.378</td>
<td>0.339</td>
<td>0.248</td>
<td>0.340</td>
</tr>
<tr>
<td>Paojiang Economic and Technological Development Zone</td>
<td>0.570</td>
<td>0.60</td>
<td>0.596</td>
<td>0.719</td>
<td>0.491</td>
<td>0.595</td>
</tr>
<tr>
<td>Keqiao Economic and Technological Development Zone</td>
<td>1.000</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.000</td>
</tr>
<tr>
<td>Keqiao District Binhai Industrial Zone</td>
<td>0.889</td>
<td>0.91</td>
<td>1.00</td>
<td>1.00</td>
<td>0.841</td>
<td>0.928</td>
</tr>
<tr>
<td>Zhuji Economic Development Zone</td>
<td>0.712</td>
<td>0.60</td>
<td>0.709</td>
<td>0.682</td>
<td>0.683</td>
<td>0.678</td>
</tr>
<tr>
<td>Zhuji Pearl Industrial Park</td>
<td>1.000</td>
<td>0.74</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.000</td>
</tr>
<tr>
<td>Shangyu Economic Development Zone</td>
<td>0.912</td>
<td>0.91</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.965</td>
</tr>
<tr>
<td>Hangzhou Bay Shangyu Economic and Technological Development Zone</td>
<td>0.782</td>
<td>0.73</td>
<td>0.847</td>
<td>0.853</td>
<td>0.801</td>
<td>0.804</td>
</tr>
<tr>
<td>Shengzhou Economic Development Zone</td>
<td>0.767</td>
<td>0.72</td>
<td>0.805</td>
<td>0.778</td>
<td>0.647</td>
<td>0.743</td>
</tr>
<tr>
<td>Xinchang Hi-tech Industrial Park</td>
<td>1.000</td>
<td>1.00</td>
<td>1.00</td>
<td>0.959</td>
<td>0.882</td>
<td>0.968</td>
</tr>
</tbody>
</table>
From Table 1, it can be seen from the overall level that the average efficiency of industrial land in 11 development zones of Shaoxing has the characteristics of polarization, but the average industrial land use efficiency of most development zones is higher and the overall level is at a good level. National land and resources conservation model is consistent with the status of the city.

3.2 Temporal variation characteristics of industrial land efficiency

From the change of time series, the fluctuation of industrial land efficiency in the development zone is obvious. Except for the Keqiao Economic Development Zone which keeps maintaining optimal conditions, the remaining 10 development zones have suffered from the fluctuation of industrial land efficiency to some extent during the past 5 years. In 2014, the industrial land efficiency of the Shaoxing Hi-tech Zone and Paojiang development zone reached the lowest point in recent 5 years, and the gap between them and other development zones is further widened. The emergence of these phenomena is not only related to the cyclical characteristics of industrial production from construction investment to output, but also closely related to the supply and supervision system of industrial land. For example, Keqiao District initiated the concept of “High yield per mu determinism” in China. In 2012, Keqiao District first adjusted the urban land use tax in Zhejiang, and the efficiency of industrial land was relatively high in its 2 development zones. Shengzhou is a city dominated by labor-intensive light industry. The land resources are relatively abundant, in the next 10 years, here are still available land of nearly 66.67km², leading to the relatively extensive industrial land use in the development zone to some extent. However, it is also possible to find out that the efficiency of industrial land use is very difficult to be effectively improved in the absence of effective intervention, which is completely dependent on the regulation of market competition mechanism.

3.3 Spatial differentiation characteristics of industrial land use efficiency

From the spatial differentiation, Keqiao Economic and Technological Development Zone, Keqiao District Binhai Industrial Zone, Zhuji Pearl Industrial Park, Shangyu Economic Development Zone and Xinchang Hi-tech Park, located in the mountainous area, have always been at a higher or optimal level. However, Shaoxing Hi-tech Zone and Paojiang Development Zone which are situated in the center of Shaoxing City have the lowest efficiency. This reflects that the site selection of the industrial land is significantly different from that of residential and commercial land. Through the horizontal comparison of the characteristics of the development zones, two development zones of Keqiao District as China’s "textile capital" "printing and dyeing town" and Zhuji Pearl Industrial Park have a higher Industry agglomeration degree. Yuecheng District, which contains Shaoxing High-tech Zone and Paojiang Development Zone, ranks the last in the comprehensive evaluation of technological innovation in 6 counties (cities, districts)\[14\]. It shows that the degree of industrial agglomeration and the level of industrial research and development have a strong positive correlation with the efficiency of land use. According to data provided by the Bureau of land and resources of Shaoxing Municipality, Yuecheng District’s industrial (storage) land for public sale price is the highest. Although the land cost is relatively, the efficiency of land use
use has not been improved accordingly. It seems that the price mechanism is not completely suitable for facilitating to improve the efficiency of industrial land, and not in accord with the previous view which is based on the traditional economic theory by emphasizing the importance of raising the price of industrial land to improve the efficiency of land use. This indicates that there is a need for further observation and verification over a longer period of time.

3.4 Level of Development Zones and the Efficiency of Industrial Land

From the level of development zones, the level of development zones is not necessarily positively related to the efficiency of industrial land, and the efficiency of industrial land in national development zones is not necessarily higher than that of provincial development zones. Among the 11 development zones, the average industrial land use efficiency of Keqiao Economic Development Zone is the highest, while the average industrial land use efficiency of Shangyu Economic and Technological Development Zone, Paojiang Economic and Technological Development Zone and Shaoxing Hi-tech Development Zone in Hangzhou Bay ranks 8, 10, 11 respectively, lower than that of the provincial development zone. This shows that the state-level development zones in the economic development enjoy a lot of policy advantages, but the efficiency of industrial land still needs to be improved, and cannot reflect its due and exemplary role. Attention should be paid to these problems in the level recognition and application policy management of development zone in the future.

3.5 Development Zone Scale and Land Use Efficiency

From the area of development zone, there is no necessary correlation between the size of the planning area and the efficiency of industrial land. In terms of the planning area, the top 4 development zones are Shaoxing Hi-tech Development Zone, Keqiao Economic and Technological Development Zone, Hangzhou Bay Shangyu Economic and Technological Development Zone, Zhuji Economic Development Zone. The average industrial land efficiency of which ranks 11, 1, 7, 9 respectively. Those taking 9-11th place are Shengzhou Economic Development Zone, Xinchang Hi-tech Park, Zhuji Pearl Industrial Park, The average industrial land efficiency of which ranks 8, 2, 4 respectively. This shows that the development zone blindly “seeking for large areas”, ignoring the industrial structure optimization, neglect of land management will lead to extensive land use and efficiency reduction.

4 Policy Implications

(1) Strengthen the planning and control of industrial land in development zones. It is necessary to rationally carry out the spatial planning, land use planning and industrial planning of the development zones so as to ensure that the construction and leading industry of the development zones match the functions of the specific areas of the city, and disharmonic areas can promote industrial transfer through the method of "reasonably weakening the secondary industry and proactively develop the tertiary industry". Strengthen the internal industrial planning in the park, pay attention to the relative agglomeration, differentiation and complementarity of the industry in the supply and management of land use, and enhance the agglomeration economic benefits of industrial enterprises[15].

(2) Put classification management of industrial land supply into practice. On the basis of
total amount control and rhythm control of industrial land in Development Zone, differential land supply mode and differential land price standard are adopted to link up the efficiency of industrial land use, the intensity of project investment with the allocation and protection of land factors. Extensive land use and repeated investment should be avoided from the links of land supply and use, transformation and upgrading as well as innovation and development of the development zones should be promoted through the change of land use pattern.

(3) Improve the assessment system of expansion and upgrading of development zones. Corresponding access threshold must be set for the investment intensity of industrial land projects in provincial and national development zones respectively, and the industrial land efficiency of development zones is taken as an important constraint index for the upgrading and expansion of development zones. Provided that any upgrade to the upper level development zone or the expansion of the planning area, the land use efficiency must be in the forefront of similar development zones, forcing it to improve the efficiency of industrial land use.

5 Conclusion

Through the study of industrial land use efficiency and its total factor productivity in 11 development zones in Shaoxing City, it can be found that:

(1) The average industrial land of Shaoxing above the provincial development zones is relatively efficient, which reflects the positive effect of Shaoxing land resources saving and intensive policy investment and innovation to a certain extent.

(2) From the change of industrial land efficiency, the efficiency of industrial land is affected by the objective reasons of cyclical characteristics of industrial investment itself, and it is also closely related to the supply and supervision system of industrial land. In the absence of effective policy intervention conditions, The use of industrial land is difficult to get rid of the original development path and can hardly be effectively improved.

(3) The site selection of the Industrial land is significantly different from the residential, commercial and other industrial land, It attaches more importance on the degree of industrial agglomeration, research and development level and other factors; and simple land price mechanism is not entirely suitable for through the cost of land to guide the efficiency of industrial land to enhance. This is obviously different from the traditional economic theory, which needs further observation and verification.

(4) The level of development zones can not reflect its guiding and demonstrative role from land use efficiency differences, which is worthy of attention in the determination of the level of development zones and the application of policy management in the future.

(5) There is no correlation between scale economies effect and the scale of land use in the development zones. More attention should be paid to the returns to scale of industrial land in the development zones and targeted management should be conducted from the industrial structure and the industrial chain itself.
Acknowledgement:

The research is supported by the Research on the Development Orientation of Characteristic Small Towns - From the Perspective of Agglomeration and Inclusion (No. 2-2050205-17-182).

References:


Analysis of Interest conflicts between the Stakeholders about Architectural Heritage Protection

Wang Ruiling 1* Liu Guo 2

Abstract: During the process of Chinese urbanization, some conflicts of interest between the stakeholders arised because different stakeholders have different interest aims and expectations about architectural heritage protection. This paper will study the conflicts between the stakeholders.

Keywords: Architectural heritage protection; Stakeholders; Interest; Dissonance; Contradiction

---

1 Ruiling Wang
Chongqing University of Science and Technology, Chongqing, China
cqwr173@163.com

2 Liu Guo
Faculty of Construction and Management of Chongqing University, China
1 Introduction

Because the interests of each stakeholder are different in the process of urbanization, conflicts between stakeholders are inevitable. In the case of building heritage, all stakeholders take actions that are conducive to their own actions in order to satisfy their own interests, that is to say, the behavior of each stakeholder bases on individual interests. Thus, the different interests of all stakeholders will cause contradiction between individual and social interests. Only by identifying the contradictions among the stakeholders can we fundamentally resolve the conflicts of interest between the stakeholders. In order to know what conflicts arise on earth between the stakeholders, the method of expert questionnaire survey and literatures collection was adopted.

2 Design of questionnaire

In this paper, the questionnaire design about conflict identification between the stakeholders is mainly divided into the following four steps:

2.1 Reading literatures widely

The paper aims to explore the conflict of interests of the stakeholders by reading literatures downloaded from Engineering Village, ICE, CNKI knowledge network, etc., and this will lay the index foundation for the follow-up questionnaire survey. By collating the retrieval results, conflict indicators of stakeholders about architectural heritage protection are preliminarily obtained.

2.2 Survey and collect materials online

In this phase, reports and cases about architectural heritage protection at home and abroad through the network are collected, then the author analyzes these reports and cases furtherly in order to find interest conflicts about architectural heritage protection in practice. The conflicts as is shown in table 1.

<table>
<thead>
<tr>
<th>cases</th>
<th>conflict performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heijing Salt architectural heritage protection</td>
<td>conflict between the government at a higher level and a lower level</td>
</tr>
<tr>
<td>The ancient city of XI’AN</td>
<td>the preservation of architectural heritage is for the sake of open tourism and increase economic returns</td>
</tr>
<tr>
<td>The ancient city of Lhasa, protection of Tianjin historic district architectural heritage</td>
<td>urban renew need build new town, the historical pattern of the old city will be badly damaged</td>
</tr>
<tr>
<td>Protection of Hong’an ancient town architectural heritage protection of the ancient town of Hong’an, Zhongshan, Gongtan</td>
<td>The compensation for demolition is unreasonable.</td>
</tr>
<tr>
<td>Protection of ancient buildings in Zhaji town</td>
<td>thought conflict of local people want to protect and cannot protect</td>
</tr>
</tbody>
</table>
2.3 Expert interview and discussion

In this step, a questionnaire is formed after expert interview and discussion. First, 15 employees about architectural heritage protection (mainly including experts, scholars and government employees) are organized to discuss the interest conflicts mentioned before. The results are shown in table 2. Then, according to the experts, deleting the indicators of “thought conflict of local people want to protect and cannot protect”. The author adopts a 5-point likert scale and a questionnaire index system is formed. Among them, the index is very important is expressed by 5 points, and 4 points means important, 3 points means general, 2 points means not important, 1 points means very unimportant.

2.4 Review the semantic and complete the questionnaire

In this phase, the teacher, 10 doctoral candidates and postgraduates are invited to review the questionnaire indicators in order to eliminate the ambiguity of initial indicators, and at the last, an investigation questionnaire about the conflicts of stakeholders’ interests is formed.

<table>
<thead>
<tr>
<th>Table 2 expert sheet of contradiction external performance of stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>code</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>IC1</td>
</tr>
<tr>
<td>IC2</td>
</tr>
<tr>
<td>IC3</td>
</tr>
<tr>
<td>IC4</td>
</tr>
<tr>
<td>IC5</td>
</tr>
<tr>
<td>IC6</td>
</tr>
<tr>
<td>IC7</td>
</tr>
<tr>
<td>IC8</td>
</tr>
</tbody>
</table>

Note: IC stands for interest contradiction in English.

3. Questionnaire distribution and recycling

A total of 193 questionnaires were distributed in this survey, among them there are 9 invalid
questionnaires, the recovery questionnaire was 137, a total of 128 valid questionnaires were collected, the effective response rate was 66%.

3.1 Analysis of survey results

Data analysis was carried out by using SPSS19.0 software, the results are shown in table 3.

<table>
<thead>
<tr>
<th>interests contradiction</th>
<th>mean</th>
<th>standard deviation</th>
<th>maximum value</th>
<th>minimum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC1</td>
<td>4.01</td>
<td>1.07</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>IC2</td>
<td>3.62</td>
<td>0.98</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>IC3</td>
<td>3.80</td>
<td>1.06</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>IC4</td>
<td>4.23</td>
<td>0.81</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>IC5</td>
<td>3.79</td>
<td>0.99</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>IC6</td>
<td>3.90</td>
<td>1.06</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>IC7</td>
<td>3.42</td>
<td>1.10</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

In order to make the magnitude of the interest conflicts more intuitive, according to the results above, the author ranks the interest contradictions between the stakeholders about architectural heritage protection, seeing figure 1.

From figure 1 it can be seen visually that the most selective is “the preservation of architectural heritage is for the sake of opening tourism and increase economic returns”, while “developers blindly pursue economic interests, but ignore social benefits” is ranked in the second place. The mean of both is above 4.00, and this shows the two indexes are the main conflicts during the procession of the preservation of architectural heritage.

It can be seen from above analysis that all the respondents believe “the development enterprises blindly pursue economic interests while ignoring social benefits in the process of urbanization”. Most of the respondents think “old city reconstruction makes the historical pattern of old cities badly damaged”. And many respondents insist that “the preservation of architectural heritage is to open tourism and increase economic benefits”. Then the author inducts, analyzes and summarizes the three contradictions, and comes to the conclusion that the conflicts between the stakeholders
are as follows: ① the contradictions between economic and social interests; ② the contradiction between urban renewal and respecting the historical pattern; ③ the contradiction between protecting architectural heritage and developing tourism; ④ the contradiction between the cost reduction and the maximization of the local government's pursuit of fiscal revenue.

4 Conclusion

Based on the analysis above, it can be seen that the contradictions between the stakeholders are important factors for conserving architectural heritage, only finding out the contradictions can we solve the problem which exist in the process of protecting architectural heritage.

Acknowledgment

Thanks very much for my doctoral tutor Professor Shen, he gave me great help and support during the writing of this paper. This research work is supported by the Humanities and social sciences research projects of Chongqing education committee, project number is”16SKGH195”；And this research work is also supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant Nos. “15AZD025” and “15BJY038”.

References


The rule of law index for land administration in China


Abstract: China has made significant development in the rule of law construction for land administration and has made a series of remarkable achievements. The legal system of land and resources is basically complete. However, the rule of law construction for land administration is still far from expectation. The solution to the gap requires scientific, systematic, quantitative and accurate evaluation of the state of the rule of law of the land and resources. This paper describes the construction method and process of the rule of law of land and resources index assessment model, aimed at providing the theoretical basis and method guidance for the evaluation of the rule of law of the local land and resources system by the Ministry of Land and Resources. The rule of law construction of land and resources is of great significance to promoting the rule of law construction in China comprehensively.

Keywords: Rule of law index; Land administration; Quantitative model; China.

1* Wang, H.
Corresponding author, School of Management Science and Engineering, Central University of Finance and Economics, China
E-mail: holy.wong@connect.polyu.hk

2 Wang, Z.F.
School of Management Science and Engineering, Central University of Finance and Economics, China

3 Chen, J.L.
School of Management Science and Engineering, Central University of Finance and Economics, China

4 Chen, J.H.
School of Management Science and Engineering, Central University of Finance and Economics, China

5 Guan, N.S.
School of Management Science and Engineering, Central University of Finance and Economics, China
1 Introduction

China has made significant development in the rule of law construction of land and resources and has made a series of remarkable achievements. The legal system of land and resources is basically complete. The degree of legalization of land and resources management enhances unceasingly. However, compared with the requirements "Construct the integration of government ruled by law, country ruled by law and society ruled by law" proposed by the Party Central Committee, the rule of law construction of land and resources is still far from perfect, which can be seen from the old system of administration according to law, the imperfect legal system, the fragmentation of work of administration by laws and so on. The solution to these problems requires scientific, systematic, quantitative and accurate evaluation of the state of the rule of law of the land and resources. By the method of index research, we can provide the rule of law construction of land and resources with clear and unified evaluation criteria, measure and evaluate the process of the rule of law construction of land and resources in an intuitive way, and promote the perfection of the rule of law of land and resources.

The rule of law construction of land and resources is of great significance to promoting the rule of law construction in China comprehensively. After more than 30 years of construction and development after the reform and opening up, we must answer the question that to what extent China’s rule of law of land and resources developed, but neither the theoretical nor the practical field can give an intuitive and accurate answer. This brings a series of obstacles to the rule of law construction of land and resources. The construction of the rule of law of land and resources index may fundamentally solve these problems.

The index is a statistical concept, usually referring to the relative indicator which reflects the changes of a social phenomenon in a certain period of time. Since the rise of the "social indexing movement" in the west in the 1960s, the index has been more widely used in the field of economics, sociology and political science, such as market open index, happiness index, corruption index, etc. (Zhang, 2001). The rule of law of land and resources index is a quantitative indicator which combines land and resources law theory, statistics theory and public management theory and reflects the state of the rule of law of land and resources through the data collection of the whole process of land and resources management, masses satisfaction investigation and professional assessment. This paper gives a detailed description of the construction method and process of the rule of law of land and resources index assessment model, aimed at providing the theoretical basis and method guidance for the evaluation of the rule of law of the local land and resources system by the Ministry of Land and Resources (or superior land administration department).

2 Related work

In 2005, the World Bank, in its "National Wealth Report", first proposed the concept of "rule of law index", defining it as a means of judging a person's willingness of observing laws and a degree of trust in the country's legal system (Lu, 2014). In the later period, as a quantitative assessment system of the level of rule of law, "rule of law index" were adopted and recognized by more and more countries and scholars. In 2007, the American Bar Association, the Pan Pacific Lawyers Association, the Pan American Bar Association organized the "World Justice Project",
and proposed that the rule of law index is a quantitative standard and an assessment system for judging and measuring the status and extent of the rule of law in a country. Since the birth of the rule of law index, its influence is in the process of expanding. In foreign countries, the rule of law index which was proposed by "World Justice Project" is widely approved as a representative. In China, Hong Kong launched a rule of law index that reflects the local rule of law status, and Yuhang of Hangzhou, Zhejiang, launched the rule of law index for its regional legal system construction.

2.1 The "World Justice Project" rule of law index

Since 2008, "World Justice Project" has held a number of "World Justice Forum", proposing that countries should continue to improve the "rule of law index" system, and use the assessment system as an important quantitative criterion in measuring rule of law status. The rule of law of the World Justice Project selected nine primary targets of "limited government, no corruption, order and security, basic rights, open government, compulsory law enforcement, access to civil trials, effective criminal justice, informal justice" and further decomposed into fifty-two secondary targets as a standard, and strive to comprehensively describe the national rule of law from multiple latitudes.

From the data sources, it mainly includes two sources: First, the use of "General Population Sampling (GPP)" by the senior professional companies, conducting a sample survey in 1000 interviewers in three cities in each country, every three years. The second is the use of "expert questionnaire (QRQ)" way, once a year, and experts, including experts and scholars from civil and commercial law, criminal law, labor law and public health and other areas (Meng, 2015). It is noteworthy that the "World Justice Project" published in 2011, the Chinese mainland will be in the scope of the rule of law index. The data are collected in three cities of Beijing, Shanghai and Guangzhou. From the point of view of its assessment method, there are too few research samples, lack of institutional investigation and other issues, leading to the lack of universality; its investigation did not fully consider the special stage of the construction of the rule of law in China and the people's understanding of the relevant content, the level of their own knowledge's impact on the assessment results, as a result, the accuracy and objectivity of the conclusions is difficult to guarantee.

2.2 The rule of law in Hong Kong

The purpose of the assessment of the rule of law in Hong Kong is to establish an indicator that can indicates the development of the rule of law in Hong Kong and to provide reliable information for improving the rule of law in Hong Kong, and one that can also serve as an indicator system for the development of the rule of law in Hong Kong and other societies. The system focuses on whether the government acts under the law and can it identify certain basic human rights and values. The rule of law in Hong Kong summarizes the rule of law into seven conditions: (1) the basic requirements of the law; (2) the government according to law; (3) no power is allowed; (4) equality before the law; (5) Fairly implement the law; (6) judicial justice can be accessible; (7) procedural justice (Dai, 2007). On the basis of seven conditions, it is refined into eighteen sub-conditions. Hong Kong's rule of law index based on the above conditions and sub-conditions, to collect the relevant can be quantified legal data and public subjective feelings’ data, assessed by the assessor analysis, and the final rule of law in Hong Kong score is 74.66 points (out of 100
points, 50 points), this score has been recognized by all sectors of Hong Kong. However, the assessment of the rule of law in Hong Kong has only been carried out this time, so far there is no follow-up plan, which makes the meaning and value of the assessment of the rule of law in Hong Kong greatly reduced, and lost the role of reference contrast.

### 2.3 The "Taiwan Public Governance Indicator System"

"Taiwan's public governance index system" has been published in the form of annual report from the beginning of 2009. The report was completed in 2008 in a way that the Taiwan "Executive Yuan Research and Development Assessment Committee" commissioned "Taiwan Public Governance Research Center" which set up in the same year to study. "Taiwan's public governance index system" is the research team based on the existing research and draws on the existing systems of major international organizations, including the Organization for Economic Cooperation and Development, the United Nations, APEC and the World Bank and other related indicators of public governance research, and finally came to seven first-level indicators, namely: the degree of rule of law, government functions, government responsiveness, transparency, prevention and control of corruption, the degree of responsibility and public participation.

In order to strengthen the construction of the rule of law government, to improve the people's confidence in the government and governance satisfaction, in 2011, "Taiwan's public governance indicators" was refined into 20 Secondary indicators on the basis of the seven first-level indicators, and then divided into 121 three indicators, each of the three indicators include intuitive evaluation and objective evaluation, points 0-10 grade scoring. The index system according to the nature of the data, can be divided into objective statistical data and subjective assessment of information. Objective indicators are taken from the region's political and economic statistics and international organization statistics; subjective indicators refer to completed foreign research reports, self-designed topics and expert interviews questionnaire. The expert questionnaires include experts in various fields, including 119 academics, 59 government officials, 39 industry executives, 34 civil society members (non-governmental organizations, media, etc.) in a total of 251 assessors.

### 2.4 The Yuhang rule of law index in Zhejiang, China

China's earliest release of the rule of law index is the "Yuhang rule of law index." On June 15, 2008, Yuhang District announced to the community 2007’s Yuhang rule of law index, the specific score of 71.6 points (out of 100 points). Yuhang rule of law index has been released since 2007, and in the following seven years, the rule of law specific score showing a trend of rising year by year. The emergence of the Yuhang rule of law index has achieved a breakthrough in the quantitative evaluation standards of the rule of law in the mainland of China from scratch, and it is a new exploration to promote democracy and the rule of law, and has made important contributions to promoting the progress of the rule of law in China (Qian, 2012).

Yuhang rule of law quantitative assessment’s object is the level of creating activities and development of the rule of law in Yuhang District, and it focuses on the construction of the rule of law and the maintenance of justice, taking standardizing public power and civil rights protection as the core, the leadership of the party as guarantee, and strive to improve Yuhang district economic, political, cultural and social fields of the rule of law level. The basic idea of Yuhang rule of law index design is to "design a rule of law index, establish four assessment levels, conduct nine satisfaction survey”, decompose the subject of the construction of Yuhang rule of law - "the
party complies with the law, the government acts in accordance with law, judicial justice, rights protection according to the law, the market norms and orderly, sound supervision system, improvement of democratic politics, improvement of the quality of people, social peace and harmony "- into twenty-seven main tasks, including seventy-seven assessment contents’ index system.

3 A Quantitative Evaluation Model for Rule of Law Index of Land Resources

Based on the domestic and foreign mainstream methods in the evaluation of the rule of law and the construction of the index system, this paper designs and constructs a quantitative evaluation model of the rule of law index of land resources to evaluate the rule of law of the provincial land resources system, using modern scientific methodology to understand and deal with the status quo and problems of the rule of law system evaluation of the land resources, measuring and evaluating the process of the land and resources rule of law construction in an intuitive way, to promote the improvement of land and resources law. In the process of building the model, basing on "the State Council on strengthening the construction of the rule of law government", "Ministry of Land and Resources on further promoting the administration of law and realizing the legalization of land and resources management” and other policies and regulations, a complete and realistic, feasible index system was build.

3.1 The Evaluation Index System

Combined the 16-character principle in Chinese "scientific legislation, strict law enforcement, fair justice, the whole people abide by the law," which was put forward on the 18th National Congress of the Communist Party of China, "comprehensively promote the implementation of the law according to law", "Opinions of the State Council on strengthening the construction of the rule of law," “Opinions of the Ministry of land and resources on further promoting the administration of law and realizing the legalization of land and resources management” and other documents requirements with the state quos of land and resources management, the rule of law of land and resources take the "legal legislation, administration according to law, fairness and justice, the government and citizens abide by the law" as the overall goal (MLR, 2011).

In the extraction of the key elements of the grading evaluation of land and resources, the provincial area is the evaluation scope, the key elements of the rule of law are excavated, the relationship between the key elements is studied. This paper chooses, inducts and summarizes the relevant contents of the rule of law of land and resources, and makes an important evaluation element through the refinement and quantification of the government's essential requirements, the use of scientific standards, the selection and identification of representative important evaluation elements. Which can reflect the general situation and characteristics of the rule of law work of land and resources, and make a comparative assessment of the progress of the land and resources rule of the law construction and the indicators in order to make an objective and reasonable evaluation.

After the interpretation and the decomposition of the overall objectives of the rule of law, the three
indicators system will be established with composition of the assessment objectives, the main task and the specific assessment. Among them, the primary indicators - the assessment objectives include four aspects: scientific legislation, administration according to law, government compliance and civil compliance, two, three level indicators - the main task and the specific assessment will be based on the overall goal of the rule of law interpretation.

Considering the evaluation of the main body, evaluation process links, evaluation methods and the concept of input multi-dimensional hierarchical structure. Avoiding the traditional superior evaluation model, evaluation of the main diversification, the introduction of innovative methods of development, both quantitative and qualitative comprehensive evaluation. Refining the evaluation process link, from the value, purpose, means, results, policy perspective integration of the results of integrated evaluation, focusing on the effectiveness, efficiency and feasibility of the rule of law for land and resources in regulating the balance and symmetry of interests. Constructing three-dimensional land resources rule of law index model: the "legal system, administration according to the law, government law-abiding, civil law-abiding" constitute the index connotation dimension; the "land resources management department, legal experts, the general public" constitute the subject of evaluation dimension; “satisfied, partly satisfied, basically satisfied, dissatisfied” compose of the legal performance dimension, as shown in Figure 1 below.

Figure 1. The evaluation system of rule of law index for land administration

The main frame and key elements of the index system which is composed of general idea, main aspects, composing factors of summarizing and construction index system are shown in Table 1 below (Only part of indicators are presented as an example due to the page limit). This index of the rule of law evaluation index system is used for the province (autonomous regions and municipalities) land resources legal performance evaluation, the following table shows a specific three-tier index system, in which one level indicators 4, two indicators 20, three indicators 68.
<table>
<thead>
<tr>
<th>first-level index</th>
<th>second-level index</th>
<th>content of assessment (third-level index)</th>
<th>assessment basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>regulation-making system</td>
<td>①</td>
<td>whether to cooperate with making relevant regulations and rules of land and resources management</td>
<td>The legislative plan reported file</td>
</tr>
<tr>
<td>normative documents management</td>
<td>②</td>
<td>whether to establish the mechanism that make mature normative documents rise to the rules in a timely manner</td>
<td>relevant records</td>
</tr>
<tr>
<td>legal system</td>
<td>①</td>
<td>whether to make normative documents according to statutory limits and procedures</td>
<td>relevant normative documents</td>
</tr>
<tr>
<td></td>
<td>②</td>
<td>whether to solicit comments in public about the important normative documents</td>
<td>solicit comments in public method</td>
</tr>
<tr>
<td></td>
<td>③</td>
<td>whether to establish the normative documents validity system</td>
<td>relevant regulations</td>
</tr>
<tr>
<td></td>
<td>④</td>
<td>whether to establish a normative document filing system</td>
<td>relevant regulations</td>
</tr>
<tr>
<td></td>
<td>⑤</td>
<td>whether to perfect the normative document legitimacy censorship</td>
<td>censorship and clean up regulations</td>
</tr>
<tr>
<td></td>
<td>⑥</td>
<td>whether to establish the “three unified” system including unified registration, unified numbering and unified release of the normative documents</td>
<td>relevant regulations</td>
</tr>
<tr>
<td>post-evaluation system</td>
<td>①</td>
<td>whether to establish comprehensive regulatory and normative post-evaluation system should be established</td>
<td>relevant regulations</td>
</tr>
<tr>
<td></td>
<td>②</td>
<td>whether to put evaluate performance reports as the main basis for amending or abolishing regulations, perfecting supporting systems and improving administrative law enforcement</td>
<td>relevant records</td>
</tr>
<tr>
<td></td>
<td>③</td>
<td>whether to establish the auditing administrative litigation system</td>
<td>relevant regulations</td>
</tr>
</tbody>
</table>
3.2 The Evaluation Methods and Steps

After completing the initial construction of the index system of the rule of law index, we will adopt Delphi method combined with AHP (analytic hierarchy process) to modify and improve the index system. Delphi method adopts expert group members' prediction opinion by back-to-back communication, after several rounds of consultation, the expert group's forecast tends to focus, finally make a forecast conclusion consistent with the predictions of the future development trend of the market. Delphi law, also known as expert opinion law or expert correspondence investigation method, is based on the system procedures, using of anonymous comments, that is, members of the team must not discuss with each other, no horizontal links, only with the investigators, and Repeatedly filling out the questionnaire, collecting consensus of the people who are asked to fill in a questionnaire and collect the opinions of each parties and those can be used to build a team communication process, deal with complex task problems management techniques.

Delphi method will be used here will be combined with AHP method, go through the two stages of rule of law index system changing and index weight setting. In these two stages, 15 to 20 legal experts and scholars will be involved in the evaluation and revision of the indicator system.

(1) Stage one

In the first phase, through the preliminary design of the index system, we will design an exports questionnaire about the importance of the indicator based on each indicator and related contents. In the first phase of the questionnaire survey, the importance of the index is analyzed by the expert scoring for each index, and according to expert scoring and comparison of professional threshold settings, the index system indicators will be deleted, optimizing the index system, to make it more systematic and scientific. At the same time in the questionnaire there will be new target options set at the end. New indicators will be added to the index system to complete the entire index system. The main style of the first phase of the questionnaire as Table 2 shown below:

<table>
<thead>
<tr>
<th>Indicator Name</th>
<th>Indicator Description</th>
<th>Description</th>
<th>Score Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicators A</td>
<td>A Related content</td>
<td>1-5 points</td>
<td>below the threshold to remove the target; above the threshold to retain indicators</td>
</tr>
</tbody>
</table>

(2) Stage two

The index weight assignment in the index system in stage two mainly divides each index by Delphi method and the AHP analytic hierarchy process mentioned above. The questionnaires involved in stage 2 are mainly set by the inverse matrix in AHP analytic hierarchy process. By comparing the relative importance between the first-level indicators and the relative importance of the secondary indicators in each level, the weight of each indicator is determined and a reference is made for the assignment of indicators. Among them, indicators in the stage two indicator system is modified on the base of the stage one. Here by combining the different assignments of different
experts, each indicator set relative scientific and reasonable weight assignment. The main form of the questionnaire used is shown as Table 3.

Table 3. Questionnaire Example 2

<table>
<thead>
<tr>
<th>Indicator</th>
<th>relative importance (in the range of 1-10)</th>
<th>relative index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator A</td>
<td>A or 1/a</td>
<td>Indicator B</td>
</tr>
<tr>
<td>Indicator A</td>
<td>B or 1/b</td>
<td>Indicator C</td>
</tr>
<tr>
<td>Indicator B</td>
<td>C or 1/c</td>
<td>Indicator C</td>
</tr>
</tbody>
</table>

(3) Public satisfaction survey

Provincial people's land and resources rule of law public satisfaction survey using a questionnaire survey and field interviews combined approach. Questionnaires were conducted in two ways: postal / online and by field handout. Field interviews are conducted by the provincial supervisory assessment team, and the selection of the interviewees is based on the selection of the respondents. The main contents of the investigation include the enterprises, institutes and related people to the land and resources; the overall impression of the situation of land and resources; the satisfaction degree over completeness degree of the relevant laws and regulations on land and resources, the degree of decision-making democratization, the degree of information disclosure, the process of administrative law enforcement, the normalization of administrative law enforcement, the punishment of illegal acts, the efficiency of the work, the degree of public participation and so on.

4 Conclusion

To answer the question that to what extent China’s rule of law of land and resources developed, this paper investigates how to build an evaluation system i.e. rule of law index for land administration in China. The rule of law index for land administration is a set of quantitative indicators which combines land and resources law theory, statistics theory and public management theory and reflects the state of the rule of law of land and resources through the data collection of the whole process of land and resources management, masses satisfaction investigation and professional assessment. By conducting this research, we can provide the rule of law construction of land and resources with clear and unified evaluation criteria, measure and evaluate the process of the rule of law construction of land and resources in an intuitive way, and promote the perfection of the rule of law of land and resources.

Acknowledgements

The authors wish to express their sincere gratitude to the Real Estate Registration Center (Law Center) of MLR in China and the NSFC (No. 71403304, 71373295, 71402200, 71473283) for funding support for the research project on which this paper is based.

References


Energy Efficiency Framework for Malaysia’s Green Office
Building Occupants

Ohueri, C.C.¹, Enegbuma, W.I.¹*, Ekambaram, P.², Wong, M.N.H³ and Kuok, K.K.³

Abstract: Construction experts have a growing concern about occupants’ behavioural impact on green office buildings, especially in tropical countries like Malaysia. Previous studies have affirmed that green office buildings in Malaysia consume substantial amount of energy due to default conditions, institutional frameworks, organizational culture, peer pressure, lack of information, behaviour discrepancies among the occupants, and more. Although the government and green building construction stakeholders have stressed the need to consider occupant’s factor during planning, design, operations and decision-making of green office buildings, there have been limited research on ways of developing a cradle to grave energy efficiency practices for green office building occupants in Malaysia. The aim of this research is to develop an energy efficiency framework practices for green office building occupants, by integrating technology, organization policy, and occupant behavioural strategies. A mixed method approach was used to collect data from fifty-two green office building occupants and two construction professionals in Malaysia, using questionnaire and interview. The study adopted purposive sampling technique in selecting the respondents’ for this research. The data from questionnaire and interview was analysed using SPSS software (version 22) and thematic content analysis respectively. The findings highlighted the significant strategies for reducing occupants’ energy use in Malaysia’s green office buildings and they include; occupants oriented design and construction, setting defined energy target, distinguished use of human and material resources, development of an energy efficiency action plan, implementation of the plan, and measurement and evaluation of implemented plan. Based on the findings, an energy efficiency framework practices was developed to guide occupants in reducing energy consumption of green office buildings in Malaysia. However, the developed framework needs to be validated to ascertain its workability in the green office building context.

Keywords: Framework, Practices, Energy Efficiency, Green Office Buildings, Occupants’.
1 Introduction

Green buildings are developed to meet the policies to reduce greenhouse gas emission, construction, operation and maintenance cost, energy use, and more. Nevertheless, many researchers have argued that green office buildings are not meeting up to these policies especially in terms of energy efficiency performance. In a study conducted by [1] to compare the actual energy consumption to predicted energy performance, he postulated that the actual energy consumed by green office buildings is always different from that predicted at design and construction stage. Scholars have attributed this performance gap to several factors such as design, construction, operation factors, and occupants’ comfort criteria, etc. According to [2], the major cause of high energy consumption in green buildings is due to lack of knowledge on the effect of various energy saving measures, especially because the influence of occupants behaviour and lifestyle has not been studied to the same extent as the technical aspects.

Occupant behaviour is among the most significant driving factors that affect energy performance of green buildings [3]. The green office building occupants are responsible for regulating the heating and cooling set-point, the ventilation rate, the window blind position, turning on/off or dimming lights, turning on/off equipment, and setting indoor thermal, acoustic, and visual comfort criteria. These occupants’ criteria choice are driven by several factors as suggested by [4]. However, the full potential of green office buildings cannot be achieved without accompanying behavioural and institutional change [5], [6], opined that a holistic approach that integrates technology, policy, and occupants based strategy is paramount to enhance occupants’ behaviour towards efficient energy use in green office buildings.

Behavioural discrepancies among the occupants of green office buildings is of a global concern. [5], proposed the use of the so-called safety factor as part of the design process to minimizing the influence of occupant behaviour on the building’s energy consumption in US. In Denmark, the impact of occupants on energy consumption have been reduced drastically using the stochastic models [2], [7], investigated the perception of occupants of eight green office buildings located in the Melbourne Central Business District (Melbourne CBD) Australia. Their study identified a wide gap in occupants’ satisfaction criteria, which is the major cause of variation in energy consumption of buildings with the same function but different occupants.

2 Malaysia Green Office Buildings

The concept of green office building is an emerging market in Malaysia and currently there are still few green office buildings in Malaysia. In June 2017, the Green Building Index (GBI) report summarized that a total of 300 green buildings were certified in Malaysia, 199 of them are Non Residential New Buildings (NRNCB) comprising mostly of commercial building especially office buildings. GBI is the most prominent green building rating tool in Malaysia [8]. According to [9], the GBI tool was developed to evaluate the building design but not how energy is managed at the operational and maintenance phase of the green building. In a bid to achieve a green nation by year 2020, the Work Department Malaysia (PWD), the Ministry of Energy, and other stakeholders have established practices that promote the adoption of energy efficiency (EE) and promotion of green technology in Malaysia [10][9]. In addition, several scholars; [10][9] and many others have conducted research on how occupants behaviour affect energy performance of both conventional and green
buildings in Malaysia.

Amidst all these efforts and proposed strategies, the energy consumption in Malaysia still remains high while energy reduction rate remains low. The International Energy Agency (IEA) reported that the carbon emission will increase by 68.86% in the year 2020[11]. In 2017, commercial buildings achieved only 0.694 kg reduction in CO2[8], probably due to no energy-efficient performance guidelines for Malaysia green office building occupants[9]. However, critics have argued that the reduction rate is not adequate to achieve the vision 2020 energy reduction by 40%. According to[12], green office buildings consume a significant amount of energy due to comfort criteria of personal choice, lack of information, access to controls, poor management policies, and lack of maintenance among the occupants.[10], stressed the need for more involvement on human aspect to achieve the objective of green buildings in Malaysia. Occupants influence on the energy consumption is relatively unexplored and experts suggest the establishment of multidisciplinary team of specialist to establish a comprehensive green building occupant’s guide.

Hence, this study aims to develop a comprehensive occupant’s energy efficiency framework for reducing energy use of green office buildings in Malaysia. The method adopted in achieving the aforementioned research objectives is discussed below.

3 Research Method

This research, adopted a descriptive study method (literature review and mixed method empirical research).[13], stipulated that mixed method research is important because it allows the use of two different research instruments to further enrich the research findings. A closed ended questionnaire and a semi structured interview was used to survey the population (green office building occupants and construction professionals in Malaysia) for this research. From the population, a sample of fifty (50) green office building occupants, two (2) construction professionals, and two (2) organization top management were selected using purposive sampling technique. Purposive sampling technique was used in this research because the researcher could not ascertain the total number of construction professionals and occupants of Malaysia green office buildings. Thus, samples were selected at random provided that they have the required information needed to actualize the objective of this research. According to[14], purposive sampling is a sampling technique adopted on the basis of availability and accessibility of respondents. Furthermore, this technique is convenient, time-saving and cost-effective.

4 Data Analysis

Data from the questionnaire was analysed via SPSS software version 22 while the interview data was analysed using thematic content analysis. The outcome of the mixed method research was triangulated using constant comparative method for a more cohesive discussion, which led to the establishment of an energy efficiency framework that will guide occupants in reducing energy use in green office buildings in Malaysia.

4.1 Questionnaire Analysis

The questionnaire survey comprised of two (2) sections.
Section A: It was used to sort the background information of the respondents (green office building occupants). According to the analysis, 32 of the respondents are male while 18 of them are female. 60% of the respondents have worked for more than 10 years while 40% have worked below 10 years. Also the nature of the job of the respondents were investigated. 20% of them work under the administrative section, 20% worked under technical department, 10% of them are desk top clerk, 25% are under the management section, and 25% worked under various other sections not specified.

Section B: This section of the questionnaire was used to investigate how occupants adjust building features in their workspace. The analysis of this survey is shown in Figure 1 & 2 below. Figure 1 shows how occupants react to the green building features in their office. According to the analysis, 37% of the occupants’ regularly adjusted the heating and cooling units based on their various comfort criteria. However, 15% of the occupants could not operate any of the green building features.

![Figure 1](image1)

**Figure 1.** How occupants adjust building features in their workspace

**Figure 2.** Behaviours that affect energy use of green office buildings in Malaysia

Thus, it can be concluded that occupants operate these building features to suit their personal comfort without considering the amount of energy being consumed.\(^{[15]}\) reported in their study that the regular adjustment of green building features is the major cause of high energy consumption in green buildings. This is also in line with\(^{[10]}\) statement that green building occupant’s exhibits behaviour that increased energy use, thereby compromising the design intent for a low energy. Their study suggested that strategies such as continuous education, technology, energy conservation planning workshop, and social awareness campaigns influence occupants’ behavioural discrepancies in the use of green buildings features.

Figure 2 above investigated the specific behaviours of the various occupants that directly or indirectly affects energy use in green office buildings. The bar chart indicates the specific activities of the occupants varies and that is the major reason why buildings of the same capacity and functions have different energy consumption rates. Although survey indicated that several green office building occupants have the attitude of always turning off the light and equipment, some of the occupants never bordered to control these appliances and their attitude contributed to the high energy consumption of their green office buildings.

Hence, researchers like\(^{[16]}\) opined that adequate awareness and training should be carried out
regularly to enable occupants understand the effect of their behaviour towards energy consumption. Furthermore, it is advised that both organization management and its workers should have a combined role to play towards energy savings of green office buildings in Malaysia. However, for a detailed inquiry, the construction professionals, top management and policy makers in the organization were interviewed to evaluate the best strategies for enhancing occupants’ behaviour towards reduction of energy consumption of green office buildings in Malaysia.

4.2 Interview Analysis

Four people were interviewed in this research. Two construction consultants (Architect and Mechanical Engineer), two top management of the green office building in Malaysia. The interview investigated occupants’ behaviour factor that causes high energy consumption of green office buildings in Malaysia, the factors that hinders organization energy reduction policies in Malaysia’s green office buildings, and strategies that can guide occupants to reduce energy use in Malaysia’s green office buildings. The interview session was recorded using a recording device, and then transcribed via thematic content analysis. Through thematic content analysis, the transcripts were analysed in order to identify the themes within them. After identifying the themes, the examples of those themes are gathered throughout the transcript, so as to address the research objectives. The gathered themes are tabulated below.

<table>
<thead>
<tr>
<th>Interviewee 1 (Architect)</th>
<th>What occupants’ behaviours cause high energy use of Malaysia’s green office building?</th>
<th>What hinders company energy reduction policies in Malaysia’s green office buildings?</th>
<th>What strategies that can guide occupants to reduce energy use in Malaysia’s green office buildings?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Occupants choice of comfort criteria, Occupants lack of energy efficiency/ sustainability orientation</td>
<td>Non adherence to organizational energy reduction policies, lack of energy efficiency guidelines,</td>
<td>Integrated design, leadership principle, commitment on the sides of occupants’ and organizations’ management, development of action plans,</td>
</tr>
<tr>
<td>Interviewee 2 (Mechanical Engineer)</td>
<td>Lack of training among occupants on use of electrical appliances, occupants’ unpredicted behaviour.</td>
<td>Method of building design and construction, lack of monitoring, lack of implementation, poor management,</td>
<td>Information and feedback strategy, energy management system (EMS) to track energy consumption, evaluation and monitoring of action plan,</td>
</tr>
<tr>
<td>Interviewee 3 (Organization’s Management)</td>
<td>Occupants lack of orientation, occupants nonchalant attitude towards energy savings,</td>
<td>Poor information on organization energy efficiency policies, non-replacement of faulty equipment, bogus policies,</td>
<td>Continuous change concept, regular workshop on energy efficiency, measurement and evaluation of energy use in green office buildings</td>
</tr>
<tr>
<td>Interviewee 4 (Organization’s Management)</td>
<td>Lack of energy efficiency targets by occupants and organization, occupants behavioural discrepancy</td>
<td>Variation in occupants energy use, lack of training, lack of occupants detailed energy guide</td>
<td>Adherence to organizational targets, hand over of necessary building information to the building occupants</td>
</tr>
</tbody>
</table>

Table 1. Thematic content analysis of interview data
The table above shows the analysis of the interview conducted in this study. According to all the interviewees, occupant’s behavioural discrepancies such as energy efficiency orientation, poor training, lack of awareness, selfish choice of comfort criteria, and more, are significant factor that leads to high energy consumption of green office buildings in Malaysia. Also, occupants’ behaviour, lack of information, orientation, and lack of implementation were the major factors affecting organization’s energy efficiency policies. The construction professional stressed on the need to involve all stakeholders during the design and construction stage of green building. Additionally, they suggested that building occupants should be provided with comprehensive information on green elements used in green building construction. Finally, they interviewees suggested that integrated green building design, development of energy savings action plans, implementation of the plans, and monitoring and evaluation of energy efficiency behaviour of occupants are the key strategies for reducing occupants’ energy use in Malaysia’s green office buildings. This corresponds with [16], who opined that energy use control is a collective effort that should be followed continuously.

4.3 Triangulation of Result

The analysis of both research instruments compliments with each other. Data from questionnaire shows that occupants’ behaviour varies in regard to energy use and this behavioural variation is a major issue in energy performance of green office buildings in Malaysia. The interviewees also identified that occupants’ attitude is a major factor that leads to high energy consumption of green office buildings in Malaysia. So they hammered on the need to inform and orientate occupants to change their behaviour on the use of green buildings features. Similar to [10] study, the respondents agreed that integrating technology, organizations policy, and occupants’ behavioural strategy should be adopted to reduce energy consumption of green office buildings in Malaysia. Based on this conclusion, a framework which incorporates occupants’ factors, technical factor, and organizational policy factor is developed.

5 Developed Energy Efficiency Framework

The end point of this research is the developed comprehensive energy efficiency framework which will guide Malaysia’s green office building occupants to reduce their energy use. The framework is shown in Figure 3 below. The framework insinuates that the necessary building information should be handed over to the building occupants once the building is completed. The framework highlights the need for determination and identification of energy conservation goals. It also suggests the use of outstanding human resources, and the development, implementation, and evaluation of energy conservation action plan. In other words, this framework suggests the integration of technology, organization policy, and occupants’ behavioural strategy for reduction of energy use in Malaysia’s green office buildings. This is in line with the opinions of several researchers; [10][15][16], who opined that a holistic approach which provides a cradle to grave energy efficiency practices for green office building occupants should be developed. This framework will be beneficial to Malaysia by reducing of energy consumption of green office buildings in Malaysia, improving social and environmental sustainability of Malaysia, and training and educating green building users on the collective need for the actualization of sustainable development goals.
6 Conclusion

Literature studies reiterated that green office buildings in Malaysia consume substantial amount of energy due to default conditions, behavioural discrepancies among the occupants, organizational culture, and poor decision during building design [10]. Therefore, this study investigated how occupants interact with their green building features, and strategies for improving occupant behavioural discrepancies in green office buildings in Malaysia. However, a mixed method research was conducted to survey the respondents. SPSS software and thematic content analysis were used to analyse the questionnaire and interview data respectively. The result was discussed via constant comparative method, which enabled us to highlight strategies for reducing energy consumption of green office buildings in Malaysia. They include; occupants oriented design and construction, setting defined energy targets, establishing distinguished intervention team, development of an action plan, implementation of the Plan, and measurement and evaluation of implemented plan. As a result of this, an energy efficiency framework that will guide occupants to reduce energy use in Malaysia green office buildings was developed. The framework has the potential of eliminating to the minimum, energy consumption of green office buildings in Malaysia because it encompasses technology, organization policy, and occupant behavioural strategies that are paramount for enhanced energy performance of green office buildings in Malaysia. However, further study needs to be conducted so as to validate the developed framework and also expand the scope of the research.

Figure 3. Energy Efficiency Framework Practices for Malaysia’s Green Office Building Occupants
References


Exposition of Conceptual Construction Cost: a Review of Modelling Techniques

Idowu, O.S.1*, Lam, K.C.2

Abstract: Conceptual cost is critical for providing a cost framework for project execution, and the outcome of the cost framework determines the viability of a project. In the last 50 years, many models for early prediction of cost or price of construction projects have been developed and classified based on criteria such as modelling technique. The existing classification system for conceptual cost requires a reappraisal. This is to ensure that the classification system is relevant as new conceptual cost models are developed. A systematic review of modelling techniques for early prediction of cost or price of construction projects is the aim of the current work. Compilation of various early construction cost and price prediction techniques was carried out by reviewing the literature. In the review process, it was observed that conceptual cost models could be classified as either, mathematical, empirical, simulation or hybrid models. A revised classification system is proposed for grouping conceptual cost models based on model principle, function and implementation. The review provides an update on conceptual cost models as an addition to the existing knowledge base of cost modelling in the architecture, engineering and construction industry.

Keywords: Model classification; Cost modelling; Modelling techniques; Conceptual cost.

1* Idowu, O.S.
Corresponding author, Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong, SAR
E-mail: osidowu2-c.@my.cityu.edu.hk

2 Lam, K.C.
Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong SAR
1 Introduction

The certainty of construction cost at the conception stage of construction projects is important to the client (private owners, investors, corporate bodies and institutions), and construction professionals, particularly cost engineers and quantity surveyors\textsuperscript{[1–3]}. Attempts to model cost of construction projects at early pre-design stage have produced various results using different modelling techniques. Researchers hold different views on conceptual cost. The argument is this, should conceptual cost be treated as a probabilistic or deterministic concept? Some researchers\textsuperscript{[4,5]} argued that conceptual cost could be treated as a judgemental concept. The arguments appear to have led to the modelling of conceptual cost using several modelling techniques with varying degree of accuracy, adequacy and relevance.

In the face of expanding knowledge in conceptual cost modelling, existing classification systems such as traditional and new-wave models might become inadequate in the future. Therefore, this paper aims to systematically review the modelling techniques used for conceptual cost modelling. A redefined classification system based on model principle, function and implementation is proposed in this paper.

2 Research Method

The methodological framework for the review process is as shown in Figure 1. A review of titles and abstracts of publication in two scientific databases (Scopus and Google Scholar) was carried out. Titles, abstracts and keywords of papers and articles having combinations of keywords such as cost, modelling, model, methodology, accuracy, forecasting, construction, preliminary, early, prediction, projects, building and methods were selected for a detailed content analysis. Subsequently, detailed content analysis of the selected papers and articles was carried out. The process was useful as it provided a good source of literature for the review. Articles that were relevant to early cost prediction or forecasting techniques were identified and selected for grouping and classification. Papers and articles that are not directly related to the aim of the review were excluded from the grouping and classification process; nonetheless, they served as a useful guide and a source of rich literature. Books on cost modelling were also reviewed. The grouping and classification of modelling techniques for predicting or forecasting early cost of construction were based on the modelling principles, functions and implementation of the models.

Figure 1. Methodological framework for systematic review
3 Conceptual cost modelling techniques

Modelling can be viewed as a process of imitating or reproducing real and observed situation or phenomena based on given input[6]; or the process of representing something designed for a specific purpose[7]. In the literature, several techniques have been employed to model early pre-design cost estimates. Reference 8 documents a list of methods that have been used to predict or forecast cost of construction at early design stage. The methods include: conference, financial, superficial, superficial perimeter, cube, storey-enclosure, approximate quantities, elemental estimating, factor estimating, and exponent estimating. Reference 9 in a paper “An agenda for cost modelling research” tried to set a direction for cost modelling. A detailed section of the work was on “descriptive primitives”. Reference 9 proposed a formal basis for classifying alternative approaches to cost modelling. Nine descriptive primitive headings were proposed as follows: relevance; units; cost/price; approach; time-point; model; techniques; assumptions and lastly uncertainty. Particular interest is directed to the ten techniques identified by Reference 9 in this paper. The ten techniques are: dynamic programming, expert systems, functional dependency, linear programming, manual, Monte-Carlo simulation, networks, parametric modelling, probability analysis and lastly regression analysis. To date, several conceptual models make use of one or a combination (Hybrid) of the mentioned techniques with slight variations.

The techniques used for cost modelling in previous research include time series technique[5,10–14], mathematical technique[15,16], linear regression[17,18], neural networks[17,19,20], Monte-Carlo simulation[21], case-based reasoning (CBR)[22,23], fuzzy regression[24], computer modelling[25], program evaluation and review technique (PERT)[26]. Hybrid techniques includes: range estimating and probabilistic scheduling also called multiple simulation analysis technique[18,26], regression analysis, neural network and case-based reasoning[27], fuzzy and neural network technique[28–30]. Recent studies have focused on the use of artificial neural networks (ANN), CBR and other machine learning techniques[17,20,31]. Such trend could be attributed to the increase in computational power of modern computers and the ability to apply machine learning techniques to huge amount of data.

Project costs have also been modelled as either a “deterministic value” or an “Uncertain variable”[15]. The mathematical model of Reference 15 did not consider the effect of variations during contract. Also, the model assumed that cash flow projections are known, making it unsuitable for early prediction of cost construction cost. Time series models derive strengths from historical facts (major source of data) and the models are very important where there is a connection between the past, the present, and the future[4]. But where there is no link between the past, present, and future, or where extrapolation cannot be carried out to forecast the future, the models become inadequate. The inherent inadequacy of time series models can be seen when there are changes in construction methodology or material usage for which there are no historical cost data for extrapolating into the future[32].

4 Conceptual cost models

Conceptual cost models are models that do not require detailed drawings for forecasting or predicting the cost of a project. Details such as use of building, type of building, location, gross floor area, number of floors, height of building, procurement route are available for decision making on conceptual cost. Nevertheless, the quantity and quality of information available is limited and project scope is not finalized[17,29,33]. Hence, the uncertainty around the accuracy and adequacy of conceptual cost has been a major point of discussion in cost modelling research. Conceptual cost models that are frequently mentioned in the literature includes: cube, storey enclosure, regression, superficial and unit models[8,16,34]. The functional representation of some conceptual cost models is as shown in Table 1. The cube, storey enclosure, approximate estimate and superficial models require sketch design, else they are of limited use. On the other hand, other models such as regression and unit models do not require sketch design, but rely heavily on historical data for reliable modelling of conceptual cost.
Table 1. Functional representation of some conceptual cost models

<table>
<thead>
<tr>
<th>Model</th>
<th>Functional representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cube</td>
<td>( C_o = \frac{C_n}{V_o} \times V_n )</td>
</tr>
<tr>
<td>Superficial area</td>
<td>( C_o = \frac{C_n}{A_o} \times A_n )</td>
</tr>
<tr>
<td>Unit</td>
<td>( C_o = \frac{C_n}{U_o} \times U_n )</td>
</tr>
<tr>
<td>Storey enclosure</td>
<td>( P = \left( \sum_{i=0}^{n} (2 + 0.15s_i) f_i + \sum_{i=0}^{n} p_i s_i + 2 \sum_{j=0}^{m} f_j + 2.5 \sum_{j=0}^{m} f_j s_j + r \right) R )</td>
</tr>
<tr>
<td>Approximate estimate</td>
<td>( C = \sum_{j=1}^{k} q_j \left( mur_j + lur_j + eur_j + s_j \right) )</td>
</tr>
<tr>
<td>Case based reasoning (CBR)</td>
<td>( PS = \left( \frac{\sum_{i=1}^{n} f(N_i, S_i)}{\sum_{i=1}^{n} w_j} \right) \times 100(%) )</td>
</tr>
<tr>
<td>(percentage similarity function)</td>
<td></td>
</tr>
<tr>
<td>Monte-Carlo simulation</td>
<td>( E(\hat{y}) = \frac{1}{N} \sum_{j=1}^{N} f(x_j) )</td>
</tr>
<tr>
<td>Linear regression</td>
<td>( \hat{y} = \beta_0 + \sum_{j=1}^{p} x_j \beta_j )</td>
</tr>
<tr>
<td>Artificial neural network</td>
<td>( \hat{y} = \phi \left( \sum_{j=1}^{p} x_j w_j + b \right) )</td>
</tr>
<tr>
<td>Support vector machine</td>
<td>( \hat{y} = \sum_{i=1}^{n} (x_i - \alpha_i^j) k(x_i, x) + b )</td>
</tr>
</tbody>
</table>

C\(_o\): cost of new project. C\(_o\): cost of similar and existing project. V\(_o\): volume of similar and existing project. A\(_o\): area of similar and existing project. A\(_o\): area of new project. U\(_o\): number of functional attribute of similar and existing project. U\(_n\): number of expected functional attribute of new project. P: forecasted price. R: unit rate. f: floor area at \( i^{th} \) floor above ground level. \( f_j \): floor area at \( j^{th} \) floor below ground level. \( p_i \): perimeter of the external wall at \( i^{th} \) floor above ground level. \( s_i \): storey height of \( i^{th} \) floor above ground level. \( n \): total number of storeys above ground level. \( m \): total number of storeys below ground level. \( f_j \): perimeter of the external wall at \( j^{th} \) floor below ground level. \( p_j \): perimeter of the external wall at \( j^{th} \) floor below ground level. \( s_j \): storey height of \( j^{th} \) floor below ground level. \( r \): roof area. C: cost of project. q: quantity of measured item. mur: material unit rate. lur: personnel unit rate. eur: equipment unit rate. s: lump sum. PS: percentage similarity. N: new case. S: stored case. w\(_j\): importance weight of the \( j^{th} \) variable. \( \hat{y} \): response variable. x: predictor variable. \( \beta \) beta coefficient. \( \phi \): mapping function. b: Bias. \( \alpha_{i} \), \( \alpha_{i}^j \): Lagrange multipliers. k\((x, s)\): positive kernel function

5 Findings and discussions

Conceptual cost models have been classified by Reference 8 and Reference 9 as: traditional models; new wave or new generation models; statistical models; knowledge based models; resource or process based models; deterministic models; and stochastic models. Reference 4 also mentioned that forecasting models can be classified as econometric models, time-series models and judgmental models. Based on the review of the existing conceptual cost models, a clear pattern was found to exists that can be used to reclassify conceptual cost models based on function, principle and implementation. Conceptual cost models are generally developed based on useful elements and the functional relations of the elements for a particular purpose\(^7\). Table 2 shows the proposed grouping and classification of various conceptual cost models and corresponding modelling techniques. The proposed classes of conceptual cost models are mathematical, empirical and simulation models. Classifying hybrid models separately was considered unnecessary. Hybrid models can be a result of the combination of various model which have been identified. For instance, the Refined James Storey Enclosure (RJSE) model (a hybrid model) of Reference 16 was
developed using the original JSE model (a mathematical model) and forward/backward stepwise regression model (an empirical model).

In this paper, models constructed on mathematical principles and for which collection of data to study relationships between variables is not required are classified as mathematical models. Model attributes are defined in terms of mathematical functions and notations. For example, the gross floor area when used in a mathematical model is considered a function, but is considered a variable when used in an empirical model.

Models that rely on observable data before they can be constructed and applied are defined as empirical models. Empirical models require that data be collected according to specific rules to eliminate bias, also the way and manner data are to be analyzed are expected to conform to good methodological framework. Machine learning (Artificial intelligence) and statistics are common techniques employed in constructing empirical models. A general methodological framework for empirical models is as follows: (1) Collect data; (2) observe the key attributes of the data; and (3) predict or provide solutions based on the observed attributes of data.

A key feature of simulation models is the probability distribution function. Unlike mathematical and empirical models. Simulation models rely on parametric distribution. The bell-shaped normal distribution is the most widely used distribution pattern used in simulation models.

Table 2. Proposed classification of conceptual cost modelling techniques

<table>
<thead>
<tr>
<th>Model class</th>
<th>Model name</th>
<th>Function</th>
<th>Implementation technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical</td>
<td>James Storey-enclosure</td>
<td>Shape</td>
<td>Algebraic equations</td>
</tr>
<tr>
<td></td>
<td>Cube</td>
<td>Volume</td>
<td>Algebraic equations</td>
</tr>
<tr>
<td></td>
<td>Unit</td>
<td>Unit</td>
<td>Algebraic equations</td>
</tr>
<tr>
<td></td>
<td>Superficial</td>
<td>Area</td>
<td>Algebraic equations</td>
</tr>
<tr>
<td></td>
<td>Superficial perimeter</td>
<td>Area-perimeter</td>
<td>Algebraic equations</td>
</tr>
<tr>
<td></td>
<td>Approximate estimate</td>
<td>Elemental</td>
<td>Algebraic equations</td>
</tr>
<tr>
<td></td>
<td>Financial</td>
<td>Production</td>
<td>Algebraic equations</td>
</tr>
<tr>
<td></td>
<td>Index</td>
<td>Indices</td>
<td>Algebraic equations</td>
</tr>
<tr>
<td></td>
<td>Fuzzy</td>
<td>Logic/Distribution</td>
<td>Probability/Machine learning</td>
</tr>
<tr>
<td>Empirical</td>
<td>Univariate</td>
<td>Regression</td>
<td>Statistics/Machine learning</td>
</tr>
<tr>
<td></td>
<td>Multivariate</td>
<td>Regression</td>
<td>Statistics/Machine learning</td>
</tr>
<tr>
<td></td>
<td>Artificial Neural Networks</td>
<td>Regression</td>
<td>Machine learning</td>
</tr>
<tr>
<td></td>
<td>Support Vector Machines</td>
<td>Regression</td>
<td>Machine learning</td>
</tr>
<tr>
<td></td>
<td>Relevance Vector Machines</td>
<td>Regression</td>
<td>Machine learning</td>
</tr>
<tr>
<td></td>
<td>Expert system</td>
<td>Knowledge-base</td>
<td>Probability/Machine learning</td>
</tr>
<tr>
<td></td>
<td>Case-Based Reasoning</td>
<td>Knowledge-base</td>
<td>Probability/Machine learning</td>
</tr>
<tr>
<td></td>
<td>Conference</td>
<td>Domain experience</td>
<td>Qualitative reasoning</td>
</tr>
<tr>
<td>Simulation</td>
<td>Monte-Carlo</td>
<td>Distribution</td>
<td>Probability/Machine learning</td>
</tr>
</tbody>
</table>

Source: Author

6 Conclusion

Cost modelling is a branch of building economics that have been modelled as either a deterministic or stochastic concept for almost 50 years. A reclassification system for conceptual cost models is proposed in this paper. Previous classification systems for conceptual cost includes: traditional models; new wave or new generation models; statistical models; knowledge based models; resource/process based models; deterministic models; and stochastic models The cross-replicative grouping observed in the current classification system might become indistinct and irrelevant in the future. A review of the literature showed that the modelling techniques for conceptual cost models could be reclassified into three classes, namely: mathematical, empirical and simulation models. However, hybrid models can be formed using any combination of the identified implementation techniques. The superficial cost model; a mathematical model, is the most widely used conceptual cost model in the construction industry due to its relative ease of use and practical applicability. Empirical models using machine learning techniques such
as support vector machines, artificial neural networks, and case-based reasoning models are currently being researched in the academic domain. The increase in computer processing power and need to have models that accurately predicts conceptual costs appears to be the main drive for current research in cost modelling. In addition to the proposed classification system, this paper also provides an update on the current state of modelling conceptual cost. The authors anticipate that; as a concise guide on modelling technique, this review will be helpful to future researchers of cost modelling in the architecture, engineering and construction industry.

References


ABM-based Environmental Performance Simulation Study of Demolition Waste Management Policies in Shenzhen, China

Zhikun Ding1,*, Wenyan Gong1, Wang Yifei2, Patrick, X.W., Zou3, Yanqing Wang4

Abstract: The environmental performance evaluation of demolition waste management has been an urgent issue due to the fast urbanization process in China. Based on complex adaptive system theory and agent-based modeling method, an agent-based simulation system for demolition waste management in Shenzhen with Repast Simphony 2.2 was developed. By sampling demolition projects in Shenzhen, the environmental performance of demolition waste management under different policy scenarios was simulated. The cost-benefit calculation was carried out in the model. The simulation results showed that the environmental performance of each policy was mixed policy > publicity and education policy > pay-as-you-throw policy > source reduction policy > benchmark policy. In addition, the total environmental net income was increased by 1 billion and 108 million RMB under the mixed policy, which was more than 7 times of the total environmental net income under the benchmark policy. Therefore, the implementation of mixed policy can effectively reduce the amount of waste generated and improve the source reduction, reuse, recycling, which can contribute to environment improvement.

Key Words: Demolition Waste; Agent-Based Modeling; Policy Research; Environmental Performance; Simulation

1* Zhikun Ding
Corresponding author, Department of Construction Management and Real Estate, Shenzhen University, China
E-mail: ddzk@szu.edu.cn

1 Wenyan Gong
Department of Construction Management and Real Estate, Shenzhen University, China
E-mail: gwy920230@163.com

2 Yifei Wang
Shenzhen Housing and Urban Construction Development Research Center, China
E-mail: wangyyyyfei@163.com

3 Patrick, X.W., Zou
Swinburne University of Technology
E-mail: pwzou@swin.edu.au

4 Yanqing Wang
Shenzhen Construction Testing Center
E-mail: 270544008@qq.com
1 Introduction

With the rapid development of economy and society, the acceleration of urbanization and urban renewal, the amount of C&D waste is in a fast lane of growth. According to official statistics, 90% of C&D waste was generated from building demolitions and the quantity of demolition waste (DW) was up to 200 million tones each year in China [1]. However, only less than 10% of DW was reused or recycled today and the rest was simply landfilled or dumped illegally [2]. It is widely recognized that demolition activities bring significant adverse impacts to the natural environment. First, the landfilled and dumped DW occupy lots of land spaces [3, 4]. According to official statistics, approximately 6000 m³ of land spaces are needed to landfill 10,000 tons of DW. Second, the illegal dumping may bring potential risks to the soil fertility, the groundwater and surface water due to the DW leachate [5] because DW usually contains a lot of paints, heavy metals and other harmful materials. Third, transportation and disposal machines used in the demolition process may bring negative effects to the environment, such as dust emissions and noise pollutions [6]. It is greatly detrimental to the sustainable urban development. Demolition waste management (DWM) becomes an urgent issue nowadays. Furthermore, how to accurately assess the environmental performance of DWM has been a hot topic in academic research.

Based on a literature review, it was found that major evaluation approaches include the environmental impact assessment (EIA), strategic environmental assessment (SEA), life cycle assessment (LCA), system dynamics (SD) and mixed assessment method. EIA is an environment management tool for encouraging more environment protection from planning and decision making to ultimate implementations [7]. Normally, EIA is used to evaluate and compare environmental impacts of different DWM alternatives so that the most promising program could be identified[8]. SEA is an instrument to implement sustainable development strategies in planning, which can be used not only in planning but also in other areas, such as waste management planning. For example, SEA was adopted to develop a regional waste management plan in an Austrian case study [9], identify potential environment problems of DWM in Kuwait [10]. LCA is a popular tool for analyzing the sustainability of DWM and has significant contributions to develop environmentally sound DWM strategies in the past few years[11]. Coelho et al[12] used LCA method to analyze the environmental impact of two different demolition methods: traditional demolition VS selective demolition.

SD is a systematic approach that is particularly useful for considering the dynamic interrelationship among variables within a social and economic system[13]. Therefore, it would be appropriate to use SD as a tool to understand a complicated C&D waste management system from a holistic perspective when assessing its environmental impact. For instance, based on a case study in the construction industry in China, a model was developed to evaluate the environmental performance of construction waste management by using SD method[14]. In order to evaluate the environmental impacts of two alternatives i.e. recycling and disposing, a SD model was established to carry out the evaluation with STELLA software[15].

Mixed assessment method is a combination of multiple methodologies which are complementary to each other so that the environmental impact of DWM can be better assessed. For example, a combination of different approaches including material flow analysis (MFA), LCA, environmental life cycle costing (ELCC), and best available technology (BAT) was applied to evaluate the overall environmental and economic performance of
the Finnish DWM system[16]. It is obvious that findings would be useful for analyzing a system environmental performance from different perspectives before decision-making.

Although a number of methods to assess environmental performance of construction and demolition activities are available as discussed above, there is a lack of empirical studies for evaluating the environmental impact of DWM in view of DWM as a complex adaptive system (CAS) that have the heterogeneity, autonomy, adaptability of stakeholders and the interaction dynamics of various stakeholders[17]. DWM is affected by a number of internal and external factors including government policy, law and regulation, market demand and supply, demolition technology and skill, land, space and environmental constraints, public and society perception, as well as cost-benefit trade-off. DWM is a complex adaptive system involving multiple stakeholders, such as design firms, landfill centers, recycling enterprises, and government departments. Hence, DWM should be examined from a complex adaptive system perspective[17]. So far no research has been done to explore the effect of stakeholder heterogeneity on DWM. In order to assess the environmental impact of DWM from a CAS perspective, it is necessary to consider the attitude and interaction of heterogeneous stakeholders within the system. Hence, this study applied the agent-based modeling (ABM) approach to evaluate the environmental impact of DWM. Furthermore, there is little research on environmental economic cost analysis. In this article, the environmental assessment indicators are measured in terms of money by applying the concept of opportunity cost. They can more intuitively reveal the environmental impact of DWM based on the economic cost-benefit analysis.

Moreover, there was no quantitative research of comparing different demolition waste management policies in literature such as source reduction policy, pay-as-you-throw policy, publicity and education policy, and their mixed policy. To fill the gap, this article used the ABM method based on the complex adaptive system theory and introduced the cost-benefit analysis of environmental evaluation to develop an agent-based simulation system for demolition waste management in Shenzhen. By sampling demolition projects in Shenzhen, the environmental performance of demolition waste management under different policy scenarios, such as mixed policy, publicity and education policy, pay-as-you-throw policy, source reduction policy, and benchmark policy will be investigated. In the following sections, first, the ABM approach was briefly introduced. Next, the design and implementation of the proposed model was delineated in detail. Then, the simulation results were analyzed and discussed. Finally, the article concluded with a summary of key findings.

2 Agent-based modeling method

Agent-based modeling (ABM), also referred to as individual-based modeling (IBM), is a bottom-up modeling method which gains more and more attention for analyzing complex systems and complex adaptive systems. ABM is a computational method that enables researchers to develop, analyze, and experiment with models composed of autonomous and heterogeneous agents that interact with each other and their local environment in order to identify mechanisms that bring about some macroscopic emergent phenomenon of interest. Compared with other modeling methods, ABM has following advantages[18]: (1) ABM has the ability to describe a complex adaptive system; (2) Macroscopic system and microscopic agents can be effectively integrated; (3) ABM can model agents’ behavior and achieve effective delineation of adaptive agents; (4) Reuse of models is optional. Based on above advantages, ABM is a new paradigm in the modeling and simulation of dynamic systems, which has gained increasing attention over the past decade. At present, there is no standard
and widely accepted protocol for the ABM modeling process. Thus, different modeling frameworks have been proposed by various researchers. For instance, Grimm et al.[19] have proposed a standard protocol (i.e. Overview, Design concepts, and Details i.e. ODD) for ABM application in ecology. Dam[18] introduced ten steps for designing an ABM based socio-technical system. Teo[20] proposed primary steps to build an ABM model for social science research. Based on the above studies, this paper proposed a five-step modeling framework for ABM (see Figure 1).

Figure 1 Flow chart of ABM method

3 Modeling and Simulation

3.1 Research question

Research questions: What are the environmental performance outcomes of demolition waste management under different policy scenarios, including source reduction policy, pay-as-you-throw policy, publicity and education policy, and their mixed policy?

Agent identification: (1) Demolition projects in Shenzhen were defined as project agents. The demolition projects referred to the completed construction projects during the first quarter of 2015. (2) Stakeholders of DWM in a project included demolition company agents, design company agents, transporter agents, reusing agents, recycling center agents, landfilling agents, government agents, and evaluation agents.

Basic assumptions: (1) Projects during the first quarter of 2015 were completed on time. (2) Starting time of demolition was the completion time of projects plus designed service life of buildings which took an average age of 60 years. So the starting simulation time was January 1, 2075. (3) The variables of source reduction behavior of demolition company agents and design company agents were in accordance with the Theory of Planned Behavior (TPB). (4) There were 3 different methods of demolition waste disposal including reuse, recycle and landfills. (5) The evaluation agent could calculate the environmental performance of DWM for each simulation period. (6) In order to simplify the model structure, the demolition waste generated at each simulation step was processed at that step. (7) The distance between demolition projects and recycling center, the distance between demolition projects and landfilling sites were assumed to follow the discrete homogeneous distribution.

3.2 Specification-formalisation

3.2.1 System identification and analysis
From the perspective of complexity science, DWM system is a CAS involving economics, environment and stakeholders who interact with each other and with the local environment[14, 15, 17]. Combined with the status quo of DWM in Shenzhen, there are four subsystems composed of DWM system i.e. the subsystem of DW generation, the subsystem of DW disposal, the subsystem of DWM policy, and the subsystem of DWM assessment. The relations between subsystems and agent types were shown in Figure 2.

Figure 2 Framework of demolition waste management system in Shenzhen

The subsystem of DWM assessment was explained in detail for demonstration purpose. Based on a literature review, the assessment indicators of DWM environmental performance were collected, and the indicators of DWM environmental performance based on simulations were calculated. At the same time, according to the disposal fee standards, other related regulations and various energy price information, the cost-benefit evaluation framework of DWM environmental performance was developed to calculate the potential costs and benefits of its environmental impact in terms of money (see Figure 3).

Figure 3 Cost-benefit mechanism of environmental performance assessment for demolition waste management
3.2.2 Concept formalization

After an analysis of the system and the agents as well as their relations, interactions and behaviors, the next step was to formalize these concepts so that it could be computer-implementable. There are two approaches to formalize the identified concepts. The first is a list of data structures and the second, a formal ontology. Considering the model in this research, the data structure approach was selected to do the concept formalization. Take the evaluation agent as an example:

- Total actual amount of DW generation: double
- Total Amount of Construction Materials Saving: double
- Land Occupation (Saving) / Loss of Fertilizer (Saving) / Loss of Water (Saving): double
- Oil Consumption (Saving) / Coal Consumption (Saving) / Natural Gas Consumption (Saving): double
- GHG Emission (Saving) / NOX Emission (Saving) / SO2 Emission (Saving) / CO Emission (Saving) / PM Emission (Saving): double
- Cost (Saving) of Land Consumption / Cost (Saving) of Water Pollution: double
- Cost (Saving) of Oil Consumption / Cost (Saving) of Coal Consumption / Cost (Saving) of Natural Gas Consumption: double
- Cost (Saving) of GHG Emission / Cost (Saving) of NOX Emission / Cost (Saving) of SO2 Emission / Cost (Saving) of CO Emission / Cost (Saving) of PM Emission: double
- Total Environmental Cost of DWM / Total Environmental Benefit of DWM / Total Environmental Net-Benefit of DWM: double

3.2.3 Model formalization

Model formalization consists of two parts. The first one is to develop a model narrative that is a detailed description of agent behaviors under study. The other one is the expression of this narrative in pseudo-code which is a straightforward delineation that uses mathematical and logical descriptions of what and how agents are supposed to behave by combination of the model narrative and formalized concepts. The behavior, rules and internal structure of each agent in the model should be discussed. Since there were many agents involved in the model, the pseudo-code was quite lengthy. For demonstration purpose, only a brief pseudo-code description of environmental performance evaluation was provided in the following section. The other model narratives could be turned into pseudo-code in a similar fashion.

Calculate-Land Occupation / Land Occupation Saving
Land Occupation = (Waste Illegal Dumped Quantity + Waste Landfilled Quantity) * Unit Land Occupation
Land Occupation Saving = Total Amount of Construction Materials Saved * Unit Land Occupation
Get Land Occupation and Land Occupation Saving
Calculate-Cost of Land Consumption / Cost Saving of Land Consumption
Cost of Land Consumption = Waste Landfilled Quantity * Unit Cost of Landfilling
Cost Saving of Land Consumption = Land Occupation Saving * Unit Cost of Landfilling
Get Cost of Land Consumption and Cost Saving of Land Consumption
3.3 Modeling-verification-experimentation

3.3.1 Software implementation

After the formulation of the model narrative and pseudo-code, the model could be programmed in a modeling or programming environment. In this paper, repast symphony2.2 software platform, combined with object-oriented programming, was adopted to develop the simulation model of DWM system. The model with 15,000 lines of source code was written with Java in Repast Symphony 2.2. Model structure specification, model parameters configuration and coding were done in the software. As shown in Figure 4, the policy control variables could be adjusted through the parameter control panel to achieve the regulation of different policies.

![Figure 4 Parameter control panel and output data window](image)

3.3.2 Model verification

Model verification is to ensure the model free of errors prior to simulation executions. In order to verify the model, several tests were taken including recording and tracking agent behavior, single-agent testing, interaction testing in a minimal model, multi-agent testing[18]. A typical example of recording and tracking agent behavior in the model was illustrated in Figure 5. In the process of coding, the syntax of Java should be strictly followed. In order to verify the codes, the built-in debug function in Repast Simphony was used to set break points in need to verify the location. All the codes were verified by observing variables window in which all parameters were passed correctly.
3.3.3 Experimentation

After the model verification, experiments could be conducted to study the research question in 3.1. The DWM status in 2015 was taken as the benchmark policy. The six sets of parameters in Table 1 were used as model initial values, and the six different policy scenarios were simulated. The 102 projects completed in Shenzhen from January to March in 2015 were input data and the corresponding number of agents for multi-agent simulation were created to explore the environmental cost effectiveness of DWM under different policies i.e. publicity and education policy, pay-as-you-throw policy, and source reduction policy.

<table>
<thead>
<tr>
<th>Parameter configurations of simulation experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter name</td>
</tr>
<tr>
<td>AttitudeTowardWasteReductionBehavior</td>
</tr>
<tr>
<td>SubjectiveNorm</td>
</tr>
<tr>
<td>PerceivedBehaviorControl</td>
</tr>
<tr>
<td>UnitPenaltyPaidDueToIllegalDumpling</td>
</tr>
<tr>
<td>UnitCostOfLandfill</td>
</tr>
<tr>
<td>RegulationsAssociatedWithDWDisposal</td>
</tr>
<tr>
<td>SightLimitOfDemolitionCompany</td>
</tr>
<tr>
<td>SightLimitOfDesigner</td>
</tr>
<tr>
<td>RatioOfGreenAgent</td>
</tr>
<tr>
<td>The existence of interactive behavior</td>
</tr>
</tbody>
</table>

3.3.4 Data analysis

For different policy scenarios, 100 simulations were repeated by using the batch operation module provided in Repast Simphony. During the course of a simulation, all output data were saved in TXT files and later transferred to an Excel document. Then the simulation results could be analyzed in conjunction with Excel scripts. In the following sections, the results of 10 environmental performance assessment indicators were
summarized in diagrams and tables. The first 4 indicators had a far larger impact on environment than the other 6 indicators such that the diagrams were independently drawn for the first 4 indicators.

1) Analysis of simulation results for benchmark policy

The environmental cost analysis was shown in Figure 6 and Table 2. Firstly, the illegal dumping and landfill of DW occupied a large amount of land spaces and reduced soil fertility, which accounted for nearly 50% of the total environmental cost. Secondly, the cost of oil consumption in transportation and landfill accounted for nearly 25% of the total cost, which was next to the cost of land consumption. In addition, the illegal dumping of large amounts of DW caused serious groundwater pollution, which led to higher environmental costs accounting for about 20% of the total cost. So water pollution became the third environmental impact consequence.

![Environmental cost analysis graph](image)

(a) The environmental cost of the four indicators under the benchmark policy

![Environmental income graph](image)

(b) The environmental cost of the six indicators under the benchmark policy

**Figure 6  Environmental costs of demolition waste management under the benchmark policy**

As shown in Figure 7 and Table 2, the trend of environmental income was generally consistent with the trend of environmental cost. At the end of simulations, the percentage of land consumption cost saving, the water pollution cost saving and the oil cost saving accounted for 47.22%, 47.07% and 5.67% of the total income. The water pollution cost saving was much larger than the oil cost saving and became the second largest
source of environmental income. The main reason was that the potential benefits of water loss reduction from the reduction, reuse and recycling of DW was higher than those of energy consumption reduction during transportation. In addition, the sum of land consumption cost saving and water pollution cost saving accounted for more than 90% of the total income, which have become the most important source of environmental income. This was attributed to the potential benefits of reduction, reuse, and recycling of DW.

![Diagram showing environmental income of four indicators under the benchmark policy](image)

(a) Environmental income of the four indicators under the benchmark policy

![Diagram showing environmental income of six indicators under the benchmark policy](image)

(b) Environmental income of the six indicators under the benchmark policy

Figure 7 Environmental benefits of demolition waste management under the benchmark policy
According to Figure 6, 7, 8 and table 2, the dominant indicators of DWM environmental performance are the land consumption, water pollution, and oil consumption. The trend of DWM environmental cost-income variations was shown in Figure 8 and Table 2. With continuous demolitions of buildings, environmental incomes and environmental costs were increasing but the growth of environmental income was almost twice as much as that of environmental costs. The environmental net profits finally approached around 208 million yuan.

Table 2  Environmental cost-benefit cumulative values of demolition waste management under the benchmark policy  
(Unit: million RMB)

<table>
<thead>
<tr>
<th>Environmental evaluating indicator</th>
<th>Land consumption</th>
<th>Water Pollution</th>
<th>Coal Consumption</th>
<th>Oil Consumption</th>
<th>Natural Gas Consumption</th>
<th>GHG Emission</th>
<th>NOx Emission</th>
<th>SO2 Emission</th>
<th>CO Emission</th>
<th>PM Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>25156.54</td>
<td>11405.64</td>
<td>15.71</td>
<td>13015.59</td>
<td>0.21</td>
<td>145.44</td>
<td>26.39</td>
<td>0.76</td>
<td>2.84</td>
<td>0.13</td>
</tr>
<tr>
<td>Income</td>
<td>30570.73</td>
<td>30482.81</td>
<td>7.87</td>
<td>3674.00</td>
<td>0.11</td>
<td>72.73</td>
<td>13.29</td>
<td>0.37</td>
<td>1.46</td>
<td>0.06</td>
</tr>
<tr>
<td>Net profit</td>
<td>5414.19</td>
<td>19077.17</td>
<td>-7.83</td>
<td>-9341.60</td>
<td>-0.11</td>
<td>-72.70</td>
<td>-13.11</td>
<td>-0.39</td>
<td>-1.38</td>
<td>-0.06</td>
</tr>
</tbody>
</table>

In summary, waste landfill disposal should, firstly, be minimized as far as possible by improving source reduction and waste recycling, reducing DW transportation and DW tail-end disposal. Secondly, the transportation route sites of landfill center and recycling factories should be optimized, which could reduce the transportation distance of waste so as to save energy consumption as a whole. Finally, illegal dumping supervisions should be strengthened and landfill charging standards should be reasonably specified in order to simultaneously reduce the amount of illegal dumping and landfill disposal.

(2) Analysis of simulation results for different policies

Some significant influential indicators of environmental performance under different policies were compared in this section, including cost of land consumption, cost of water pollution, cost of oil consumption, cost of GHG emission. The environmental cost of each indicator with longitudinal cumulative values was shown in Figure 9.
(a) The cost of land consumption for DWM under different policies

(b) The cost of water pollution for DWM under different policies

(c) The cost of oil consumption for DWM under different policies
Under different policy scenarios, the values of environmental evaluation indicators determined the environmental cost-income. From a quantitative perspective, the largest was the loss of water, the others in sequence were GHG emission, oil consumption, loss of fertilizer. The minimum was the land occupation. From the view of cost-benefit, the environmental costs of the four indicators were, in sequence, land consumption costs, oil consumption costs, water pollution costs, and GHG emission costs (see Figure 9). It was found that there is an order difference in terms of quantities and costs. For instance, the land occupation was the least, but its environmental costs were very high. So it should be the focus of management. According to the simulation results, the environmental profits of DWM under different policy scenarios were calculated. As shown in Figure 10, the net profit under the benchmark policy was 151 million yuan, 358 million yuan under the source reduction policy, 730 million yuan under the pay-as-you-throw policy, 884 million yuan under the publicity and education policy, 1 billion and 259 million yuan under the mixed policy. Thus, the simulation results showed that the environmental performance outcome of each policy was mixed policy > publicity and education policy > pay-as-you-throw policy > source emission reduction policy > benchmark policy.
The primary task of validation is to confirm the model is suitable for the target domain and useful for the problem appreciation in this study. In principle, the following four methods can be used to validate, including historical repetition, expert consultation, literature validation, and model reconstruction. In this article, the model validation included document verification and expert opinions. At the system identification stage, semi-structured interviews were conducted among the main stakeholders in the system, including the design manager, demolition project manager, and recycling plant leader. Five independent interviews were conducted. Based on interviews of the stakeholders, the model was more in line with the current status of DWM in Shenzhen. Taking the pay-as-you-throw policy as an example, the control parameters included the cost of unit landfill, the cost of illegal dumping and the soundness of waste disposal laws and regulations. The three parameters are mainly extracted from findings of Li Jingru, Yuan Hongping, Tam, V.W. and other related research results. For example, Tam et al[21] explored the system dynamics model of Shenzhen construction waste management, and Yuan et al[22] investigated how to determine the reasonable construction waste landfill fee. The results showed that reasonable charges can effectively reduce the amount of waste, landfilling and illegal dumping with the landfill cost of 80 yuan/ton to achieve best outcomes. By varying the above 3 parameter values to configure the pay-as-you-throw policy, this article simulated the outcomes under different policy scenarios. By contrasting the results of pay-as-you-throw policy with those of the benchmark policy, the above conclusions were confirmed. Expert validations were applied at all stages of the model development so that the model could represent essential aspects of the real-world system.

3.5 Model use

The model presented can be used for decision making i.e. different scenarios can be simulated to make best decisions. For instance, the model for the environmental impact assessment of DWM can be used by government in DWM policy making. It can also be utilized by project stakeholders (e.g. design or demolition companies) in the construction industry since the model enables a new way to evaluate environmental impacts of DWM at a project level. The model can also be applied in a regional level if data about regional demolition projects can be collected. In particular, the simulation model can illustrate how various interactions and decisions made by DWM stakeholders might affect opportunities for waste reuse and recovery thereby the environment. For example, with the increasing ratio of green demolition managers, waste reusing and recycling show an upward trend while waste landfill, illegal dumping and transportation decline. As a result, the negative environmental impacts could be reduced.

3 Conclusion

Demolition waste management is drawing more and more attention worldwide in terms of environmental concerns. This article described the application of ABM as a bottom-up approach to evaluate the environmental performance of DWM activities under different policies. The simulation model integrated all major variables affecting the environmental performance of DWM and was capable of exploring behaviors of these heterogeneous stakeholders from a CAS perspective. The assessments covered different environmental cost-income resulting from land consumption, water pollution, coal consumption, oil consumption, GHG emission as well as the impact of NOX, SO2, CO and PM emission. In this manner, the environmental performance assessment of DWM was comprehensively investigated.
This article, for the first time, provided a quantitative environmental performance comparison of different DWM policies. The simulation results showed that the environmental performance rank of each policy was mixed policy > publicity and education policy > pay-as-you-throw policy > source emission reduction policy > benchmark policy. Thus, government should promote DWM publicity and education activities, implement the pay-as-you-throw policy, refine relevant laws and regulations on the disposal of DW, focus on enhancing designers and demolition managers’ awareness of source reduction, and eventually encourage all stakeholders to proactively carry out demolition waste management. The objective to reduce the waste generated, increase the source reduction, reuse, recycle, and improve environmental performance could be achieved.

Future research should focus on the following two aspects: First, integrate big data of buildings with geographic information systems (GIS) to take advantage of the huge building information and the physical simulation space so that the model could be more consistent with the real world. Moreover, further research may include landfill site selection and transportation routes optimization. Second, improve agents’ decision rules in the model. For example, agents could be designed with more intelligent learning capabilities by introducing game theory, genetic algorithms, deep learning etc.

4 Acknowledgement

This research was conducted with the support of the National Science Foundation for Young Scholars of China (Grant No. 71202101); Social Science Research Support Grant (No.17QNFC34), Shenzhen University; Humanities and Social Science Research Funding, Ministry of Education of P.R.C (No.10YJCZH025); Scientific Planning Research Grant, Ministry of Housing and Urban-Rural Development of P.R.C (No. 2009-K4-17, No. 2011-K6-24).

5 Reference


Developing Lean Management Framework for Building Information Modelling (BIM)-based Construction Project

Gupta, Sagar¹ and Moon, Sungkon²*

**Abstract:** Building information Modelling is considered as an emerging new paradigm shift in the recent years to solve the fragmentation in Architecture, Engineering and construction/operation industry by promoting collaboration between different stakeholders. Although many researchers advocate that BIM provides a platform for efficient information exchange and collaboration between different stakeholders, a distinct gap persists in the communication between the various phase stakeholders within the building information modelling framework. This purpose of this paper is to understand the existing problems and to propose a lean project management framework for a BIM-based construction project in future to address the complexity involved in information exchange process. Therefore, firstly the ongoing technical problems with data interoperability between different BIM models and existing unidirectional communication mechanism between different phase stakeholders are expounded. Secondly, the lean production principles and lean construction tools and techniques are discussed in the following section. In future, the author plans to conduct a case study based on an ongoing BIM-based construction project incorporating the newly proposed conceptual framework to analyse its application and effectiveness in real time environment.

**Keywords:** building information modelling (BIM), BIM information exchange framework, lean production, lean construction techniques, pull theory

---

¹ Gupta, Sagar
Department of Civil and Construction Engineering, Swinburne University of Technology, Melbourne, VIC 3122, Australia, Email: 100991434@student.swin.edu.au

²* Moon, Sungkon
Corresponding author, Department of Civil and Construction Engineering; and Centre for Sustainable Infrastructure, Swinburne University of Technology, Melbourne, VIC 3122, Australia, Email: sungkon.moon@gmail.com
1. Introduction

The ever growing demand for speed, cost and quality control in construction, coupled with the advancement in technologies, rise in environmental issues and the persistent fragmentation in the AEC industry has led to the steep increase in the complexity of construction processes (Gidado, 1996). One of the main reasons for complexity is the mutual interdependencies among various stakeholders involved in the project, which includes design team, engineers and contractors (Sears et al., 2008, Bryde et al., 2013). The low degree of information sharing and collaboration between the project stakeholders has resulted in the low efficiency of the construction industry production (Li and He, 2013).

The inefficiency in information exchange and sharing has been a recurring and ignorant problem in the construction industry (Tian and Xue, 2014). Li and He (2013) argued that the primary reason for this is the excessive amount of data, extensive variety of sources, complex nature, and scattered storage system. Furthermore, the success of the project delivery predominantly depends on the effectiveness and productivity of information management and exchange between the project’s participants and software systems (Dastbaz et al., 2017).

The concept of Building Information Modelling was brought into light based on the idea of efficient storage and management of large complex data generated throughout the life cycle of the construction project in an integrated way (Eastman et al., 2011). BIM translates the conventional paper-based designs into a virtual interactive environment, thus presenting a better level of efficiency, communication channel and collaborative environment that is far superior to the traditional construction tools (Bryde et al., 2013).

In a BIM-based collaborative model, it is imperative for project stakeholders to exchange all the design information for better decision making and workflow (Pazlar and Turk, 2008). However, the various members involved in the BIM-based model make use of different type of software depending on their work trade that results in loss of data while exchanging information and this includes unnecessary duplication of information for data reclamation (Oh et al., 2015). Azhar et al. (2012a) claim that the existing approaches to solve data interoperability, such as Industry Foundation Classes (IFC) and XML Schemas, possess inherent inhibitions. Exchanging building information without data loss is necessary for BIM’s success in any project delivery (Golabchi and Kamat, 2013).

The information flow between the architects/engineers and the end users (fabricators, MEP detailers) is unidirectional and collaboration incoherent in the early design phases in BIM framework (Succar, 2009). Even though BIM promises to foster a closely knitted project team throughout the project lifecycle, architecture and engineering design teams are still not in cohesion with the MEP and fabrication coordination teams at the site (Dossick and Neff, 2009). Therefore, a different management approach is required to optimise the process of communication and collaboration between various phase stakeholders (Dossick et al., 2009).

Lean management approach can be the proposed solution to minimise the excessive communication time and promote closely connected relationships between different disciplines. The lean project management approach is different from other conventional approaches in the objectives it seeks after such as waste reduction and value generation, as well as in the structure, relationship and members involved in each phase of project delivery (Ballard and Howell, 2003). Moreover, the core principles of lean thinking, i.e. pull and flow helps to optimise the production process by maintaining downstream to upstream communication and constant flow of product without any interruptions and wastage (Picchi and Granja, 2004).

Therefore, this research aims to introduce a newly proposed lean conceptual framework for BIM-based construction project, one that integrates Lean principles into Building information modelling concept to optimise the communication process and collaboration between projects participants involved in different project lifecycle phases. The present paper comprises mainly of a literature review to form the background study for future work. The literature review has been divided into two sections. The first section begins with a critical examination of the data interoperability and information exchange mechanisms within the BIM framework. In the second section, an overview of lean production principles and the implementation of lean in the construction industry has been provided. The problem statement/ Research Gap is established in the next section followed by the proposed future direction and conclusion.
2. Literature Review

2.1 Building Information Modelling

The following sections explore the areas of the evolution of BIM utilisation over the years, BIM model interoperability, BIM information exchange mechanism and finally the implementation of Integrated Project Delivery.

2.1.1 Historical evolution of BIM utilisation

The concept of Building Information Modelling was brought into light based on the idea of efficient storage and effective management of large complex data generated throughout the life cycle of the construction project in an integrated way (Eastman et al., 2011). The advent of new technologies and supporting applications over the past years has enabled to exploit the information contained in the BIM model for the following:

1. BIM design tools to develop a schematic model of a building before designing an extensive building model to enable a comprehensive evaluation of intended schema and alternative plans (Eastman et al., 2011).
2. Visualisation: 3D & 4D renderings for accurate visualisation and verification of design intent and decision making at any phase of the process (Eastman et al., 2011).
3. Fabrication/Shop Drawings: Automatic fabrication and generation of shop drawings using 3D models (Azhar et al., 2012b).
5. Conflict and Clash detection: Instant checking of interferences between MEP service systems using the 3D model scaling (Eastman et al., 2011).
6. Life cycle analysis to improve energy efficiency and sustainability by linking BIM model to energy analysis tools (Eastman et al., 2011).
7. 3D Laser scanning to scan existing facilities and automatically embed information in BIM models for future buildings (Azhar et al., 2012b).

The development of numerous applications with the capacity for direct information exchange amongst them has opened up the opportunity for better stakeholder relationships and enhanced productivity (Singh et al., 2011). BIM scholars contend that BIM provides the impetus for considerable change required to reduce the AEC industry’s fragmentation and boost stakeholder collaboration (Pour Rahimian et al., 2014). However, even though BIM provides a platform for connections between project participants, it is not yet successful in developing close-knit collaboration and efficient information exchange among various members involved (Dossick and Neff, 2009).

2.1.2 BIM Model Interoperability

The primary motivation behind the implementation of BIM tool is the opportunity to share BIM 3D Model, use and exchange the information embedded outside the Modelling software environment. The model information may be shared at different levels of granularity, varying from the entire data enriched BIM model, specific model views, constituent parts, particular segments to a single name-value pair (Kalinichuk, 2015). Moreover, building’s parts are managed in a different way by different professions (for example, installation of internal reinforcement by fabricator is of no concern to the architect) (Sacks et al., 2010).

These disciplines make use of diverse software systems having distinctive specifications confined to their area of expertise. The interactions between these systems run in parallel, and the integration needs to be seamless for effective collaboration (Dastbaz et al., 2017). Hence, interoperability between various systems such as BIM software, design analysis software, cost estimating software, scheduling software, facility management software is imperative (Conover et al., 2009). Moreover, Interoperability while being technically appropriate must also foster a level of interpretation and coherence among elements in different views (Sacks et al., 2010).

Interoperability is defined as the “ability of two or more systems or elements to exchange information and to use the information that has been exchanged” (Dastbaz et al., 2017). Exchanging building information without data loss is imperative for BIM’s success in any project delivery (Golabchi and Kamat, 2013). Information exchange through the medium of IFC file format presents many constraints, and multiple attempts have been made to address the same (Steel et al.,
2012). Past studies on interoperability through IFC reveals that massive loss of data occurs in the process of information exchange as IFC-based format data exchange does not provide full interoperability (Golabchi and Kamat, 2013). However, researchers have claimed that despite the recent progress in development and implementation of Industry Foundation Classes (IFC), still a lot more effort is required to attain fully functional and efficient interoperability between data exchanges (Li and He, 2013).

2.1.3 BIM Information Exchange Mechanism

The interactions in BIM comprises of push-pull knowledge exchanges arising within or between the project participants, software technologies, and industry guidelines/standards. Push transactions mean the transfer of information from one member to another (Architect instructions to the contractor) while pull transactions mean furnishing information when requested by another participant (RFI submitted by fabricators and subcontractors) (Succar, 2013). Even though BIM attempts to foster collocated or closely linked collaboration teams throughout the project lifecycle, architecture and engineering design teams are still not in cohesion with the MEP and fabrication coordination teams at the site. Hence, there is still a requirement for further research for better coordination between MEP teams using the Building Information models (Clevenger and Khan, 2013). Therefore, with the end goal of efficient integration and collaboration, designers or architects need to have detailed communication with the end parties (subcontractors and fabricators) who receive data to comprehend their work strategies, skills set and the way they consolidate information.

2.1.4 Integrated Project Delivery

BIM implementation is not complementary with every project delivery method. One of the conventional project delivery approaches, Design-BID – Build (DBB) poses the greatest challenges to BIM implementation as in this system the contractor comes on board after the design phase has completed and therefore must prepare a separate BIM model which increases the risk of low data interoperability. So, therefore, traditional approaches can benefit from BIM implementation only if it is introduced in the early design phase (Kalinichuk, 2015).

As a new project delivery approach, integrated project delivery (IPD) promotes collaboration and integration between the project participants throughout the building lifecycle phases such as design, planning, and construction (Ghassemi and Becerik-Gerber, 2011). Industry specialists have been trying to implement BIM technology in parallel with IPD model in an endeavour to solve construction problems (Haoxuan, 2013). However, due to the restraints provided by BIM in the form of architectural model development, the implementation of BIM technology in conjunction with integrated project delivery in the large construction environment is still challenging (Ma et al., 2014).

2.2 Lean Production

The following sections explore the application of Lean principles in production and construction industry. The tools and techniques based on Lean theory present in manufacturing and construction industry are discussed.

2.2.1 Lean Production Theory

The term ‘lean production’ was first instituted by the research group studying the automobile manufacturing sector of America, Japan and other countries and was published in the book “The Machine That Changed the world” (Womack et al., 1990). Lean was associated with the efficient production of vehicles with less time and investment; using less floor space and utilising fewer engineering hours (Gao and Low, 2014).

Lean production is the extension of the concepts already present in the Toyota production system (Bertelsen and Koskela, 2004). The Toyota production system principles present knowledge about the way a process is perceived, recorded and evaluated for improvement. The TPS uses a process aligned approach which is directed at value enhancing for the customer by eliminating the waste and maintaining a continuous production flow (Lapinski et al., 2006).

Toyota Engineer Ohno (1988) was the mastermind behind the development of Lean production. Ohno emphasised more on building custom products catering to the need of customer demands (Holweg, 2007). He established a set of objectives for the production system based on Total quality management (TQM) and efforts to minimise the total machine set up time. He
emphasised on manufacturing the car adhering to the requirements of a particular customer, delivering it immediately, without maintaining intermediate inventories (Ohno, 1988, Howell, 1999, Gao and Low, 2014).

2.2.2 Lean Production Principles
Koskela (1992), devised the “new production philosophy” influenced by Shingo’s work and Toyota Production system, based on concepts: Just in time (JIT) and Total Quality control (TQC) practised in automobile production. Liker (2004), however, argued that the principles identified by Koskela were process focussed and neglected the human resource and social facet of lean production (Gao and Low, 2014). Liker in his book emphasised that Lean is just not a set of tools and techniques implemented at site, but it is a holistic system developed for people to enable their continuous improvement. He suggested that to reap full benefits of lean production, apply the philosophy of one-piece-flow to every domain of business to eliminate the various muda wastes (Liker, 2004).


• Value: Accurately determine the main characteristics of an individual product and the associated value for the client
• Value stream: Establish value stream for each product by reducing variability and eliminating waste
• Flow: Produce continuous flow without any disruptions and stoppages
• Pull: Allow the customer to pull value of the product from the manufacturer suited to their requirement
• Pursue perfection: Continuous development by eliminating all non-value-added tasks and waste in the production process

2.2.3 Lean Principles in Construction
Lauri Koskela was the one who first introduced the revolutionary concept of “Lean Production” in manufacturing to the construction industry, asking it to examine and embrace these new theories (Ballard and Howell, 2003). Koskela (1992) in his report asserted that “Construction Management is a transformation-based philosophy where the focus is on transforming inputs to outputs with typically no management of the transformation process itself”. Koskela introduced the TFV theory of production integrating the previous theories in a conceptual framework consisting of three views (Koskela, 2000):

➢ Transformation (T) of raw materials as input product to a robust structure in the form of output,
➢ Flow (F) of the raw materials or information to end product passing through various production stages, and
➢ Value (V) generation for the customer by the elimination of waste.

The principles of lean construction aim at achieving maximum value for the customer at the project level, carrying out parallel design development of process and product and the implementation of production control throughout the life cycle of the project (Howell, 1999).

2.2.4 Lean construction tools and techniques
Although many tools have been developed and implemented in the past few years, this study focuses on the ones relevant to future work.

Lean project delivery system (LPDS)
The Lean project delivery system is framed, regulated and refined to realise the TFV theory goals proposed by Koskela (Koskela, 2000, Koskela et al., 2002). The LPDS helps to enable the smooth transition from lean production to lean construction. The primary motive of lean project delivery system is to follow lean principles, i.e., to understand and produce according to customer needs, to deliver when required and to execute without any error and waste. This principle is applied to all the delivery phases such as procurement and fabrication, assembly and installation, commissioning and decommissioning for effective decision making (Mastroianni and Abdelhamid, 2003)

Ballard et al. (2002) introduced the Lean project delivery system, in which the relationship between different phases and the concerned participants mutually overlap.

The essential features of LPDS include (Ballard, 2000):
• The project is structured and managed as a value generating process
• The introduction of cross-functional teams to involve downstream stakeholders in the early design phase.
• Project control is more focused on execution than dependent on error detection
Efforts are directed at making workflow reliable than improving productivity
- Use of pull techniques for smooth flow of information and material between the participants
- Maintaining buffers to tackle demand variability
- Incorporating feedback loops for continuous improvement at every level

**Last planner system of Production control (LPS)**

Last planner system of production control caters to the Flow (F) aspect of the Koskela theory (Bertelsen and Koskela, 2004). Last planner system (LPS) is a tool that structures the process workflow and helps to tackle the problems of variability and uncertainty in the construction industry. These are the set of people who provide updates regarding the progress of short term weekly tasks, generally the trade supervisors such as construction foreman, fabricator, and subcontractors. They provide information regarding the tasks which can be completed in near term than detailed plans (Ballard and Howell, 2003).

The last planner system is based on a pull type system approach, and it helps to gain benefits in all four major aspects of project performance – quality, cost, schedule and safety (Baldwin and Bordoli, 2014). In pull technique, work is done backwards from the planned completion date, to properly define and sequence activities so that their completion results in work for the next phase. This rule of “pulling” helps to eliminate non-value adding activities and overproduction waste, which is aligned with Ohno’s theory of lean production (Ballard and Howell, 2003). The pull technique enables the designers and engineers to understand the task better and prepare more efficiently by obtaining the prerequisite information in advance through the fabricator or site foreman (Ballard, 1999).

**3. Summary/ Research Gap**

Although many researchers argue that BIM provides a solution for effective information management and exchange, still many issues persist in data interoperability and the communication mechanisms. The data loss in IFC round tripping and model interoperability issues limits the collaboration of different stakeholders and the effective implementation of integrated project delivery (IPD) approach. The instructions are pushed from architects and engineers to the people in charge of execution which creates a gap in understanding of design concepts. This further leads to wastage of time in clarifying the design misinterpretations and clashes as the communication is routed through the contractor’s team which delays the process. These communication issues necessitate the implementation of a different management framework to minimise the communication cycles between the design team and site coordination team to develop an efficient BIM model for successful project delivery.

The lean theory is essentially focussed on developing a robust production system that brings together all the workforce to work towards common objectives: one-piece-flow, eliminate waste and generate maximum value for the customer. The downstream to upstream communication practice promotes effective collaboration within the organisation, eliminates the extra correspondence time between different phase stakeholders and facilitates maximum value for the client by eliminating waste through feedback loops. The last planner system (based on pull thinking) contributes to facilitating prerequisite information for a specific task to the design team which helps them to understand the task better, solve conflicting instructions and collect information to prepare better for future tasks.

**4. Future Discussion/Direction**

Based on the above-mentioned findings, the author proposes to develop a lean conceptual framework for BIM-based construction project, one that integrates Lean principles into Building information modelling concept to optimise the communication process and collaboration between projects participants involved in different project lifecycle phases. This model will be primarily based on utilising pull technique for information exchange. In this framework, the end users will be closely involved with the design team in the early design phase to make decisions regarding design suitability. The architects and structural engineers will pull prerequisite information from the Fabricators and MEP detailers to prepare the design for different elements involved in the project. The architects and structural engineers will work in cross-functional teams and collaborate to develop one comprehensive model. Based on the conceptual framework, the author plans to conduct
a case study on a live BIM-based construction project to critically examine the model’s suitability and effectiveness in a real environment and make the required improvements.

References


Li, Z. & He, D. 2013. Discussion of a Method of Collaborative Construction Project Information Management Based on BIM. *ICCREM 2013: Construction and Operation in the Context of Sustainability*.
Succar, B. 2013. Building Information Modelling: conceptual constructs and performance improvement tools. *School of Architecture and Built Environment Faculty of Engineering and Built Environment University of Newcastle*.
Responses

Subject: CRIOCM 2017 notification for paper 118
Thank you for submitting your paper in our conference. On behalf of the Organizing Committee, I am pleased to inform you that your paper has been peer-reviewed and accepted. Please consider the reviewer comments below and update your submission on easychair account within next two weeks.

Please kindly note that conference presentation and inclusion in the conference program of your paper are subject to the following conditions:

1. The accepted paper shall be presented at the Conference by one of the authors who is a registered participant;
2. The completed Registration Form and full payment for the presenter are received before 15th of October. Please click here to complete registration.

Please note that the early bird registration will close on 15 September 2017.

We thank you for your contribution and look forward to your participation in the Conference. If you need a letter of acceptance to facilitate your visa and travel arrangements, please contact the Conference Secretary by e-mail at: CRIOCM2017@swin.edu.au.

Regards,
Morshed

Response: Dear CRIOCM2017 organizing committee, thanks for your work. We have revised the paper according to reviewers' comments.

----------------------- REVIEW 1 ---------------------
PAPER: 118
TITLE: Cooperative Innovation Behavior Incentive Mechanism for Project-based Supply Chain
AUTHORS: Guangdong Wu, Huanyu Wu, Goerge Zillante and Jian Zuo

Overall evaluation: 2 (accept)

-------- Overall evaluation --------
Good paper that analyses the relationship between project duration, quality and effort. It might be a good idea to define the coefficients a little better beforehand in the paper. The paper is overall well-written with the exception of a few glaring mistakes so it needs to be proofread.

Response: Thanks for your comments. We have revised the paper carefully according to your suggestions.
PAPER: 118
TITLE: Cooperative Innovation Behavior Incentive Mechanism for Project-based Supply Chain
AUTHORS: Guangdong Wu, Huanyu Wu, George Zillante and Jian Zuo

Overall evaluation: 1 (weak accept)

--------- Overall evaluation ---------
General comments:
This paper is well written with logical flow. However, the purpose and conclusion needs more explanation. Such as time, quality and cost are dependent or independent objectives? This paper seems to contribute new knowledge but there are some technical ambiguities.
Response: Thanks for your comments. We have revised the paper carefully according to your specific comments below.

Specific comments:
Introduction: In supply chain relationship and information are also exchanged such as asset and knowledge. Explain cooperative innovation as understanding of innovation is different among construction stakeholders also shared values.

Why client and contractor role is significant to research as other stakeholders also influence such as suppliers.

Response: Thanks for your comments. We agree that other stakeholders such as suppliers play important roles in construction. We chose project owners and constructors as the research objects due to two main reasons. Firstly, they are two most important stakeholders in construction project. Secondly, the model established in this study is limited at addressing only two objects, so we only chose these two stakeholders. We have added more words to explain this in the revised version.

What does benefits of project mean, is it ‘performance’?

Response: Thanks for your comments. The “benefits of project” is a kind of “performance”, which is expressed by currency. We have added the explanation in the new version.

Why only duration and quality are important control objectives in construction?

Response: Thanks for your comments. This is also because of the limitation of established model.

What is incentive mechanism, is it not included in project contract, parties decided the mutual expectations?
Response: Thanks for your comments. Incentive mechanism includes measures taken by project owners. These measures aim to reduce constructors’ opportunistic behaviour and to improve their efforts. We have explained this in the revised version.

What kind of construction project has been considered for current research?

Response: Thanks for your comments. Civil engineering projects are considered in the study. We have explained this in the revised version.

Model analysis: Propositions need proper example or reference.

Response: Thanks for your comments. Due to the limitation of pages, we deleted the examples in the paper.

Conclusion: What is meant by cooperative incentive behaviour. More justification is needed to match the results with proposed model.

Response: Thanks for your comments. Cooperative incentive behaviour refers measures taken by project owners and constructors to improve project overall benefits and constructor’s benefit. We have added more words to explain this in the revised version.
Cooperative Innovation Behavior Incentive Mechanism for Project-based Supply Chain

Wu, G.D\(^1\)*, Wu, H.Y.\(^2\), Zillante, G.\(^3\) and Zuo, J.\(^4\),

**Abstract:** Considering the relative importance between project objectives of duration and quality control, this paper developed an incentive model to analyse the cooperative innovation behavior in project-based supply chain to maximize project benefits. The results show that the efforts of contractor on project duration objective and quality control objective are positively related to factors including importance of objectives and contractor comprehensive output coefficient; while these efforts are negatively correlated with effort cost coefficient. The project benefits indicator witness an increase and a followed decreases according to the variation of contractor’s efforts and benefit distribution coefficient, both representing inverted "U" shape relationships. The established effort cost coefficient always show a target relative importance equilibrium, hence project owners could use a low-level incentive intensity to promote contractors to arrange the input of resources. Apart from the effect of constructor’s characteristics, benefit distribution coefficient is also affected by the relative importance of control objectives and the uncertainty of external environment. Thus project owners should choose appropriate incentive intensity by balancing these two factors to improve the project benefits, and benefits of project owner and constructors.

**Keywords:** construction project; project-based supply chain; cooperative innovation; incentive mechanism

---

\(^1\) Wu, G.D.
Corresponding author, School of Tourism and Urban Management, Jiangxi Finance and Economics University, China
E-mail: gd198410@126.com

\(^2\) Wu, H.Y.
School of architecture and built environment, the University of Adelaide, Australia
E-mail: Huanyu.wu@adelaide.edu.au

\(^3\) Zillante, G.
School of architecture and built environment, the University of Adelaide, Australia

\(^4\) Zuo, J.
School of architecture and built environment, the University of Adelaide, Australia
1 Introduction

During the implementation of projects, multiple project-based organizations are involved in resource exchange and knowledge interaction. Since the difference of aptitude among organizations, single-functional project-based organizations may not be able to complete the delivery of integrated projects independently \(^1\). Hence, supply chain has become the main organizational form to realize cooperative innovation. Project-based organizations including project owner and constructor involved in construction projects are independent legal entities or rational individuals, and they have their own independent interest demands \(^2\). Due to the difference in core knowledge and ability, and the information asymmetry, both project owner and contractor may conduct moral hazard behaviors \(^3\). Duration objective, quality objective and cost objective are always expected to be achieved in the delivery of projects, but the relative importance of these objectives varies according to different types of construction projects \(^4\). For a typical construction project, the resource investment is limited at a certain level. The unbalanced investment on a particular objective may reduce the investment of resource in other objective, thereby reducing overall benefits of the project (currency performance).

The project duration and quality are two important control objectives for a construction project. The duration control should be based on a certain quality level, while the quality control should be achieved within a certain duration as well. These two control objectives both affect the realization of project value \(^5\). Besides, interest demands of project-based organizations would change gradually along with the progress of project. Therefore, how to develop an incentive mechanism, which could match interest demands of stakeholders and improve relationship quality of them, has become an important task in inter-organizational cooperative innovation activities in project-based supply chain \(^6\).

This paper aims to investigate the cooperative innovation behavior between the two major project-based organizations of project-based supply chain in civil engineering projects, i.e., project owner and contractor. The relative importance of the project duration and quality objective will be taken into consideration. A project output function based on the Cobb-Douglas function is employed to determine the relative importance of the project duration objective and quality control objective \(^7\). The influence relative importance of control objectives on behavior choice, benefit distribution coefficient and project benefits has been analyzed based on coordination strategies: project duration objective and quality control objective. The findings can provide valuable information for project owner to manage the inter-organizational cooperative innovation behavior relationship in project-based supply chain.

2 Model Description and Solution

2.1 Model Description

For a specific project-based supply chain, considering the inherent characteristics of the construction project, centering on the realization of the project benefit, this paper assumes that there are two equal cooperation project-based organizations: the owner and the contractor. The relative importance of the project duration objective and quality objective will be taken into consideration. A project output function based on the Cobb-Douglas function is employed to determine the relative importance of the project duration objective and quality control objective \(^7\). The influence relative importance of control objectives on behavior choice, benefit distribution coefficient and project benefits has been analyzed based on coordination strategies: project duration objective and quality control objective. The findings can provide valuable information for project owner to manage the inter-organizational cooperative innovation behavior relationship in project-based supply chain.
In this formula, $A$ is the comprehensive output coefficient of the contractor resource input, which reflects the overall technical level and management ability of the contractor. That is the ability of transforming the resource input into the project output. It is related to the operation and management level, staff quality and technical level, etc. In different construction projects, due to different requirements of the contract, the emphasis degree of the contractor on the project duration and quality objectives is different. $p$, $q$ respectively represent the emphasis degree of the contractor on the control objectives, i.e. the relative importance of the project duration and quality objectives. $p>0$, $q>0$ and $p+q=1$. $\zeta$ is the exogenous random variable influencing project value adding, it obeys the normal distribution $\zeta \sim N(0, \sigma^2)$.

(2) Assume that the effort cost function of the contractor $C(a_1, a_2)$ is a strictly monotone increasing function of its effort level $a$:

$$C(a_1, a_2) = \frac{1}{2} \eta_1 a_1^2 + \frac{1}{2} \eta_2 a_2^2$$

In this formula, $\eta_1$ and $\eta_2$ are the effort cost coefficients of the contractor on the project duration and quality objectives, $\eta_1>0$, $\eta_2>0$. They respectively represent the cost coefficients of the contractor resource input for the realization of the scheduled duration and quality targets. In the actual construction project, the effort costs of different control objectives are interrelated. In order to ensure the existence of the numerical solution of the model, this paper assumes that the effort costs of the contractor on the project duration and quality objectives are mutually independent according to [9].

(3) The risk preferences of the owner and the contractor are different. The owner is risk neutral, while the contractor is risk evasive. They both seek to maximize their own benefits, which complies the hypothesis of the rational economic man. Assume that the negative utility function of the contractor has the invariant and absolute risk evasive characteristics, it satisfies additivity in state and time.

(4) The linear form of the contract remuneration provided by the owner to the contractor is:

$$s = c + \beta R$$

In this formula, $c$ is the fixed payment for the contractor, it's assumed to be constant, $\beta$ is the benefit distribution coefficient, $0 \leq \beta \leq 1$.

According to the assumptions above, the contractor benefit expected utility of the net present value can be obtained as follows:

$$U_1 = s - c(a) - \frac{1}{2} \rho \beta^2 \sigma^2$$

In this formula, $\frac{1}{2} \rho \beta^2 \sigma^2$ is the risk premium of the contractor, i.e. the stable certain earnings of the contractor by giving up $\frac{1}{2} \rho \beta^2 \sigma^2$ of earnings as an exchange. The owner benefit expected utility of the net present value is as follows:

$$U_2 = R - s$$

So the benefit expected utility of the project is:

$$U = R - c(a) - \frac{1}{2} \rho \beta^2 \sigma^2$$

Based on the above hypotheses, for maximizing the benefit utility function of the project, the
incentive problem of the cooperative innovation behavior between the owner and the contractor in the project-based supply chain is jointly determined by $a_i$ and $\beta$:

$$\max_{a_i, \beta} U$$

s.t. $a_i, \beta \in \arg \max U_i$

$\arg \max U_2$

2.2 Model Solution

Considering the importance of the control objectives, the first order condition of the cooperative innovation behavior incentive in the project-based supply chain is:

$$\frac{\partial U_1}{\partial a_1} = 0, \quad \frac{\partial U_1}{\partial a_2} = 0$$

Solve the equations above, and according to the extremum property of the binary function, the point $a = (a_i^*, a_i^*)$ is the maximal value of function $U_1$, so:

$$ \begin{cases} 
  a_i^* = A\beta \left( \frac{p}{\eta_1} \right)^{\frac{1+\rho}{\rho}} \left( \frac{q}{\eta_1} \right)^{\frac{q}{2}} \\
  a_i^* = A\beta \left( \frac{p}{\eta_1} \right)^{\frac{1+\rho}{\rho}} \left( \frac{q}{\eta_1} \right)^{\frac{q}{2}} 
\end{cases} \quad (7) $$

Substitute formula (7) into formula (6) and take partial derivative of $\beta$, make it equal to 0:

$$\frac{\partial U}{\partial \beta} = Apa_i^{\rho-1} \frac{\partial a_i}{\partial \beta} + Aqa_i^{\rho+1} \frac{\partial a_i}{\partial \beta} - \frac{\eta_i a_i}{\eta_i a_i - \eta_i a_i} \frac{\partial a_i}{\partial \beta} - \frac{\rho \beta \sigma^2}{\rho \beta \sigma^2} = 0$$

And $\frac{\partial^2 U}{\partial \beta^2} = -A^2 \left( \frac{p}{\eta_1} \right)^\rho \left( \frac{q}{\eta_1} \right)^\sigma - \rho \sigma^2 < 0$, there exist $\beta'$ as the maximal value of function $U_1$, so:

$$\beta' = \frac{A^2}{A^2 + \rho \left( \frac{\eta_2}{p} \right)^\rho \left( \frac{\eta_2}{q} \right)^\sigma \sigma^2} \quad (8)$$

Substitute formula (8) into formula (7), then:

$$ \begin{cases} 
  a_i^* = \frac{A^3}{A^2 + \rho \left( \frac{\eta_2}{p} \right)^\rho \left( \frac{\eta_2}{q} \right)^\sigma \sigma^2} \left( \frac{p}{\eta_1} \right)^{\frac{1+\rho}{\rho}} \left( \frac{q}{\eta_1} \right)^{\frac{q}{2}} \\
  a_i^* = \frac{A^3}{A^2 + \rho \left( \frac{\eta_2}{p} \right)^\rho \left( \frac{\eta_2}{q} \right)^\sigma \sigma^2} \left( \frac{p}{\eta_1} \right)^{\frac{1+\rho}{\rho}} \left( \frac{q}{\eta_1} \right)^{\frac{q}{2}} 
\end{cases} \quad (9) $$
3 Model Analysis and Simulation

3.1 Model analysis

Proposition 1 The effort level of the contractor on the project duration and quality objectives is positively related to its comprehensive output coefficient, and negatively related to the effort cost coefficient of the duration and quality objectives. That is, the greater the comprehensive output coefficient, the easier for the contractor to transform the resource input into project benefit, thereby increasing the effort level on the duration and quality objectives. While the greater the effort cost coefficient of the duration and quality objectives, it means that the contractor need to input more resource to achieve the same project output, which reduces the enthusiasm of the contractor to make efforts on the control objectives, thereby decreasing the effort level on the duration and quality objectives.

Proof:

\[ \frac{\partial u_i}{\partial A} = \frac{1 + (A^2 + A^{-3})\rho\left(\frac{n}{p} - \frac{n}{q}\right)\sigma}{\left[ A^2 + p\left(\frac{n}{p} - \frac{n}{q}\right)\sigma \right]^{1/2}} > 0 \]

\[ \frac{\partial u_i}{\partial \eta_1} = -\frac{\left[ 1 + p\left(\frac{n}{p} - \frac{n}{q}\right)\sigma \right]^{1/2} + \rho\left(\frac{n}{p} - \frac{n}{q}\right)\sigma^2}{\left[ A^2 + p\left(\frac{n}{p} - \frac{n}{q}\right)\sigma \right]^{1/2}} < 0 \]

\[ \frac{\partial u_i}{\partial \eta_2} \]

and \[ \frac{\partial u_i}{\partial \eta_2} \] have similar situations, so the conclusion has been proved.

Proposition 2 The effort level of the contractor on the project duration and quality objectives is positively related to the relative importance of the control objectives. The more important the control objective, the higher level of the effort from the contractor on the objective. Therefore, combining with conclusion 1, the greater the comprehensive output coefficient, the more important the objective, the lower the effort cost coefficient, and the higher the effort level of the contractor on the control objective. For the contractor, if the importance degree of a control objective is obviously higher than another objective, in order to effectively achieve the goal, the contractor may devote the resource to the more important goal while ignore the other goal. Accordingly, the effort level of the contractor on the control objective is also higher, which results in that the effort level on another objective may be relatively lower.

Proof:

\[ \frac{\partial u_i}{\partial \rho} = \frac{\left[ 1 + p\left(\frac{n}{p} - \frac{n}{q}\right)\sigma \right]^{1/2} + \rho\left(\frac{n}{p} - \frac{n}{q}\right)\sigma^2}{\left[ A^2 + p\left(\frac{n}{p} - \frac{n}{q}\right)\sigma \right]^{1/2}} > 0 \]

\[ \frac{\partial u_i}{\partial \eta} \]

has a similar situation, so the conclusion has been proved.

Proposition 3 Take \[ z = \left(\frac{n}{p}\right)^{\gamma} \left(\frac{n}{q}\right)^{\gamma} \], it’s easy to know that the benefit distribution coefficient \( \beta \) is a decrease function of \( z \). That is, when \( z \) reaches its maximal value, the benefit distribution
coefficient is minimum; when \( z \) reaches its minimal value, the benefit distribution coefficient is maximum. It means that for given duration and quality objectives, if the owner can comprehensively balance the importance relationship of the two targets and let the contractor input resources in a balanced and coordinated way, then nearby the poles of \( z \), a reasonable and effective incentive interval can be formed. At this time, the owner can urge the contractor to work harder with a relatively low incentive intensity.

**Proof:** Solve the linear programming problem on \( p \) and \( q \) on \( z \):

\[
\max z = \left( \frac{\eta_1}{p} \right)^\lambda \left( \frac{\eta_2}{q} \right)^\lambda
\]

s.t. \( 0 < p \cdot q < 1 \)

\[ p + q = 1 \]

Construct the Lagrange function under the constraint conditions:

\[
F = \left( \frac{\eta_1}{p} \right)^\lambda \left( \frac{\eta_2}{q} \right)^\lambda - \lambda(1-p-q)
\]

Take partial derivatives of \( p \), \( q \) and \( \lambda \), and make them equal to 0, solve the simultaneous equations, then:

\[
\begin{align*}
\lambda &= \frac{\eta_1}{\eta_1 + \lambda_1} \\
\lambda &= 1 - \frac{\eta_2}{\eta_1 + \lambda_1}
\end{align*}
\]

According to the extremum property of the binary function, there exist \((p', q')\) which makes \( z \) get the maximum value, so the conclusion has been proved.

### 3.2 Data Simulation

#### a. The Relationship between the Relative Importance of the Control Objectives and the Contractor Effort Level

Combining with formula (7), (8) and (9), under the condition that \( A=10 \), \( \eta_1=2 \), \( \eta_2=2 \), \( \rho=0.5 \), \( \sigma^2=0.005 \), this paper simulates the change situation of the contractor effort level on the duration and quality objectives \((a_1, a_2)\) with the variation of the relative importance of the control objectives \((p, q)\). The results are shown in Figure 3. Chart (c) is the generated function diagram after the substitution of \( q=1-p \) and \( p=1-q \) into \( a_1 \). By comparing chart (a) with chart (b) in Figure 3, it can be found that the more important the control objective, the higher the contractor effort level on that objective, then the contractor will correspondingly reduce the effort level on the other objective, which verifies the analysis of conclusion 2. What’s more, chart (c) in Figure 3 further verifies conclusion 2. It is worth noting that, under the circumstance that \( \eta_1=\eta_2=2 \), the contractor effort level on the duration and quality objectives \((a_1, a_2)\) is symmetrically distributed. Due to the priority and scarcity of the resources, the contractor needs to reasonably allocate the resources to the duration and quality objectives rather than excessively emphasize on one target. Excessive pursuit of a control target will reduce the achievement degree of another target or cause it difficult to achieve. Hence, for the contractor, under the premise of fully considering the benefit sharing, it must balance the relative importance of the duration and quality targets and rationally allocate its own efforts.
b. The Relationship between the Relative Importance of the Control Objectives and the Benefit Distribution Coefficient

Combining with formula (8), under the condition that $A=10$, $\rho\sigma^2=25$, this paper simulates the change situation of the benefit distribution coefficient ($\beta$) with the variation of the relative importance of the control objectives ($p$, $q$) under the circumstance that $\eta_1=2$, $\eta_2=2$; $\eta_1=2$, $\eta_2=4$; $\eta_1=2$, $\eta_2=8$. The results are shown in Figure 4. It can be seen from Figure 4 that when the effort cost coefficients of the control objectives are different, the benefit distribution coefficient first decreases and then increases with the change of the relative importance of the control objectives. The change situation represents a "U" shape, which verifies the analysis of conclusion 4. Excessive emphasis on any of the control goals will cause the distribution coefficient develop towards the direction which is not conducive to maximizing the project benefit. Although the effort cost coefficients of the contractor on the duration and quality control goals are different, there always exist an equilibrium of the relative importance of the control goals ($p^*$, $q^*$) which makes the benefit distribution coefficient minimum ($\beta^*$). At this time, around the pole ($p^*$, $q^*$), the owner can balance the importance of the duration and quality targets of the contractor with a relative low incentive intensity, so as to make the contractor reasonably arrange its efforts.

4 Conclusions

This paper developed an incentive model for cooperative innovation behavior in the project-based supply chain, considering the relative importance of duration objective and quality objective in civil engineering projects. The study found that effort level of constructor on duration objective and quality objective is positively related to the comprehensive output coefficient, and negatively related to the respective effort cost coefficient. Contractor is more likely to put more efforts on a certain objective which is proven to be more important. For the given relative importance of
control objectives and effort cost coefficient, there is always an equilibrium point. This enable project owner to promote contractor to make more efforts on control objective with relatively lower incentive intensity. Contractor should be aware of the relative importance of control objectives and then put more resource on control objectives, which could help to improve overall project benefits and constructor’s benefits.

Acknowledgement

This study is supported by the National Natural Science Foundation of China (71561009 and 71310165), China Postdoctoral Science Foundation (2016M590605 and 2017T100477), Postdoctoral Science Foundation of Jiangxi Province (2016KY27), Social Science Planning Foundation of Jiangxi Province (16GL32), and Natural Science Foundation of Jiangxi Province (20171BAA218004).

References

A preliminary framework for site planning and site design in green buildings

Huo, X.S.1*, Yu, A.T.W.2

Abstract: Green building is an effective means to implement economic, social and environmental sustainability in the construction industry. Site planning and site design (SP&SD) is a key issue in forming sustainable site in green building development. There is lack of a comprehensive framework for SP&SD in green buildings according to previous research. In this research study, a preliminary framework for SP&SD was explored. To develop this framework, a desk study by the authors was conducted to and major variables in SP&SD of green buildings were identified. In addition, 12 face-to-face interviews with practitioners in green building development were carried out. Through the interview, the process of SP&SD in green buildings was discussed, and the design principles, relationships between stakeholders, and effective planning and design approaches were explored respectively. Content analysis and coding were adopted to analyze the interview data. A preliminary framework for SP&SD was established based on previous literature and the interviews, which can provide references for effective SP&SD in green building development. In future research, the validation of the framework can be further explored based on case studies.

Keywords: Green building, Site planning and site design, Interview, Framework

---

1* Huo, X.S.
Corresponding author, Department of Building and Real Estate, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR, China
E-mail: Xiaosen.huo@connect.polyu.hk

2 Yu, A.T.W
Department of Building and Real Estate, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR, China
1 Introduction

Green building, as the implementation of sustainable development in construction industry, is a widely-accepted concept and idea around the world. Site planning and site design (SP&SD) is an early stage and a key issue in a construction project, and site planners must consider how to minimize disturbance on construction site \cite{1}. A sustainable site is the one on which land use density, landscape, water use, and other issues are considered and planned in ways that help reduce the ecological footprint of a new or renovation construction\cite{2}. Sustainable sites bring about economic merits by providing opportunities for people to connect with nature, and encourage more social and environmental responsibility by improving human health and social well-being\cite{3}. Previous research has already explored SP&SD and sustainability from different perspectives, such as sustainable site design including ecological and holistic strategies, which helps repair and restore existing site systems instead of altering or impairing them\cite{4}. Low Impact Development was proposed as sustainable storm water management strategy that prevents groundwater quality reduction and protects drinking water supply\cite{5}. Well site layout planning is also investigated by applying Building Information Modeling, Ant Colony Optimization, Nonstructural Fuzzy Decision Support Systems or other applicable technologies and tools\cite{6}\cite{7}\cite{8}.

However, previous research studies normally focus on parts of SP&SD and its relationship with green buildings and sustainability. There is lack of a comprehensive framework for effective SP&SD in green buildings. To fill up this research gap, this research study aims to develop a preliminary framework for SP&SD of green buildings in China. Face-to-face interviews and content analysis are used to achieve this research aim. The preliminary framework can provide references for effective SP&SD of green buildings in future practice.

2 Literature Review

Site planning is defined as “the art of arranging structures on the land and shaping the spaces between an art linked to architecture, engineering, landscape architecture and city planning”\cite{9}. Generally, planning and design brings a vision to implementation, and site planners need to minimize the disturbance on construction during this process. The process of SP&SD is illustrated in Figure 1\cite{10}.

![Figure 1 SP&SD process](image)

Sustainable SP&SD not only benefits the economy, i.e. reduces long-term costs, but also does good to society and environment\cite{10}. For social benefits, sustainable SP&SD increases pedestrian...
safety, forms attractive surroundings, and improves sense of community. For environmental part, sustainable SP&SD conserves energy, reduces air and water pollution, reduces urban heat islands, and protects biodiversity and natural processes. To facilitate sustainable SP&SD process in green buildings, several measures were proposed by previous research. For instance, Analytical Hierarchy Processes were helpful in forming indicator framework in brownfield redevelopment on site level[11]. Low Impact Development was efficient in storm water management, which also minimizes operation and maintenance costs in green building development[12]. A Tacit-based Decision Support System was also developed[13] through key factors in site planning focusing on the tacit knowledge acquisition process to facilitate site layout planning.

When it refers to elements in SP&SD of green buildings, a list of main variables in SP&SD of green buildings was developed through a comparative analysis on green building rating tools[14]. The main variables include land use, site assessment, passive building design, open space, green vehicle parking, reduced parking footprint, ecological value and protection, cultural heritage, landscaping and irrigation, microclimate around buildings, neighborhood daylight access, storm water management, environmental management plan, etc. Sustainable relevant issues in land use include natural resource availability and ecosystem protection[15]. Site assessment considers site conditions and evaluates sustainable options and informs related decisions about SP&SD[10]. Passive design refers to[16] a design approach which uses natural elements, such as sunlight, to heat, cool, or light a building. Open space provides[17] environmental functions and recreational opportunities in urban areas. The provision of green vehicle parking space helps reduce vehicle footprint, and restriction of the amount of land area dedicated to surface parking helps minimize parking footprint[18]. Cultural heritage preservation[19] is essential in sustainable development and cultural features on or around construction site should be retained or protected. The concept of Low Impact Development and sponge city focus on storm water management in urban areas, also the landscape irrigation on site[5]. Microclimate is[20] the distinctive of a small-scale area, which includes pedestrian level wind, elevated temperature mitigation, and natural air ventilation on site, is also an essential consideration in SP&SD of green buildings. Neighborhood daylight access is influential on humankind’s moods and energy level, which should be considered and analyzed during SP&SD process[21]. A comprehensive environmental management plan on site minimizes disturbance on local system and is beneficial to human health[22].

Previous literatures relevant to SP&SD in green buildings are summarized above. Several research studies have been conducted from different perspectives of SP&SD, and the importance of this early process in green building development has been realized. There is lack of research that focuses on the management issues of SP&SD in green buildings. This research explores the major variables, whole process, stakeholder relationships, sustainable principles, and approaches of SP&SD in green buildings.

3 Research Methodology

To identify major variables in SP&SD of green buildings, a desk study was conducted by the authors[14]. To further develop a preliminary framework for SP&SD in green buildings, face-to-face interviews with experienced practitioners in green building development was selected as the major research method. To conduct interviews, target practitioners were contacted in advance by email to determine whether they are willing to participate in the face-to-face
interviews, and an interview guide including the research aim and proposed interview questions was attached in the email for their references. The criteria of identifying the potential practitioners are considering their working categories, and their working experiences in green building area. After identifying the agreeable interview time, 12 in-depth face to face interviews were conducted, including 3 in Hong Kong, and 9 in mainland China. Each of the interview lasted for half an hour to an hour, which depended on discussions with the interviewees and their understandings on these research questions. All the interviewees are guaranteed that the interviews will only be used for research purpose, and their personal information will be kept confidential.

The interview questions are summarized as follows:
Q1. According to your own experiences in SP&SD in green buildings, what are the major differences when comparing with conventional buildings?
Q2. How do you think about the SP&SD process in green buildings based on the one proposed by other researcher[10] (Figure 1)?
Q3. In SP&SD of green buildings, how the major stakeholders are involved (such as government agencies, green consultants, clients, designers, surveyors) in the process?
Q4. How do you think about the sustainable principles in SP&SD of green buildings?
Q5. Green building development is moving from a single building to green building area, where land use planning is an important part. Based on your own experience, in SP&SD of green eco-city area, what are the effective planning and design methods?

Content analysis and coding were adopted to analyze the interview data. Content analysis is a research technique that makes replicable and valid inferences from texts to the contexts of their use, and was adopted in previous research[23]. So, qualitative content analysis was adopted in this research to analyze the interview data. Coding was also conducted during the analysis of interview data, which is a process of segmenting and labelling text to form descriptions and board themes in the data. In the data analysis, three columns were designed in one page, where the interview data was recorded in the middle one, codes that describe the text segment were shown in the left one, and the corresponding themes or other ideas were in the right one.

4 Results and Discussion

4.1 Interview data analysis

4.1.1 Differences between conventional buildings and green buildings

In SP&SD, conventional buildings consider more about the maximization of land use. While in green buildings, the requirements of green building rating tools must be considered at the beginning of SP&SD. For green buildings, how to balance the relationships between the environment and land use, and how to combine maximizing potential and minimizing impacts must be considered, as one characteristic of green building is respecting natural environment as much as possible. Another difference is green buildings consider more about the neighborhood, such as in HK BEAM Plus, the daylight access to neighborhood buildings must be reached during SP&SD. In addition, for green SP&SD, continuous evaluation and feedback is also a significant difference.

4.1.2 SP&SD process in green building
As stated above, one significant difference in SP&SD between conventional buildings and green buildings is that green buildings stress more on evaluation and feedback. The process of SP&SD in green buildings was developed based on the one proposed in previous research[10]. In successful site planning and site design process, site analysis is an important step. Site analysis considers fundamental elements of the project such as the site of proposed buildings, access to and from the site, lot layout, parking requirement, vehicular and pedestrian circulation, and storm water management strategy. When it turns into design process, it needs feedback or review stage by stage. In conceptual design, designers put some general requirements in green building rating tools into the design. In the detailed design, a technical document can be formed gradually, then is the construction document. As green designers in green SP&SD, they need to check whether the green requirements of construction site have been reached to, based on their own understanding of green concept and green requirements. After the construction documentation, green specialists also need to evaluate whether required green designs have been taken into construction. After the project is finished, an evaluation should be conducted to assess whether the green requirements have been met in the design stage, and whether the green requirements and design are effective. If not, some requirements in green building rating tools can be optimized or modified accordingly. In addition, the feedback after project implementation also provides references for future green projects.

4.1.3 Stakeholders in SP&SD of green buildings

In SP&SD process, the participation of the government provides constrains and policy guidance in green building development. For instance, some basic indexes including floor area ratio, greening rate, and building density are set in advance by the government. The government also provides guidance for other stakeholders and their behaviors during SP&SD process. In conventional SP&SD, the developers and the designers are two major participants in this process. While in green SP&SD, the green consultants should also be involved at the early stage. The developers consider how to balance green requirements and construction costs, and the consultants provide professional technical information for them. Developers decide to choose green technologies that cost less and gain more scores in green building evaluation. Then designers conduct SP&SD correspondingly based on the requirements of the developers. While one interviewee suggests that in future green building development, green consultation and green design should be involved in an integrated way, i.e. the designers in future should get a higher level and have green consultation knowledge. Constructors, as the implementers of the projects, need to obey the requirements and arrangements of the developers in each process. In general, consultants play the role of a link in SP&SD of green buildings. Consultants make some green requests in SP&SD, which should be completed by designers, urged by developers, and guaranteed by governments. In addition, the public as an important part of green building implementation, should provide suggestions during the whole construction process.

4.1.4 Principles in SP&SD of green buildings

After discussion with the interviewees, three major sustainable principles are summarized in SP&SD of green buildings, including considerations from the environmental, economic, and social aspects.

**Based on natural environment.** The first issue in this principle is site security. At the beginning of SP&SD, the soil contamination degree, including the amount of radon in the soil
must be detected. During site slope design and slope greening arrangement, site security should also be considered. Another issue is designing with natural environment, such as designing building layout properly on site, which utilizes the sunlight and natural ventilation. Regional natural environment differences should be involved, and SP&SD should be conducted according to local conditions.

**Based on social environment.** In SP&SD of green buildings, surrounding transportation and neighborhood public facilities should be taken into consideration, as one characteristic of green building is people-oriented. In addition, historical and cultural characteristics protection should be involved in green buildings or green ecological urban areas. For instance, when developing green buildings in different regions, SP&SD should be in line with local architectural culture.

**Based on economic applicability:** Economic feasibility is an important consideration for the developers in construction project. From technical level, there are numbers of technologies help to conduct effective SP&SD in green buildings, while the developers will choose those ones that not only meet the requirements of green building rating tools, but also have economic feasibility and operability on site. To mobilize initiative of participants in green building development, initial investment should be controlled in an acceptable range.

### 4.1.5 Approaches in SP&SD of green buildings

The interviewees were invited to list some common approaches used in SP&SD in green buildings, most of them stated that in SP&SD, more important things are the skills, attitudes, and understandings of the architects and designers. While some of they still provide several effective approaches in SP&SD of green buildings such as flexible approach, negative planning, biophilic design, regenerative approaches, and participatory planning. Flexible planning approach leaves rooms for future adjustment, modification or revision, which is applicable in urban development. Negative planning is a reverse spatial planning method which gives priority to preserving and planning nonurban development area. Biophilic design is a sustainable design in architecture which re-connect people with the natural environment, including natural materials, natural light, vegetation, natural views and other experiences of the natural world into the modern built environment. Regenerative approach includes the systemic view and the continuity of the developmental process, in order to pursue the required co-evolutionary partnership between ecological and socio-cultural systems\[24\]. Participatory planning\[25\] enables users to anticipate possible conflict situation and to propose methods possessing maximum satisfaction from the viewpoint of the public.

### 4.2 A preliminary framework for SP&SD of green buildings

Based on the major variables proposed by desk study conducted by the authors\[14\], and the interview data analysis, a preliminary framework for SP&SD of green buildings was drawn in Figure 2.
5 Conclusion

SP&SD, as the smallest sale of urban development, is a key issue in green building development. A preliminary framework for SP&SD of green buildings was developed to lay a foundation to effective SP&SD in the future. In this research study, a desk study conducted by the authors was taken as a reference to identify main variables in SP&SD of green buildings, and 12 face-to-face interviews were conducted to explore other essential elements in a framework for SP&SD of green buildings, including whole process of SP&SD in green buildings, design principles, relationships between stakeholders, and effective planning and design approaches in green building development. Content analysis and coding were conducted to analyze the interview data. The preliminary framework can provide references for effective and comprehensive SP&SD in green building development. To validate the proposed framework, further research study such as case study will be conducted in the future.

References


An Exploration on the Planning and Positioning of Characteristic Towns in China: The Perspective of Industrial Agglomeration and Ecological Livability

Yu Yang¹, Qinlu Chen², Yuzhe Wu³*

Abstract: The characteristic town is a new thing in the development process of Chinese cities and a new carrier of China's new urbanization. In this paper, from the perspective of industrial agglomeration and ecological livability, we put forward two planning and positioning ideas for the characteristic towns: the tag-end of cities and the front-end of rural areas. Moreover, we choose Longquan Celadon Town and Hangzhou Deqing Moganshan Town from Zhejiang Province, China these two cases to carry out an in-depth analysis and comparison of their positioning and development. The methods used in this paper mainly include: literature review, case analysis and comparative study. Finally, around the planning and positioning of characteristic towns, the article will put forward our own suggestions on their developing mechanisms. We think that the planning and positioning of characteristic towns should be based on regional characteristics, involve both in industrial agglomeration and ecological livability but have a focus on one aspect to make better planning strategies.

Keywords: Characteristic towns; Urban tag-end; Rural front-end; Industrial agglomeration; Ecological livability; Planning and positioning.

---

¹ Yu Yang
Department of Land Management, Zhejiang University, Hangzhou 310058, China

² Qinlu Chen
Department of Land Management, Zhejiang University, Hangzhou 310058, China

³* Yuzhe Wu
Corresponding author, Department of Land Management, Zhejiang University, Hangzhou 310058, China
E-mail: wuyuzhe@zju.edu.cn
1 Introduction

1.1 International background

“Characteristic town” concept is not a Chinese original idea, it has a certain historical development base in the Western countries. Foreign characteristic towns generally cultivate the leading enterprises or basic industry to a certain space gathered, and finally the formation of industrial clusters, coupled with the town's own high-quality ecological and cultural resources, and ultimately the characteristic towns take shape. Those international characteristic towns have a global-wide influence based on their industrial characteristics (Table1). For example, Grasse is not only the world's most famous source of perfume raw materials, but also the world's fragrant lovers pilgrimage. Only perfume products with the words of “made in Grass” will be recognized as a combination of luxury, elegance and high quality. [1]

There are also many theoretical models on development of small town. Though empirical research, McGee (1991) found that the linkages between rural and urban areas is increasingly close, and he labeled those spatial zones on the peri-urban fringes of the city cores characterised by the most intense interaction between urban and rural processes as “desakota”. [2][3] Mike Douglass (1991) thought that regional network system between urban and rural area should be established though the study of northeastern Thailand. [4] Giffinger et al. (2007) put forward the idea of a smart city. [5] Toppeta (2010) set up three - dimensional development model of urbanization in 2010. [6] Based on the above concept, small town model proposed by Bajracharya (1995) began to attract much more attention. [7]

<table>
<thead>
<tr>
<th>Nation</th>
<th>Name</th>
<th>Positioning</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>America</td>
<td>Hershey</td>
<td>The world’s sweetest place</td>
<td>Chocolate and candy making</td>
</tr>
<tr>
<td></td>
<td>Greenwich</td>
<td>Greenwich Fund town</td>
<td>Hedge Fund</td>
</tr>
<tr>
<td>France</td>
<td>Grasse</td>
<td>Agricultural industrialization town</td>
<td>Flowers and plants and perfume industry</td>
</tr>
<tr>
<td></td>
<td>Provence</td>
<td>The most romantic city in the world</td>
<td>Tourism</td>
</tr>
<tr>
<td></td>
<td>Vichy</td>
<td>Spa health resort</td>
<td>Spa health industry</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Davos</td>
<td>Spa resorts, conferences, sports resorts</td>
<td>Leisure industry</td>
</tr>
<tr>
<td>Germany</td>
<td>Herzogenaurach</td>
<td>Global Sporting Goods Center</td>
<td>Sporting goods</td>
</tr>
</tbody>
</table>

1.2 China's practices

In 2014, the CPC Central Committee and the State Council issued the "National New Urbanization Plan (2014-2020)", which proposed to focus on the development of small towns with special resources and location advantages, and cultivate professional characteristic towns through the planning and guidance. In the same year, the first public reference of the "Characteristic Towns" concept is put forward when the governor of Zhejiang Province Qiang Li visited the "Cloud Habitat Town" in Hangzhou. In April 2015, the Zhejiang provincial government issued a related document and proposed to strive to cultivate and plan around 100 characteristic towns through 3 years. Then the characteristic towns model proposed by Zhejiang was approved by the central government. So

in 2016, Ministry of Housing and Urban Rural Development and the other two national ministries jointly issued "Notice on Carrying out the Cultivation of Characteristic Towns ". Since then, the cultivation of characteristic towns has risen to be a national action, and a total of 127 first small towns with Chinese characteristics have been set up at the national level. China has rose boom of "characteristic town" construction.

In the official documents of Zhejiang Province, the positioning of the characteristic towns is: relatively independent of the urban area, with clear industry positioning, cultural connotation, tourism resources and a certain community function platform. \(^5\) Zhejiang Province currently approved to create provincial characteristic towns with a total number of 79, each of the characteristic towns’ industrial positioning is around their own historical and cultural characteristics and industrial base. Focusing on the information economy, environmental protection, health, tourism, fashion, finance and other future pillar industries, but also take into account the tea, silk, rice wine, Chinese medicine, celadon, wood carving, stone carvings and other historical and classic industries, to realize the integration of production, life and ecology, to achieve the mixed use of the industry, culture, tourism and living functions.

2 Literature review

In the opening of the "Wealth of Nations", Adam Smith wrote such a story of making a paper clip. If a person makes a paper clip alone, the maximum efficiency of the day is 1 to 20 (depending on its proficiency). Yet by 10 people and the composition of the production chain, one day we can produce 48,000, an average of 4800 per person, and the efficiency increased by 240 ~ 4800 times. \(^8\) For the agglomeration, Yuzhe Wu (2013) gave another vivid example. \(^9\) In the transport industry, for lack of agglomeration, rural areas cannot guarantee everyday transport tasks. Only in the town the transport industry can be produced.

In 2009, the World Bank's World Development Report improved the traditional definition of urbanization, combined with spatial density and distance estimates, and proposed the concept and measurement of agglomeration index. \(^10\) This index considers that the following three conditions are met in the agglomeration area (or dense area) as a benchmark for arriving in the town: (1) population density exceeds a certain threshold, the specific measure used in 150 people / km\(^2\); (2) arrives at a larger gathering area within 60 minutes of a specific measure within a defined reasonable traffic time; (3) reaches a threshold of 50,000 people.

As for agglomeration in the construction of small towns, Zhiyang Liu (1999) pointed out that the largest population gathering is the real goal of small towns’ construction.\(^11\) P Martin and GIP Ottaviano (2010) presented a model in which growth and geographic agglomeration of economic activities are mutually self-reinforcing processes. \(^12\) SS Rosenthal and WC Strange (2001) examined the micro foundations of agglomeration economies for U.S. manufacturing industries, and the results indicate that proxies for labor market pooling have the most robust effect, positively influencing agglomeration at all levels of geography.\(^13\) Analysis of Masahisa Fujita and Jacques-François Thisse(2003) supported the idea that the additional growth spurred by agglomeration may lead to a Pareto-dominant outcome such that, when the economy moves from dispersion to

---

In the Garden City theory, Ebenezer Howard (1898) argued that the influx of rural labor into the city lies in the "gravitation" of large cities. So he proposed to establish a "new gravity" to overcome the "old gravity." Every city can be regarded as a magnet, and each person as a magnetic needle. At the same time, only to find a way to constitute a gravity greater than the existing city of the magnet can we get to effectively, naturally and healthily redistributed population. The city's complete infrastructure, full employment opportunities attract a large number of rural population to urban migration. So that many people think that the city and the village can only choose one, that is, the city and the countryside must be separated. But Howard believes that the characteristics of urban and rural areas can be integrated. Based on the "people-oriented" concept, the construction of natural environment beautiful small towns which are close to the fields and parks, with full employment opportunities, high wages, low rent, no smoke, no slums and free cooperation is possible.

The study carried out by A Zanella, AS Camanho and TG Dias (2015) developed a tool to assess livability in European cities covering two components of livability: human wellbeing and environmental impact, which emphasized the livability of cities and people's life quality. Research of Nan Chen, Keshi Chen and Xinyu Li (2015) was based on the case of Yilan County in Taiwan, which demonstrated the possibility of transforming a backward agricultural town into developed pastoral city, and the possibility of long-term development with environmental quality as the goal.

For China's characteristic towns, population agglomeration is the most basic requirement. Only a certain number of people gathered in the town, the town's infrastructure can be more perfect, the town's living costs can be lower, the town's industrial division of labor can be more and more efficient, and so that the town can be more dynamic. If there is no sufficient number of people and the accumulation of various factors of production, the characteristic towns can only be regarded as rural areas. At the same time, the urban traffic distance cannot be more than 1 hour by car, which means they need to be in the 1-hour traffic circle with urban areas to maintain close contact.

Secondly, characteristic towns must meet the requirement of ecological livability, with a sound infrastructure and a beautiful ecological environment at the same time. And strive to become the perfect combination of urban and rural advantages and China's unique pastoral city.

### 3 Two ideas on the planning and positioning of characteristic towns

Due to the unique urbanization process of Chinese characteristics, gaps between the city and countryside are significant, resulting in a significant urban-rural dual development structure. Based on China's urban-rural dual development pattern, we have mapped the urban-rural transition band spectrum of Fig1. In Figure 1, we use agglomeration to refer to the characteristics of the city and livability to represent the characteristics of rural areas. Agglomeration and livability are at both ends of the banded spectrum while the characteristic town is located in the middle of the spectrum with combination of the advantages of both city and rural areas. Of course, we can also say that the characteristic town is the tag-end of the city (lower agglomeration level than the city but the degree of livability close to the countryside). Meanwhile, it can also be described as the front-end of the countryside(lower livability level than the rural areas but a higher degree of industrial agglomeration)

It is important to note that, in our study, agglomeration mainly refers to the developing
condition of local industrial economic, including industry, population and the accumulation of various factors of production. And livability mainly refers to the local living environment, including the natural environment, life supporting infrastructure and so on.

Figure 1: Band spectrum of urban and rural transition in China

The planning positioning of characteristic towns at the tag-end of the city is based on a certain degree of agglomeration to meet the ecological needs of living. Driven by radiation in metropolitan areas, characteristic towns at the tag-end of the city already have a certain agglomeration base. And these towns are generally able to meet the "one hour traffic circle" requirements. As a new carrier of the new urbanization, characteristic town is an important way to alleviate the "urban disease" of the Chinese city. Its beautiful ecological environment construction and convenient infrastructure can not only provide comfortable pastoral scenery, but also it is easily covered by the metropolitan infrastructure and related services. Therefore, as the tag-end of the city, characteristics towns achieved economic agglomeration on the basis of ecologically livability, become the ideal habitat for urban residents.

The planning positioning of characteristic towns at the front-end of the rural area is based on its comfortable ecological environment to meet the agglomeration requirements of industry and infrastructure. The planning address of characteristic towns located in the rural front is generally in the urban suburbs. Compared to the city, this kind of towns has a more close to the rural ecological environment of living conditions. And compared to rural areas, its infrastructure and industry agglomeration degree is far ahead. Whether through the population, capital, infrastructure or other high-end industrial elements of the gathering, the construction of characteristic towns will be an important part of urbanization in rural areas. And characteristic towns will be the integration of urban and rural areas of their own characteristics, achieve agglomeration of infrastructure, special industries and urban civilization in the ecological livable conditions.

In order to understand the planning positioning of the characteristic towns better, we will need some cases to compare and explain. The concept of the characteristic town originated in China's Zhejiang Province, and the development of characteristic towns in Zhejiang is also more mature and successful. So we chose two characteristic towns from Zhejiang Province as the representatives of the development of Chinese characteristic towns to illustrate their planning positioning and to confirm our point of view.

4 Cases of characteristic town in Zhejiang Province

4.1 Urban tag-end: Moganshan Town

Moganshan Town is located in west of Deqing County, Huzhou, Zhejiang Province, adjacent to the state-level scenic spots – Mogan mountain. Its area is 185.77 square kilometers. The town is located in the hinterland of the Yangtze River Delta, about 100 kilometers away from Shanghai, and about 40 kilometers from Hangzhou city (Figure 2), which is an important part of Hangzhou metropolitan
area. The town has jurisdiction over 18 administrative villages, 3 residential quarters with the household population of 31000 people and the resident population of 31000 people.6

There are many historical buildings in the town, of which the national cultural relics protection units "Moganshan villa group" have reached 238 villas. In recent years, there are a large number of artists, designers practice "low-carbon environmental protection" concept through low-carbon tourism and homestays, which will also help to achieve "ecological pure" pursuit. The town is also known as the "Universal Villa Expo Park", with magnificent Western villas all over the area. At the same time, Moganshan town is also based on the culture of the Republic of China, creating a unique atmosphere of the Republic of China, making the town and Moganshan scenic complement each other. Inside the town, the mountains stretch, the natural resources are very rich, and there are 232 thousand acres of forest, forest coverage rate of more than 90%.

The town provides convenient traffic and parking facilities, and actively builds the slow traffic circle around Mogan Mountain. In accordance with relevant standards, flood prevention, fire prevention and other disaster prevention facilities have been built. Urban infrastructure has been basically covered in rural areas, initially realizing the integration of urban and rural development. Taking people's livelihood as the foundation, the town government has constantly improved the public facilities such as medical, educational, cultural, business and administrative services, and also improved the quality of service.

The town's beautiful ecological environment construction and convenient infrastructure make it easy for people to enjoy the comfort of pastoral scenery and can be easily covered by the metropolitan infrastructure and related services. As an important part of the Hangzhou metropolitan area, based on its urban tag-end planning positioning, Moganshan Town has realized the livability based on agglomeration, which is the ideal habitat for urban residents.

![Figure 2: Locations of Moganshan Town and Celadon Town](image)

6 Data source: Deqing County Moganshan Town People's Government official website http://mgs.deqing.gov.cn/contents/964/18125.html
4.2 Rural front-end: Longquan Celadon Town

Longquan Celadon Town (shown in Figure 2) formerly is known as Shangyang town, located in west of Longquan City, Zhejiang Province, 36 km from Longquan City. Celadon Town has a total area of 162 square kilometers, and the total population is about 17,000 people. There are criss-crossing streams and high and low peaks in the town, and the scenery is very beautiful. At the same time, traffic here is also very convenient with Longpu high-speed and 53 provincial highway passing through the town. The town's GDP in 2015 was 650 million yuan, per capita net income of urban residents was 29011 yuan, and per capita net income of rural residents reached 14583 yuan.7

According to the characteristic towns’ development data in the first quarter announced by the Lishui Municipal Government in May 2016, we found that Longquan Celadon Town has made great achievements in this year. The total investment value of fixed assets was 24.0550 million yuan (including 18.42 million yuan as the investment of special industries), the private investment was 10.71 million yuan, and the total industrial output value was above 19255.10 million yuan. From the beginning of the year to the end of the season, the total number of tourist reception reached 137.7 million people.

In its planning and construction process, Longquan Celadon Town, on the one hand, focused a lot on exploring the traditional celadon skills and culture. On the other hand, in order to achieve the revitalization of celadon culture and promote the construction of new urbanization, Longquan celadon town vigorously strengthened the research, design and other aspects, paid much attention to creating a strong celadon brand, so that the degree of recognition of celadon brand can get further improved. At the same time, through the construction of Shanghai and Shangyang these two windows, Celadon Town solved the problem of narrow sales channels, which is more conducive to the internationalization of celadon town and market-oriented development.

It can be seen that, on the basis of historical culture and industrial background, through the continuation of historical context, respect for tradition and focus on cultural connotation and distinctive features, Longquan Celadon Town successfully achieved further innovation and development of historical culture and traditional industries. The town gathered a large number of high-end production factors, and thus brought great economic and social benefits, led the regional economic progress and prosperity.

5 Findings

Through case analysis and horizontal comparison, we find that China's characteristic towns have roughly two planning positions: the urban tag-end or the rural front-end. Characteristic towns as the urban tag-end, such as the Moganshan Town, enjoying superior infrastructure and service brought by cities nearby, can get the city's radiation of development, which exactly promoted the urbanization process. This type of town should strengthen the construction of ecological environment in the planning and construction, and strive to cultivate suitable pastoral complex for city residents to travel and go sightseeing. That means, on the basis of a sound infrastructure, such town need to take the ecological livability as a unique advantage.

---

7 Data source: Lishui City Bureau of Statistics
Characteristic towns as the rural front-end, such as the Longquan Celadon Town, which is far from the city and relatively lack of infrastructure but has good natural environment. In order to accumulate high-end production factors, this kind of towns should play their own unique advantages under the premise of the protection of the ecological environment and constantly improve the infrastructure to create more attractive business environment and industrial atmosphere.

| Table 2  Comparison of the two characteristic towns |
|-----------------|-----------------|
|                | Moganshan Town  | Longquan Celadon Town |
| Population      | 31000           | 17000                |
| GDP in 2015     | 1.065 billion yuan | 650 million yuan    |
| Distance from the nearest county | 10 km          | 36 km               |
| Distance from Hangzhou | 40 km          | 400 km              |
| leading industry | Leisure tourism industry | Celadon industry and tourism |
| Positioning features | Suburban leisure town | Historical and cultural town |

6 Discussion and Conclusions

Our exploration on the planning and positioning of the characteristic towns is based on two aspects of industrial agglomeration and ecological livability. No matter how characteristic towns develop, they must achieve economic efficiency and livable environment these two most basic requirements. But in fact, we can lead to many different conclusions on how to plan and build a characteristic town from many different angles. Specific planning and construction should be based on the local actual economical, natural and social conditions, which would help to get their own local characteristics of industry and irreplaceable competitiveness of development.

As a conclusion, in the planning and development of characteristic towns, we should develop livability in the urban tag-end and strengthen industrial agglomeration in the rural front-end. The government needs to find a Pareto optimal between agglomeration and livability, trying to build a new "pastoral city" with the integration of the advantages of both urban and rural areas and achieve both industrial agglomeration and ecological livability.

Acknowledgments

The research is supported by the National Natural Science Foundation of China (No.71373231).

Reference


Predesign Quantity Estimation for Building Information Modelling using Support Vector Machine

Idowu, O.S. 1*, Lam, K.C. 2

Abstract: Conceptual cost models are necessary for project planning at stage 0 and 1 of the Royal Institute of British Architect (RIBA) plan of work. However, existing cost models are considered as black box models and do not provide cost details of materials, personnel and equipment at the conceptual stage of a project. Consequently, conceptual cost models cannot take advantage of the parametric nature of building information modelling (BIM). The development of models for estimating conceptual quantities of framed reinforced concrete (RC) structures using supervised machine learning is the aim of the current research. Predictor variables such as live loads and soil bearing pressures were defined and used for constructing conceptual quantity models for RC foundations. Quantity models were developed for comparison using a combination of non-parametric support vector regression, linear regression and bootstrap resampling techniques. Gross soil reaction and gross floor loading were discovered to have a major influence on the quantities of concrete and reinforcement used for RC foundations. The outcome of the research showed that conceptual quantities can be a source of parametric information for use in BIM prior to 2D and 3D parametric modelling. Future research could explore the modelling of conceptual quantities for walls, finishes and services using machine learning techniques. Estimating conceptual quantities could assist construction planners in early resource planning and cost control.

Keywords: Conceptual quantities; Bootstrapping; Building Information Modelling; Reinforced concrete; Support vector regression.

1* Idowu, O.S.
Corresponding author, Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong SAR
E-mail: osidowu2-c@my.cityu.edu.hk

2 Lam, K.C.
Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong SAR
1 Introduction

Budgetary requirements and project viability make the need to ascertain the cost of construction at the conceptual stage of building projects a necessary task\textsuperscript{[1,2]}. Conceptual cost models can be used to provide cost estimates for building projects at stage 0 and 1 of Royal Institute of British Architect (RIBA) plan of work. Recent trends in conceptual cost modelling has seen an increase in the use of artificial intelligence to provide early cost estimates of building projects. However, several conceptual cost models can be considered as black box models. The reasons are: (1) the output of the models does not provide any information or detail on constituent parts that make up construction cost, and (2) the relationship between construction resources and cost is not provided by the models.

The output of existing conceptual cost models are not parametric in nature, hence, are of limited use in building information modelling (BIM) for cost control purposes except at stage 6 during final accounts. The BIM framework is parametric in nature\textsuperscript{[3-5]}. The parametric framework (PF) of BIM is evident in the various definitions of BIM\textsuperscript{[3,6]}. The PF of BIM through the use of the industry foundation classes (IFC) facilitate sharing, viewing, extraction and manipulation of information between construction professionals\textsuperscript{[3,4,7]}. The communication of budgetary information to guide project design within the PF of BIM has not been given detailed attention in the literature. The concept of 5D BIM is only applicable when parametric 3D information is available\textsuperscript{[6]}. However conceptual cost is required at stage 0 and 1 of RIBA plan of work when parametric 3D information are not available.

In view of the stated limitations of current conceptual cost models, this paper aims to develop models for estimating conceptual quantities using a machine learning technique. The main objective of this research is to predict the quantities of structural elements for reinforced concrete (RC) buildings without the need for sketch drawings or 3D-BIM. The current research is part of an ongoing academic work, and due to the importance of foundation construction, foundation quantities of RC is presented in this paper. The outputs of the models developed in this paper are quantitative in nature and could provide parametric information for cost control purposes within the PF of BIM. Similarly, other anticipated benefits of conceptual quantity models in the architecture, engineering and construction (AEC) industry includes: (1) reduction in the time for preparing tender bills of quantities, (2) improved cost certainty at the conceptual stage, and (3) performance evaluation of early cost prediction at all phases of the construction process.

2 Existing conceptual quantities models

Existing literature highlights the importance of modelling conceptual quantities\textsuperscript{[1,8,9]}. The Multi Step Ahead (MSA) approach to conceptual cost reported in Reference 1 and the hybrid technique used in Reference 8 justified the use of building element quantities (BQ) and construction material quantities (CMQ) in cost prediction models. The BQ and CMQ models were developed based on knowledge discovery in databases (KDD) methodologies. The primary focus of the MSA model was not to predict the BQ, but to use the predicted values of the BQ to improve prediction accuracy of the first level of cost groups of the entire MSA model. Overall, the prediction accuracy (mean absolute percentage error) of the BQ models were considered adequate. The model of Reference 8 was designed to meet the Association for the Advancement of Cost Engineering (AACE) class 4 estimates for process industries. The CMQ of Reference 8 was the total of material quantities (concrete and reinforcement) for storage units. There was no detailed elemental breakdown, probably due to the type of structure considered; Greenfield cement plants. Having insight into cost estimates provides managers the ability to make informed decisions, adequately track progress and control project resources during conception, bidding and construction phases of projects\textsuperscript{[6]}.

3 Research method

Modelling quantities of foundation element by using project information such as live load and soil bearing pressure as predictor variables is explored in this research. Modelling can be defined as the process of imitating or representing real life systems or phenomena\textsuperscript{[10-12]}. The final output of the process is called a model. Models require theoretical and operational
constructs in order to observe the relationships between variables and represent real-life phenomena\(^{[12,13]}\). There are at least 14 KDD methodologies for modelling\(^{[14]}\). The cross industry standard platform for data mining (CRISP-DM) is one of the KDD methodologies for modelling. The CRISP-DM is considered a standard for data mining and knowledge discovery which can be applied to a wide range of disciplines\(^{[14,15]}\), and is therefore adopted for this study. The six stages of the CRISP-DM as shown in Figure 1 are: business understanding, data understanding, data preparation, modelling, evaluation and deployment. Modelling tools such as statistics, rule-based computer programs and machine learning (Neural Networks) has been used in previous quantities modelling research\(^{[1,8,9]}\). However, the use of support vector machines (SVM) for conceptual quantities estimation has not been explored in detail in the literature. SVM has been reported to have good predictive capabilities, and has been used extensively in fields of computer vision and language processing with promising results\(^{[16]}\). Therefore, this research explores the use of SVM for quantities prediction. The SVM modelling tool as adapted in this research is described in the next section.

![Figure 1. Methodological framework for CRISP-DM](image)

### 3.1 Modelling technique: support vector regression and bootstrapping

Support vector regression (SVR) is an implementation of support vector machine (SVM) for quantitative response\(^{[17]}\). SVM is a supervised machine learning algorithm used for solving classification and regression problems and is based on advanced statistical learning theories\(^{[17,18]}\). The objective of SVR is to find a regression function based on a set of input data which can be used to predict a desired value (output). The underlying principle is to transform data into a new and higher dimensional space using a kernel function. Linear hyperplanes are further constructed to regress the transformed data in the higher dimensional space. The kernel function provides the ability to implicitly compute the inner products of the features (predictors) in the higher dimensional space. The mathematical representation of SVR is given as:

\[
\hat{y} = f(x) = \sum_{i=1}^{N} (\alpha_i^* - \alpha_i) k(x_i, x) + b, \quad (1)
\]

where, \(\alpha^*\) and \(\alpha\) are Lagrange multipliers, \(b\) is bias and \(k(x_i, x)\) is the kernel function that implicitly maps the predictors into a higher dimensional space. There are various kernels that can be implemented such as polynomials function and Gaussian radial basis function (RBF). For the SVR function to be estimated, the regularization constant (\(C\)), the loss function (i.e., epsilon-insensitivity (\(\epsilon\))) and the kernel parameter must be specified\(^{[19]}\). The RBF kernel is used in this research due to its reported good performance for regression tasks\(^{[19,20]}\). The kernel parameter for RBF is the sigma (\(\sigma\)). The SVR equation for modelling conceptual quantities for the current research is given as (2).

\[
f(x) = \sum_{i=1}^{N} (\alpha_i^* - \alpha_i) \exp\left(-\frac{||y_i - \hat{y}||^2}{2\sigma^2}\right) + b \quad (2)
\]

The bootstrap method belongs to the class of resampling methods such as the jackknife and subsampling\(^{[21]}\). Nonparametric bootstrap with replacement is employed in the current research. For each bootstrapped dataset, regression coefficients and SVR hyperparameters (\(C\), \(\epsilon\) and \(\sigma\)) are used to make predictions in the current research. Nonparametric bootstrap does not require any assumption about the distribution of a population statistic. Thus, providing the advantage of observing the probability distribution function of any statistic.
of interest for a given population or dataset. The bootstrap method provides a means of generalizing a population where the number of original samples are not large enough or where observation of the entire population is not feasible. The current research explores the stated advantages of the bootstrap resampling method for range prediction of conceptual quantities.

4 Definition of model variables

Project data from a total of 21 RC buildings (9 residential and 12 commercial buildings) designed using B8110 were collected for the research. Five predictor variables and one response variable are considered in each of the models. The predictor variables are total gross floor loading (GFL), total building height (H), Number of Floors (NF), gross soil reaction (GSR) and building footprint (BF). The response variable in each model are the measured foundation quantities (i.e., concrete volumes, reinforcement tonnage and formwork area). The soil bearing pressure, design live load, total gross floor area, gross floor area of the lowest floor in contact with the foundation, H, NF and foundation quantities were obtained from output sheets of structural calculations and structural drawings supplied by structural engineering firms in Nigeria. The definition of predictor variables as used in this paper are presented next

4.1 Gross floor loading (GFL) and gross soil reaction (GSR)

The function of a building determines the value of the design characteristic live load ($Q_k$). The $Q_k$ in combination with other design parameters are used in designing the sizes of structural members and finally the quantities of materials. Previous studies has reported the significant impact of gross floor area (GFA) on construction cost. Hence, GFA was combined with the $Q_k$ to form a new predictor variable called GFL in order to explore the relationship between quantities of foundation elements and total building live load.

The type and size of a foundation is an essential part of foundation design, and is largely dependent on the soil strength. The foundation of a building is determined by the effective stress distribution of the soil around and below the foundation unit. Therefore, before any foundation design (type and size) can be carried out, the strength of associated soil profile must be established. Material quantities are usually derived from the dimensions (e.g., length, breadth, width, depth, height, and thickness) of structural elements. By reason of the effect of soil bearing pressure on the size of foundations, this research also seeks to explore the relationship between soil bearing pressure and material quantities of foundation elements. Hence, the soil bearing pressure is used in combination with the GFA of the lowest floor in direct connection with the foundation unit and soil to form the GSR variable. The GSR is defined in this research as the total reactive or upward force of the soil beneath the building footprint. The word “reaction” is used in GSR to characterise the direction of soil resistance, which is upward against the building load.

4.2 Building footprint (BF), height (H) and number of floors (NF)

Conceptual cost models have shown that BF, H and NF are significant variables affecting the cost of construction. Hence, the three variables are also used in the development of the models, as they can be obtained during stage 1 of the RIBA plan of work. The BF is the area of the floor closet to the natural ground level, and gives an indication of the size of a building in relation to the area of the project site. In the current research, H is taken up to the top level of concrete roof beams and slabs.

5 Modelling RC foundation quantities

Nonparametric regression is employed for modelling the quantities of the foundation element. Nonparametric regression aims to predict continuous values from a set of distribution without a priori knowledge of the distribution parameters. Tied rank Spearman was used to investigate the monotonic relationship and linearity of the variables. Tied rank Spearman correlation (3) is considered appropriate for nonparametric measure of rank correlation when an observation repeats more than once for any variable in a dataset.

The correlation matrix as shown in Table 1 is a relative mix of weak and strong
relationships, indicating variable monotonicity and non-linearity between the predictor and response variables.

### Table 1. Correlation matrix of predictor and response variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Tied rank Spearman’s correlation ($R_p$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GFL</td>
</tr>
<tr>
<td>GFL</td>
<td>1.000</td>
</tr>
<tr>
<td>GSR</td>
<td>0.806</td>
</tr>
<tr>
<td>H</td>
<td>0.617</td>
</tr>
<tr>
<td>NF</td>
<td>0.525</td>
</tr>
<tr>
<td>BF</td>
<td>0.837</td>
</tr>
<tr>
<td>FNDN.CONC</td>
<td>0.920</td>
</tr>
<tr>
<td>FNDN.RFT</td>
<td>0.614</td>
</tr>
<tr>
<td>FNDN.FMK</td>
<td>0.176</td>
</tr>
</tbody>
</table>

\[ R_p = 1 - 6 \left( \sum_{i=1}^{l} d_i^2 + \frac{1}{12} \sum_{j=1}^{k} m_j \left( m_j^2 - 1 \right) \right) + n \left( n^2 - 1 \right) \]  

Where $d$ is rank deviation, $m$ is the number of times a particular data repeats for a particular variable in the dataset, and $n$ is the number of observations in the dataset.

A total of 12 linear (LR) models were initially constructed. Four linear models for each response variable was designed with predictors as shown in Table 2. The root mean squared error (RMSE), the sum of square error (SSE) and the Adjusted $R^2$ were computed for all the constructed linear models. Models with the lowest RMSE, lowest SSE and highest Adjusted $R^2$ values are considered as “models with a good fit”. However, a good fit does not necessarily mean good predictive accuracy\[2,17\]. Based on the stated metrics as shown in Tables 3 to 5, the LR-4 was selected as it had the lowest RMSE and SSE values for all response variables. The selection of LR-4 reduced the number of linear models to 3. A total of 3 SVR models were then constructed using the variables from the LR-4 models. Having equal number and type of predictor and response variables in the selected LR and SVR models provides a basis for adequate comparison between the models. The SVM was trained using 18 projects representing 85% of the total data collected. A 3-fold cross-validations was implemented during model development for performance comparison. In order to reduce the propensity of over or under fitting the models, optimization of the hyperparameters ($C$, $\sigma$ and $\varepsilon$) was performed by grid search for each of the SVR models. Bootstrap technique was subsequently used to generate 5000 datasets. The developed LR and SVR models were then implemented on the bootstrapped datasets to provide range predictions for foundation quantities.

### Table 2. Predictor variables used for constructing classical linear models

<table>
<thead>
<tr>
<th>Model</th>
<th>Type of regression model</th>
<th>Number of predictors</th>
<th>Predictors</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR-1</td>
<td>Linear</td>
<td>1</td>
<td>GFL</td>
</tr>
<tr>
<td>LR-2</td>
<td>Linear</td>
<td>2</td>
<td>GFL, GSR</td>
</tr>
<tr>
<td>LR-3</td>
<td>Linear</td>
<td>3</td>
<td>GFL, GSR, H</td>
</tr>
<tr>
<td>LR-4</td>
<td>Linear</td>
<td>4</td>
<td>GFL, GSR, H, NF</td>
</tr>
</tbody>
</table>

### Table 3. Metrics for foundation concrete

<table>
<thead>
<tr>
<th>Model</th>
<th>RMSE (m³)</th>
<th>SSE (m³)²</th>
<th>Adj. $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR-1</td>
<td>77.686</td>
<td>104,630.65</td>
<td>0.628</td>
</tr>
<tr>
<td>LR-2</td>
<td>68.403</td>
<td>84,221.18</td>
<td>0.692</td>
</tr>
<tr>
<td>LR-3</td>
<td>63.498</td>
<td>72,575.65</td>
<td>0.716</td>
</tr>
<tr>
<td>LR-4</td>
<td>62.975</td>
<td>71,386.41</td>
<td>0.699</td>
</tr>
</tbody>
</table>

### Table 4. Metrics for foundation reinforcement

<table>
<thead>
<tr>
<th>Model</th>
<th>RMSE (kg)</th>
<th>SSE (kg)²</th>
<th>Adj. $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR-1</td>
<td>13,103.400</td>
<td>3,090,582.348.00</td>
<td>0.136</td>
</tr>
<tr>
<td>LR-2</td>
<td>12,954.060</td>
<td>3,020,537.028.00</td>
<td>0.100</td>
</tr>
<tr>
<td>LR-3</td>
<td>10,484.260</td>
<td>1,978,553.873.00</td>
<td>0.368</td>
</tr>
<tr>
<td>LR-4</td>
<td>10,429.960</td>
<td>1,958,114.228.00</td>
<td>0.327</td>
</tr>
</tbody>
</table>
Table 5. Metrics for foundation formwork

<table>
<thead>
<tr>
<th>Model</th>
<th>RMSE (m²)</th>
<th>SSE (m²)</th>
<th>Adj. R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR-1</td>
<td>113.021</td>
<td>229,928.30</td>
<td>(0.026)</td>
</tr>
<tr>
<td>LR-2</td>
<td>112.687</td>
<td>228,570.50</td>
<td>(0.088)</td>
</tr>
<tr>
<td>LR-3</td>
<td>111.017</td>
<td>221,844.80</td>
<td>(0.131)</td>
</tr>
<tr>
<td>LR-4</td>
<td>106.032</td>
<td>202,370.40</td>
<td>(0.111)</td>
</tr>
</tbody>
</table>

6 Range estimating and validation

Range estimates were developed and validated for 3 LR and 3 SVR models. 5000 datasets consisting of 18 observations per dataset were bootstrapped with replacement for each LR and SVR model. The models were then used to make 5000 predictions in order to obtain range predictions for quantities of structural elements. The range predictions were further used to obtain the probability distribution function for each structural quantity. An effective way of assessing the predictive performance of regression models is by measuring the deviations between the predicted values of the models and the expected value based on a set of input. The performance of the model was evaluated using the absolute percentage error APE (APE=$\left|\frac{E_{qy} - P_{qy}}{E_{qy}}\right|\times 100\%$), where $E_{qy}$ and $P_{qy}$ are the expected and predicted quantities respectively. Three out-of-sample projects were used in validating the models.

The statistics obtained from the range estimates were the median, mode and mean values. Predicted median quantities were used for validating the models. Median quantities were preferred as they are not affected by outliers and are more suitable as a measure of central tendency for skewed distributions. Modal quantities have the challenge of multi-modal values and are more suited for ordinal data. Mean quantities on the other hand, are only reliable where the distribution is not skewed, and the effect of outliers are insignificant\,[31,32]. In a total of 18 predictions (9 LR and 9 SVR) as shown in Table 6, approximately 55% of the SVR models had a median APE of less than 20%. However, approximately 22% of the LR models had a median APE of less than 20%. The highest median APE for the SVR and LR models were 52.772% and 87.378% respectively. This implies that the SVR model has a better predictive accuracy than the LR model for estimating quantities in foundations.

Table 6. Absolute percentage error of median quantities in foundation

<table>
<thead>
<tr>
<th>Project</th>
<th>Foundation concrete</th>
<th>Foundation reinforcement</th>
<th>Foundation formwork</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LR</td>
<td>SVR</td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>33.373</td>
<td>1.250</td>
<td>47.299</td>
</tr>
<tr>
<td></td>
<td>19.754</td>
<td>34.754</td>
<td>52.772</td>
</tr>
<tr>
<td>P2</td>
<td>48.999</td>
<td>8.457</td>
<td>81.047</td>
</tr>
<tr>
<td></td>
<td>34.754</td>
<td>52.772</td>
<td>87.378</td>
</tr>
<tr>
<td>P3</td>
<td>36.052</td>
<td>41.599</td>
<td>87.378</td>
</tr>
<tr>
<td></td>
<td>50.125</td>
<td>52.772</td>
<td>52.772</td>
</tr>
</tbody>
</table>

Sensitivity analysis was performed on the SVR models in order to gain knowledge from the information extracted by the supervised machine learning algorithm. Sensitivity analysis provides an insight into the SVR models by showing the importance of predictor variables on response variables\,[33]. The sensitivity analysis showed that GSR and GFL are important variables that affects quantities in foundations as shown in Figure 2. Although the NF and H are also important, the sensitivity analysis suggests that GFL and GSR has a greater influence on quantities in foundations than NF and H.

Figure 2. Sensitivity bar chart of predictors on foundation quantities
7 Conclusions

The present research was designed to estimate conceptual quantities by modelling the effect of GFL, GSR, BF, NF and H on the quantities of foundation for RC buildings. The outcome of this study shows that detailed parametric information (quantities) can be predicted without the need for sketch or design drawings. This is the first study to predict the quantities of RC foundation element by exploring the effect of soil bearing pressure and live load with the use of SVM. A key objective of the current research was to predict the quantities of structural elements without the need for 2D or 3D parametric information. Using the developed models in this study, parametric information (i.e., the volumes of concrete, tonnage of reinforcement and area of formwork) were predicted for RC foundation structural element without the need for design drawings. Therefore, designing to cost for cost control purposes within the parametric framework of BIM could be achieved by comparing the parametric information from the conceptual quantity models with the 2D and 3D parametric details from architects and structural engineers. Comparison between the APE metric of the LR and SVR models revealed that SVR models outperform the classical LR models for range estimates of conceptual quantities in RC foundations.

The quantity models developed in this paper are limited to the foundations of cast-in-situ RC buildings to be designed using BS8110 design principles in Nigeria. However, the methodology and method adopted in the research could be implemented in other locations, and for different constructional methods Modelling conceptual quantities for use in the AEC industry is a research direction to be explored with a view to expanding the knowledge base of cost modelling. The ability to estimate the quantities of cost items at the pre-design stage could reduce the time quantity surveyors use in preparing tender bills of quantities. The developed models can also provide parametric budgetary information for cost control purposes in BIM at stage 0 and 1 of RIBA plan of work. Thereby providing project and construction managers the ability to effectively monitor scope creep and control project cost at all stages of project development within the BIM framework.

References


Mapping global public interests in green buildings

Chang, R.D.\textsuperscript{1}, Gan, X.L.\textsuperscript{2} and Lu, Y.J.\textsuperscript{3}\textsuperscript{*}

Abstract: The development of green buildings is inseparable from public awareness and supports. However, most existing studies focus on the supply side, namely the design and construction of green buildings, with few studies address the public awareness and interests in green buildings. Little is known about whether people in different countries have different levels of interests in green buildings, and how people’s such interests change along with time. This study aims to assess and map global public interests in green buildings, thereby contributing to future global efforts to promote sustainable built environment worldwide. Based on Google Trends and the latest data visualization technique, this study analyzes the changing public interests in green buildings across the globe during the past five years. The findings reveal that public interests in green buildings significantly varies in different countries, and it is generally lower than public interests in other environmental topics such as climate change and renewable energy. It is urgent to raise the public awareness and interests in green buildings worldwide, especially in developing countries. This study establishes a basis for formulating future international political and industrial agenda to promote sustainable built environment worldwide.

Keywords: Green buildings; Public interests; Google Trends; Text mining; International comparison.

\textsuperscript{1} Chang, R.D. Department of Building, National University of Singapore, Singapore. E-mail: bdgcr@nus.edu.sg
\textsuperscript{2} Gan, X.L. School of Economics and Management, Southwest University, Chongqing, China
\textsuperscript{3} * Lu, Y.J. Corresponding author, Department of Building, National University of Singapore, Singapore. E-mail: luy@nus.edu.sg
1 Introduction

The construction industry is one of the biggest exploiters of resources and has major impacts on the living and working environment. It is a significant contributor to many environmental problems such as loss of soil and agricultural land, loss of forests and wilderness, and air pollution. It is also a major user of the world's non-renewable energy resources and minerals. Energy consumption of buildings in developed countries comprises 20–40% of total energy consumption. In the UK, the construction industry is accountable for 50% of carbon emissions, 50% of water consumption, 35% of landfill waste and 13% of all raw materials utilized[1]. The steel consumption of the Chinese construction industry comprises more than 20% of the world’s total consumption, while construction waste accounts for 45% of China’s total garbage[2]. As the construction industry has such enormous global impacts economically, socially and environmentally, the sustainability of this industry is of vital importance to the overall sustainability of our planet.

As an effective approach to improve the sustainability of built environment, green buildings have received increasing attention in both academia and industry. Governments worldwide have prioritized the development of green buildings in the architecture, engineering and construction (AEC) sector[3]. Extensive studies have been conducted on green buildings. However, the development of green buildings is inseparable from public acceptance and support. On the one hand, public support gives legitimacy to and could significantly influence the policy-making of green buildings[4]. On the other hand, the public is potential clients of building projects, and thus, their preference and interests could significantly influence the market performance of green buildings[5]. The consumer behavior model indicates that the decision making of purchase is composed of five stages, namely problem awareness, information search, evaluation of alternatives, the decision to purchase, and actions following the purchase[6]. Problem awareness and information search of green buildings are the prerequisites of procurement of green buildings. Despite the extreme importance of public interests in affecting green buildings, few studies aim to systemically investigate the public interest of green buildings at both the country and international level. Little is known in terms of which country has the public with the highest interests of green buildings, how the public interests change along with time, and how green buildings are perceived in the public worldwide compared with other environmental topics such as renewable energy. This study aims to assess and map the global public interests in green buildings, thereby contributing to future global efforts to promote sustainable built environment worldwide.

2 Methodology

In response to the growth of the web, the concept of webometrics arose to refer to the efforts to measure and evaluate all types of information available on the web. Web search data has great potential in revealing social phenomena at a big scale, which traditionally could be very difficult to measure accurately. The power of internet big data has been demonstrated by increasing number of studies. For instance, published in Nature, a model for accurately forecasting the level of influenza based on queries data in Google’s search engine was proposed by Ginsberg[7]. Similarly, web search traffic has also been utilized to examine issues on management, technology diffusion, consumer behavior, financial market and public policy[8]. However, despite the increasing recognition and importance of web search data in the above research areas, few studies utilize this data in the AEC field.

The public interests in green buildings could be reflected by the web search activities of the public, which could then be analyzed through the web search traffic information provided by Google Trends. Google Trends is a web service from Google that reports the frequency of a search query relative to the total number of searches in a specific region over a specific period of time[6]. In this study, a list of keywords related to green buildings was proposed based on previous studies and the weekly search volumes of these words from June 2012 to June 2017 was gathered. Specifically, to generate the keywords on green buildings, a text mining technique was adopted to mine the academic publications with the highest citations in the database of Web of Science, which only includes high-quality publications and is deemed to be more rigorous than other databases such as Google Scholar[9]. Considering articles published in early years generally have higher citations than new literature, the top 20 articles with most citations in the timespan of both 1900-2016 and 2010-2016 were retrieved. The
used search query is: green build* OR sustainable build* OR green construct* OR sustainable construct* OR low energy build* OR zero energy build* IN TITLE. There was a total of 31 articles retrieved, with 9 of them were ranked among the top 20 most cited articles in both 1900-2016 and 2010-2016. Table 1 presents parts of the 31 articles for illustrative purpose.

Table 1. Examples of the retrieved most cited articles on green buildings

<table>
<thead>
<tr>
<th>Title</th>
<th>year</th>
<th>Journal</th>
<th>Times cited</th>
<th>Ranking: 1900-2016</th>
<th>Ranking: 2010-2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Energy use in the life cycle of conventional and low-energy buildings: A review article</td>
<td>2007</td>
<td>Energy and Buildings</td>
<td>392</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>• Adaptive thermal comfort and sustainable thermal standards for buildings</td>
<td>2002</td>
<td>Energy and Buildings</td>
<td>376</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>• A low energy building in a life cycle - its embodied energy, energy need for operation and recycling potential</td>
<td>2002</td>
<td>Building and Environment</td>
<td>261</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>• Zero Energy Building - A review of definitions and calculation methodologies</td>
<td>2011</td>
<td>Energy and Buildings</td>
<td>256</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>• Sustainable construction - The role of environmental assessment tools</td>
<td>2008</td>
<td>Journal of Environmental Management Building and Environment</td>
<td>234</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>• Applying multi-objective genetic algorithms in green building design optimization</td>
<td>2005</td>
<td>Building and Environment</td>
<td>202</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>• Green roofs; building energy savings and the potential for retrofit</td>
<td>2010</td>
<td>Energy and Buildings</td>
<td>199</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>• A green roof model for building energy simulation programs</td>
<td>2008</td>
<td>Energy and Buildings</td>
<td>183</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>• Net zero energy buildings: A consistent definition framework</td>
<td>2012</td>
<td>Energy and Buildings</td>
<td>152</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>• From net energy to zero energy buildings: Defining life cycle zero energy buildings (LC-ZEB)</td>
<td>2010</td>
<td>Energy and Buildings</td>
<td>146</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

Subsequently, these 31 most cited articles were mined individually to identify the terms mentioned most in a text mining engine, namely http://www.wordclouds.com/. To propose the most popular terms appeared in these most cited articles, the following functions were used.

\[
\sigma_i = 0.5 + \frac{T_i}{T_{\text{max}} + T_{\text{min}}} \left( \frac{C_i}{C_{\text{max}}} \right)
\]

\[
PI = \sum_{i=1}^{n} \sigma_i N_i
\]

Where: \(\sigma_i\) denotes the weight of article i to adjust the number of occurrence of a certain term in this article; \(T_i\) denotes the year article i published; \(T_{\text{max}}\) and \(T_{\text{min}}\) denote the year that the latest and earliest article published in these 31 articles, namely 2014 and 1998 respectively, \(C_i\) denotes the times the article i has been cited; \(C_{\text{max}}\) denotes the highest citation times received by these articles, namely 392 in this case; PI denotes Popularity Index, which is used to rank the most popular terms appeared in these articles; \(N_i\) denotes number of occurrence of a certain term in article i; and finally n denotes the number of articles, namely 31 in this case.

By using these two equations, terms appeared in these most cited articles were ranked thereby identifying the terms with the highest adjusted number of occurrence, namely the PI. The top 60 most popular terms were used to construct a word cloud [10] to visualize the focus of green building research, and the top 30 most popular terms were used to develop the search keywords on green buildings in Google Trends. The search volume was then analyzed from two perspectives, namely the temporal perspective which examines the changes in the public interests in green buildings along with time, and the spatial perspective which compares the public interests in different countries.
3 Results

3.1 Text mining of the highly-cited articles on green buildings

The text mining of the highly-cited articles reveals the top 30 most popular terms of green buildings, as shown in Table 2, and the top 60 most popular terms as shown in Fig. 1. The most popular terms are energy, building, green, roof and system. Based on the top 30 most popular terms, five sets of phrases were obtained. These five sets represent five research themes of the most cited studies, including 1) green building in general, 2) green roof, 3) building thermal performance and comfort, 4) building energy and 5) building material and cost.

Table 2. The top 30 most popular terms in the highly cited articles

<table>
<thead>
<tr>
<th>Rank</th>
<th>Terms</th>
<th>PI</th>
<th>Rank</th>
<th>Terms</th>
<th>PI</th>
<th>Rank</th>
<th>Terms</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>energy</td>
<td>1156</td>
<td>11</td>
<td>sustainable</td>
<td>111</td>
<td>21</td>
<td>storage</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>building</td>
<td>1107</td>
<td>12</td>
<td>optimise</td>
<td>104</td>
<td>22</td>
<td>renewable</td>
<td>69</td>
</tr>
<tr>
<td>3</td>
<td>green</td>
<td>299</td>
<td>13</td>
<td>use</td>
<td>98</td>
<td>23</td>
<td>comfort</td>
<td>68</td>
</tr>
<tr>
<td>4</td>
<td>roof</td>
<td>258</td>
<td>14</td>
<td>ZEB</td>
<td>94</td>
<td>24</td>
<td>life</td>
<td>67</td>
</tr>
<tr>
<td>5</td>
<td>system</td>
<td>215</td>
<td>15</td>
<td>solar</td>
<td>93</td>
<td>25</td>
<td>cycle</td>
<td>65</td>
</tr>
<tr>
<td>6</td>
<td>thermal</td>
<td>180</td>
<td>16</td>
<td>method</td>
<td>88</td>
<td>26</td>
<td>cost</td>
<td>64</td>
</tr>
<tr>
<td>7</td>
<td>environment</td>
<td>171</td>
<td>17</td>
<td>cooling</td>
<td>87</td>
<td>27</td>
<td>heating</td>
<td>63</td>
</tr>
<tr>
<td>8</td>
<td>temperature</td>
<td>170</td>
<td>18</td>
<td>assessment</td>
<td>82</td>
<td>28</td>
<td>consumption</td>
<td>62</td>
</tr>
<tr>
<td>9</td>
<td>design</td>
<td>131</td>
<td>19</td>
<td>air</td>
<td>78</td>
<td>29</td>
<td>construction</td>
<td>58</td>
</tr>
<tr>
<td>10</td>
<td>performance</td>
<td>130</td>
<td>20</td>
<td>material</td>
<td>74</td>
<td>30</td>
<td>indoor</td>
<td>58</td>
</tr>
</tbody>
</table>

Fig. 1. Word Cloud of the top 60 most popular terms in the most cited 31 articles
To compare the global public interests in green buildings and other sustainability issues, apart from the five sets of key phrases, another two sets of key phrases were also used as search keywords in the Google Trends engine. Therefore, a total number of seven sets of key phrases were used as search keywords in Google Trend, including:

1. Green building(s) + sustainable building(s)
2. Green roof(s)
3. Building thermal + thermal comfort + building cooling + building heating + indoor temperature
4. Building energy
5. Building material + life cycle cost
6. Renewable energy
7. Climate change + sustainable development

3.2 Temporal evolution of global public interests in green buildings

The public search volume on the five sets of key phrases of green buildings from June 2012 to June 2017 (five years) was extracted from Google Trends. Fig. 2 shows the temporal changes of the public interests in green buildings, reflected by the research volume, during the studied period. It is clear that among the five themes, generally green building is the most popular in the public, followed by building material and cost, building energy, green roof and thermal comfort related, even though these themes have varying public interests and sometimes have similar search volumes. The results show that public interests in green buildings are different from the research priorities. The highly cited academic studies place a higher priority for green roof and thermal comfort while the global public has higher interests in building material and cost.

![Fig. 2. Temporal evolution of global public interests in green buildings](image)

Then, three of the five themes of green buildings were chosen to be compared with the public interests in sustainable development and renewable energy, as shown in Fig. 3. It shows that the public interests in climate change/sustainable development and renewable energy is significantly higher than that of green buildings. More importantly, comparing Fig. 3 and Fig. 2 reveals that the public interest in sustainable development/climate change shows an upward trend along with time, while the public
interests in green building present a downward trend. This suggests that the global public interests in green buildings are not catching up with the increasing interests and awareness of sustainable development in public. This contrast reflects that during the past five years, the public has increasing interests in sustainable development and renewable energy, but decreasing interests in green buildings, which suggests that the importance of green buildings in contributing to sustainable development has not been well communicated to the general public.

![Graph showing comparison of public interests in green buildings and sustainable development]

Fig. 3. Comparison of public interests in green buildings and sustainable development

3.3 Spatial distributions of global public interests in green buildings

The public interests vary significantly in different countries. By comparing the public interests in sustainable development/climate change and the theme of green building in general, it can be discovered that the public in many developing countries, especially in many African countries, have very high interests in sustainable development, while green buildings received the highest public interests in developed countries. This mismatch suggests the concepts and approach of promoting sustainable development through green buildings have not yet entered many developing countries. Thus, there is a long way to go to raise the global public interests in green buildings in many parts of the world.
Fig. 4. Comparison of the spatial distribution of public interests in green buildings and sustainable development

Fig. 5. specifically mapped the public interests in the other four major themes of green buildings. Australia, America, Canada, India and UK have the highest public interests in these major themes. This reconfirms that the public interests in green building are the highest in major developed countries. The concept and approach of green buildings need to be conveyed to the public in developing countries. Specifically, in terms of thermal comfort, the public in the UK, India and US has the highest interest in the world, while regarding the topic of green roofs, the public in the UK, Canada, Australia, US and Philippine has the highest interests. Similarly, the public in Australia, US and Canada has topped the interest ranking of building energy. In contrast, regarding the public interest in building material, United Arab Emirates, South Africa, Nigeria and India have the highest ranking. This implies that the public in different countries has various interests in green buildings, which may be associated with the characteristics of the country such as its climate, culture and economy development status.

Fig. 5. Comparison of the public interests in four major themes of green buildings
4 Conclusion

Using online search volumes obtained from Google Trends, this study investigates the global public interests in green buildings which have not been done by existing studies. Firstly, text mining of the most cited articles on green buildings has been conducted to reveal the most popular key words in green buildings. The top 60 key words were used to generate the word cloud and the top 30 key words were used to generate the main themes of green buildings. Green building in general, building thermal related, green roof, building energy and building material/cost are discovered to be the five major themes. The search volumes on these main themes, together with sustainable development and renewable energy, were compared and analyzed. The results show that compared with the growing public interests in sustainable development and renewable energy, the public interest in green buildings is not only significantly lower, but also has been decreasing over the past five years. The public in many developing countries, especially in many African countries, have very high interests in sustainable development, while green buildings received the highest public interests in developed countries such as Australia, America and Canada. This result implies that the public interests in green buildings need to be significantly improved, especially in developing countries.

References

More Inclusive Approaches to Smart Cities: No one is left behind

Ma, Ruiqu¹*, Lam, Patrick.T.I.²

Abstract: Smart cities have proliferated worldwide in recent years, responding to the efficiency drive of urbanization. However, the approach of Smart City risks deepening the digital-divide problem. While massive technologies are intensively deployed, some potentially disadvantaged groups such as the aged and disabled people are often excluded and left behind due to their limited abilities and opportunities in interacting with others. There is a compelling call for policy measures to enhance the accessibility and inclusion of these disadvantaged groups in smart city development. This study aims at discussing the role of technology in urban development, and more importantly the causes and solutions of digital-divide by reviewing current situations and practices. It firstly introduces the scopes of smart city and the role of technology as an enabler, rather than as the only determinants of smart city development. Then it discusses the phenomenon of digital divide and its root causes. It is found that digital-divide is a complex with multiple layers, and it can be caused by various factors including insufficient facilities/services, individual attitude barriers and the lack of external support. Based on lessons from the practice of enhancing digital inclusion in Singapore and South Korea, this study concludes with the recommendations for narrowing digital-divide to build an inclusive smart city.

Key words: Smart City; Information Communication Technology; digital-divide; social inclusion.

¹* Ma, Ruiqu
Corresponding author, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong SAR, PR China.
E-mail: ruiqu.ma@connect.polyu.hk

² Lam, Patrick.T.I.
Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong SAR, PR China.
E-mail: tsun.ip.lam@polyu.edu.hk
1 Introduction

The boom in smart cities brings unprecedented opportunities for city managers, innovation entities and citizens. City managers promote the application of Information Communication Technology (ICT) across important domains such as power supply, waste management and healthcare. Innovative corporations are engaged in developing helpful products and services that can facilitate a wide segment of population. Hence, a substantial proportion of people living in smart cities will approach a diverse range of eServices, such as ePayments and eExchange. This trend, however, risks deepening the digital-divide for potentially disadvantaged groups such as disabled people and the elderly. The occurrence of social inequity and imbalance goes against the aim of smart city which is to improve citizens’ life quality. Digital inclusion, therefore, is called for creating a harmonious smart city. A broader spectrum of human and social resources should be devoted to building an integrative smart city along with advanced technologies (Caragliu et al., 2009).

The aim of this research is to discuss the role of information technology in smart city development, and find causes and solutions of digital-divide. The paper is structured as follows: it firstly introduces the scopes of smart city and the role of technology. The following section discusses multiple layers of digital-divide, its existence worldwide and possible causes. Based on the digital inclusion practices in Singapore and South Korea, this study concludes by making general recommendations for narrowing digital-divide to build an inclusive smart city.

2 The Role of Technology

Technology is the cornerstone of smart city development. It tackles lots of challenges confronting cities ranging from population growth to resource shortage and the need for economic reconstruction. ICT empowers people to understand, experience, and manage urban environment in a more efficient and sustainable way (Batty et al., 2012). It is worth noting that ICT is not merely about infrastructure and devices, it makes diverse public services available electronically thus improving citizens’ life quality (Global Initiative for Inclusive Information and Communication Technologies, 2016).

Although technology is advocated as the key force of social development and basis for all human activities by Technological Determinism, it is not always the panacea. Relying on technology alone would bring problems such as digital-divide. The theory of Technological Determinism has been criticized as it over-evaluates the importance of technology. Technology applications are not regarded as an end, but should aim at solving teething problems of cities. Social Construction of Technology (SCOT) responds to technological determinism by arguing that the true value of technology depends on the proper way that technology is embedded in its social context. The relationship between technology and society or human activities is ‘intertwining’, instead of simply cause-and-effect and technology should have performance upon a complex social field (Murphie & Potts, 2003).

3 Digital-divide

3.1 What is Digital-divide

At the very early stage, the concept of digital-divide simply referred to the physical ownership/accessibility of ICT. But it has been evolving continuously. A widely-accepted definition of digital-divide was proposed by the Organization for Economic Co-operation and Development (OECD) in 2001: “the gap between individuals, households, businesses and geographic areas at
different socio-economic levels with regard both to their opportunities to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities”. Hence, digital-divide goes beyond owning a computer or internet access or otherwise (Bradshaw, 2011). What really influences the society and economy is the ability of using ICT and to benefit from using it.

Besides the multi-layered feature of digital-divide, its multifaceted existence makes it rather complex to solve. It is found that digital-divide exists among various demographic groups, such as between female and male, rich and poor, aging and young, normal and disabled. It is also present in countries with different development levels and districts (Department of Economic and Social Affairs, 2016). The following section introduces the global existence of digital-divide, especially in some highly-developed places.

3.2 Digital-divide Worldwide

By 2016, 53% of people worldwide (3.9 billion) are offline (International Telecommunication Union, 2016), and 2 billion people do not possess a mobile phone (World Bank, 2016). According to the World Development Report 2016, most offline population is in India and China. But this is also the case in more developed places, for example, over 120 million people in North America remain offline. This echoes the omnipresence of digital-divide.

UK, as a global leader in technology innovation, faces the crisis of digital-divide too (House of Commons, 2016). It is found that 23% (12.6 million) grown-ups in the UK are without fundamental digital skills (Ipsos MORI, 2015). In those, about half are disabled, 63% over 75-year old and 60% without educational qualifications. If no appropriate action is taken, a large group of 7.9 million people will be lacking in digital skills by 2025, as estimated by the Centre for Economics and Business Research (2015). The gap of digital skills caused a loss of £63 billion a year in terms of the potentially additional GDP (Azad et al., 2012). For the sake of alleviating negative influences of digital-divide in the UK, a Digital Engagement Council was established in the early 2016 along with the Digital Strategy to facilitate cross-sector cooperation in closing digital-divide.

In Hong Kong, a metropolis, despite the variety of Personal Computer (PC) being owned and the high Internet penetration among different societal groups, the problem of digital-divide in the form of unequal accessibility still prevails. According to Hong Kong’s statistics of Thematic Household Survey Report No. 59, persons ‘aged 10 and above’ owning smartphone during the 12 months before enumeration accounted for 83.0% in 2015, while those ‘aged 65 and above’ a merely 35.4%, retired persons 43.1%, and those with only primary education 45.4%. At present, since Hong Kong is accelerating the development of knowledge-based economy as energized by the application of ICT, narrowing digital-divide is listed as a major task in its “Digital 21: IT Strategy”.

3.3 Possible Causes of Digital-divide

Based on previous research, it is found that digital-divide can be caused by different factors, being categorized as facility/service accessibility; individual ability and attitude; and external support.

Facility/service accessibility. It is concerned with the availability and accessibility of the Internet, PC, smart phone and other information technologies and communication facilities. Digital-divide in terms of this aspect can be caused by the lack of access to internet and digital devices (Cullen, 2001; Bélanger & Carter, 2009); and poor quality of e-services (Cuervo & Menéndez, 2006).

Individual ability and attitude. This type is about personal digital skills and
attitudes/concerns about technology. It includes computer ill-literacy and lack of skills (Cullen, 2001; Bélanger & Carter, 2009; International Telecommunication Union, 2011); personal attitude barriers (Botha et al., 2001); weak information awareness (Andreasson & Jian, 2015); and concerns about personal information leakage (Botha et al., 2001).

**External support.** Insufficient support from the government and other organizations makes it difficult for the disadvantaged groups to adjust to the digitalized society. Major causes include the lack of special concerns for disadvantaged groups (Van Dijk & Hacker, 2003; Van Dijk, 2006; Fuchs, 2008); lack of training programs for unskilled citizens (Cullen, 2001); and insufficient engagement initiatives (Cheang & Lei, 2015).

### 4 Case Studies of Bridging Digital-divide

#### 4.1 Singapore

Singapore recently moves fast on rooting technology into almost every aspect of citizens’ life. Although it is still at the initial stage of achieving the ambitious goal of becoming “smart nation” due to a range of advanced services remaining in trials, it has always been trying to ensure that every citizen is equally well-served. It is found that the digital inclusion process of Singapore has experienced five stages, being summarized as “5 Cs” (Bradbrook & Fisher, 2004). The first stage is ‘Connectivity’ during which the internet network, citywide Wi-Fi and other facilities were provided for disadvantaged people; the next stage is ‘Capability’ which trained and aided economically and socially disadvantaged groups. The phase of ‘Content’ opened a broad range of e-services and data to the public, and was accelerated by the following stage of ‘Confidence’ which ensured a secure, easy and innovative digitalization environment. The last stage, namely ‘Continuity’, motivated digital engagement to gain productivity and improve life quality continuously.

Considerable efforts had been made by Singapore’s public sector. Examples include: 1) Infocomm Accessibility Centre (IAC) had trained 1,500 individuals with disability during 2007 to 2012, to enable them to use some information technologies independently. Nearly 5,800 training places had been provided by IAC during this project period; 2) Infocomm Media Development Authority (IMDA) initiated the ongoing program of NEU PC Plus to offer students and disabled people from 17,000 low-income households an affordable price to possess a new computer; 3) Infocomm Development Authority (IDA) set the Silver Infocomm Curriculum to help the elderly step up ICT use by building hotpots to provide internet and computer access for free, and providing IT trainings at a low price.

Several general solutions to bridge digital-divide can be learnt from Singapore’s practices and existing research. Firstly, in order to make information facilities and services accessible, city managers need to increase network coverage (Cullen, 2001; Chang & Yang, 2010; Andreasson & Jian, 2015), provide financial support for computer acquisition/Internet access (Botha et al., 2001; Cullen, 2001); and root the applications of ICT upon the local circumstance and diversity (Yonazi et al., 2012). Furthermore, extra support for disadvantaged groups is called for enhancing their information literacy and removing their attitude barriers (Andreasson & Jian, 2015) by providing education and training for them (Cairney & Speak, 2000; Chang & Yang, 2010; Andreasson & Jian, 2015); and motivating digital inclusion initiatives of both citizens and the private sector (Cheang & Lei, 2015).
4.2 South Korea

Besides the governmental efforts, integrative efforts from different stakeholders (e.g. private and public sectors) can accelerate the process of bridging digital-divide. An exemplary case of this is in South Korea, which is fast stepping forward its information-based society. After realizing the problem of digital-divide early in 1984, South Korea’s government has devoted to solving it, mainly by establishing the Information Technology Training Centre (ITTC) to provide free computer training to the public; implementing the “Cyber Korea 21” Initiative from 1999 to 2002 to transform the country into a knowledge-based economy; employing e-Korea Vision during 2002 to 2004 with the aim of achieving the national informatization; and publishing a white paper “Bridging the Digital Divide” in 2003 which suggested enabling ICT accessibility and connectivity nationwide, and so forth.

Among a range of projects to bridge the digital-divide in South Korea, the ubiquitous connection to broadband is critical to facilitate the national communication as a common base (Menon, 2011), and has gained great success. The project of Broadband Convergence Network (BcN) was implemented from 2004 to 2010 with three phases, aimed at wholly achieving ubiquitous connectivity to the BcN network, enhancing economic productivity and employment. Many private experts, consultants and managers participated in BcN’s Research and Development (R&D) activities to perform their duties within the strategy and standardization proposed by the government. Examples of stakeholders include the Ministry of Information and Communication (a public sector entity), Korean Information Society Development (a research institute), and Hanaro Telecommunications (a private telecommunication firm). According to the annual report by Korea Communications Commission (2013) Communications Commission, the subscription of BcN reached 98% by 2012 in urban areas if mobile broadband is taken into account. The successful and rapid adoption of broadband in South Korea attributes to the government’s holistic approach which involves both governmental drive and other social efforts to create a broadband ecosystem (Kim et al., 2010). The integrative endeavors from public and private sectors enable affordable e-services and a rich digital content. Although the accessibility problem of Internet and digital devices has been fixed greatly, there is still a long way to improve citizens’ digital literacy to bridge digital-divide further. As found in the study of Park and Jae Kim (2014) based on the analysis of digital-divide index in South Korea, the gap in skills and utilization of ICT has not been addressed totally.

4.3 The Comparison between Singapore and South Korea

Both Singapore and South Korea have initiated a range of projects to bridge the national digital-divide. Their main efforts are centrally driven and devoted into widening internet connectivity and equipping citizen with digital skills. But South Korea seems to have applied a more holistic approach/strategy to integrate the efforts from different stakeholders. This action can alleviate the burden of the government and solve the problem efficiently, and more importantly, it can generate higher productivity and additional employment opportunities. Although Singapore and South Korea are highly-connected countries in Asia in terms of physical accessibility, the sub-optimal issues of digital-divide and the gap in digital skills and utilization have not been addressed totally. More efforts are needed, such as leveraging social forces for a long-term development (Shin & Jung, 2012) and embedding user experience design in current e-service (Cheang & Lei, 2015). However, they are already exemplars in the Asian arena.
5 Conclusion: Digital Inclusion

ICT is the cornerstone of smart city development. But the intense use of ICT alone cannot make a city smart even a range of smart projects seem so-called “cool”. ICT application should not be an end in itself, but is supposed to tackle teething problems of the city, including energy shortage, traffic congestion, poor healthcare and so forth. As such, technology is able to yield good performance upon the social context. Currently digital-divide occurs among various social groups and cities with the fast-growing trend of smart city development. The inequality of access and use of ICT broadens existing socioeconomic gaps (Fuchs, 2008). Digital-divide can be caused by factors including insufficient facilities/services, individual attitude barriers and the lack of external support. The penetration and multi-layered feature of digital-divide make it complex to solve. In the study, Singapore and South Korea are selected as two positive examples with considerable efforts to narrow digital-divide among potentially disadvantaged groups. Some lessons of workable measures can be drawn from their practices, such as improving the accessibility of internet and computers, providing training for disadvantaged groups, and motivating digital inclusion initiatives of both public and private sectors. Besides that, Digital Literacy Education at a community-level has been proposed currently to enhance digital citizenship and democracy by assisting people to participate in community and culture activities relevant to ICT learning (Lee, 2015). Even then the journey of bridging digital-divide is still uneasy. More efforts from the aspect of sociocultural empowerment and service design are needed.

The notion of “No one is left behind” requires digital inclusion across the whole society. A broad range of factors in terms of infrastructure, economy and society are needed to build a real inclusive smart city. This study rises the discussion about the role of technology in a dialectical way and analyzes the phenomenon of digital-divide and its root causes. It sheds some light for the importance of a further study of the potential pitfalls in the development of smart cities and the associated digital-divide within specific smart services.

References


Technology Capacity and Establishing an Agenda for Change: Centre for Regional Research and Innovation, University of Western Sydney.


Changes of Industrial Structure and Its Regional Difference in Zhejiang Province

Yanfang Wu¹, Yuzhe Wu²*

Abstract: In recent years, China's economic growth slowed down gradually, the irrational industrial structure has become a crucial factor restricting economic development. In this context, the paper chooses Zhejiang Province as a research case, and uses the shift share method to analyze the dynamic relationship between the evolution of industrial structure and economic growth of 11 cities in Zhejiang. The results show that: ① The shift share method has a great advantage in analyzing the industrial structure, it is more profound than the simple analysis of economic growth rates. ② The industrial structure of Zhejiang province has shifted from industry oriented to service oriented, the tertiary industry has more reasonable structure than the secondary industry, but the competitiveness of both are not obvious. ③ The coastal cities in Zhejiang province are more developed with a more reasonable industrial structure, the cities in the middle or south of Zhejiang Province are less developed because of the problem of irrational industrial structure and lack of advantageous industries.

Keywords: Zhejiang province; Industrial structure; Regional economics; Shift share analysis.

¹ Yanfang Wu
Department of Land Management, Zhejiang University, China

²* Yuzhe Wu
Corresponding author, Department of Land Management, Zhejiang University, China
E-mail: wuyuzhe@zju.edu.cn
1 Introduction
Since the reform and opening up, China’s economic construction has achieved rapid development, but in the long-term formation of extensive economic development model, China’s economic development constraints are increasingly prominent. It is showed that China’s GDP growth rate has been decreased since 2012 and the GDP growth rate fell to 6.7% in 2016. With the industrial structure shifted from industry oriented to service oriented, China has gradually enter the late stage of industrialization. however, the development of China’s industry is faced with many problems, such as the unreasonable industrial structure, the low output of industrial enterprise, which has been unable to meet the needs of economic development. Therefore, optimizing the second industrial structure and vigorously developing the third industry has become the main direction of the transformation of many cities' economic structure.

Zhejiang province is in the Yangtze River Delta along the southeast coast of China. It is one of the fastest growing and most developed provinces in China, and all the economic indicators are in the forefront of the country. The analysis of the industrial structure of different cities in Zhejiang province is of great significance to its industrial upgrading and structural adjustment. Therefore, this paper will compare the economic development and industrial structure of 11 cities in Zhejiang Province, and analyze the advantages and disadvantages of each city in the industrial structure by empirical analysis. The research can provide scientific basis for industrial planning and regional economic policy in these cities.

2 literature review
The relationship between industrial structure and economic growth is always a focal point the domestic and foreign scholars paid attention to. The foreign scholars began to study the theory of industrial structure in seventeenth century, William Petty proposed that the industry was generally much more profitable than agriculture and Commerce according to the specific state of the British. Subsequently, based on the conclusion of Petty’s analysis, Clark(1960) put forward the Petty-Clark theorem. The theory was that, With the rising national income per capita, the labor force would transfer from the primary industry to the second and tertiary industries[1]. Kuznets(1971) studied the industrial structure of the economy under the continuous development of national income and labor force from the perspective of industrial distribution. His research showed that changes in per capita national income would lead to the adjustment of industrial structure[2]. Nicole(2008) studied the economic structure of European countries, and the results showed that there was a significant convergence between European countries. The phenomenon was due to the continuous development of national economy and the continuous transform from industry to service industry[3].

The domestic scholars had also discussed the relationship between industrial structure and economic growth from different angles. Gan Chunhui(2011) constructed a metrological economic model of industrial structure change and economic growth. Empirical analysis showed that there was a positive correlation between the optimization of industrial structure and economic growth in China. The rationalization of industrial structure and the process of advanced process was accompanied by obvious characteristics of economic growth[4]. Fang fuqian(2011) used TGARCH model to analyze the relationship between industrial structure and economic growth, the results
showed that the impact of three industries on China's economic was different, the key to optimize the industrial structure comprehensively was to promote the rapid development of the third industry\cite{5}. Zhou Mingsheng(2013) studied the contribution of the three industries to economic growth by regression analysis, the research showed that the optimal development of the three industries, especially the upgrading of the second industry and the third industry, was closely related to economic growth\cite{6}. Some scholars have also analyzed the industrial structure of some provinces or regions and proposed suggestions to promote their industrial structure and economic growth. Luo Yongle(2005) used the shift-share method to analyze the economic growth of various regions in Hunan Province, and calculated the contribution of the industrial structure to the economic growth in the three economic zones and the prefecture-level cities\cite{7}. Yuan Jiuhe(2007) applied structural change value K, Moore structural change value and specialization index to measure the evolution of western industry, the results showed that the overall evolution of the western industry was accelerating, but the proportion of agriculture was too high, the technical level of the manufacturing industry was low and the tertiary industry was lagging behind\cite{8}.Yang Jiawei(2013) used various indicators and methods to analyze the industrial structure characteristics of Henan Province\cite{9}, Duan Xiaowei(2017) further analyzed the spatial and temporal pattern of industrial transfer in Henan\cite{10}. However, the studies have been mostly carried out around the western or central region of China, and few studies have been done on the eastern part\cite{11}.

3 Analysis

3.1 Research Area

The study area, Zhejiang Province, is one of the most active economic China provinces, with the area of 105 thousand square kilometers and about 56 million people. In 2016, Zhejiang's gross domestic product reached 4648 billion, and the per capita GDP reached 83157 yuan, higher than the national average. At the same time, the three-industrial structure of Zhejiang adjusted to 4.2:44.2:51.6 (Figure 1). While the economy is developing rapidly in Zhejiang Province, there are some differences between the 11 prefecture level cities, which is not only detrimental to the sustained and stable development of these cities, but also to the promotion of the overall competitiveness of Zhejiang Province. Therefore, it is necessary to make a comparative study of the economic development and industrial structure of each city, and explore the direction of its industrial transformation and upgrading.
3.2 Research Method

Shift-share analysis method is proposed by American scholar Daniel (1942) [12] and has been summarized and perfected by Duun (1960) [13], Massell (1961) [14], Houston (1967) [15] and other scholars, which has been widely used in the fields of regional economy, geography and planning. This method regards the change of regional economy as a dynamic process, and takes the economic development of the region (province or country) as the frame of reference, and separates the influencing factors of regional economic development by the method of component decomposition. The specific analysis method is as follows:

Let \( E_{ij0} \) be the annual output value of the area \( i \) industry \( j \) at the first year of base period, and \( E_{ijt} \) be the annual output value of the area \( i \) industry \( j \) at the last year of base period. \( R_{ij} \) is the annual growth rate of the annual output of the area \( i \) industry \( j \) in the whole period. By definition:

\[
E_{ijt} = E_{ij0}R_{ij}
\]  \hspace{1cm} (1. 1)

The upper form can be decomposed into:

\[
E_{ijt} = E_{ij}R_j + (E_{ij0} - E_{ij})R_j + E_{ij0}(R_{ij} - R_j) = N_{ij} + P_{ij} + D_{ij} \hspace{1cm} (1. 2)
\]

In the formula, \( R \) is the cumulative growth rate of the output value of all the industries in the country, \( R_j \) is the cumulative growth rate of the output value of the industry \( j \) in the country, and \( E_{ij} \) is the local annual output value compared with the region (province or country) where the share of the industrial sector as the weight of the standardization.

The first term on the right side of the equation is the national share(N), which is equal to the cumulative growth rate of the output of all industries in the country (or the region), indicating the impact of national (or the regional) economic development on local economic development.

The second term is the industrial mix(P), it refers to the deviation from the growth of local industrial sector in relation to the national standard, caused by the difference in the proportion of the local industrial sector and the proportion of the corresponding sector in the country (or the region). The greater the value is, the greater the industrial structure contributed to the growth of the economy.
The third term is the regional share (D), it refers to difference between the cumulative increase in the annual growth rate of the regional i industry j and the cumulative growth of the output value of the industry j in the country. If the regional share is greater than 0, it indicates that the regional development industry j has a geographical advantage relative to the whole country, and the larger the value, the more obvious the geographical advantage.

3.3 Results and Analysis

Based on the theory and calculation method mentioned above, with the data from "China City Statistical Yearbook (2013-2015)" , "Zhejiang Province Statistical Yearbook (2013-2015)" and other resources, the shift share analysis results of industry during the period from 2012 to 2016 are calculated, as shown in Table 1.

Table 1. Industrial Analysis Results of Cities in Zhejiang Province

<table>
<thead>
<tr>
<th>Cities</th>
<th>Primary Industry</th>
<th>Secondary Industry</th>
<th>Tertiary Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td>D</td>
</tr>
<tr>
<td>Hangzhou</td>
<td>2.0</td>
<td>39.5</td>
<td>8.2</td>
</tr>
<tr>
<td>Ningbo</td>
<td>2.1</td>
<td>41.6</td>
<td>-7.6</td>
</tr>
<tr>
<td>Wenzhou</td>
<td>0.9</td>
<td>17.7</td>
<td>6.0</td>
</tr>
<tr>
<td>Shaoxing</td>
<td>1.5</td>
<td>28.6</td>
<td>-5.0</td>
</tr>
<tr>
<td>Taizhou</td>
<td>1.6</td>
<td>31.1</td>
<td>21.3</td>
</tr>
<tr>
<td>Jiaxing</td>
<td>1.2</td>
<td>23.4</td>
<td>-32.2</td>
</tr>
<tr>
<td>Jinhua</td>
<td>1.1</td>
<td>20.8</td>
<td>-8.3</td>
</tr>
<tr>
<td>Huzhou</td>
<td>1.0</td>
<td>19.0</td>
<td>-14.8</td>
</tr>
<tr>
<td>Quzhou</td>
<td>0.6</td>
<td>12.3</td>
<td>-4.5</td>
</tr>
<tr>
<td>Zhoushan</td>
<td>0.7</td>
<td>12.9</td>
<td>33.4</td>
</tr>
<tr>
<td>Lishui</td>
<td>0.6</td>
<td>12.3</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Remark: In the table, N stands for the national share, P stands for the industrial mix and D stands for the regional share.

As shown in Table 1, The economic development of the 11 cities in Zhejiang is consistent with the law of industrial structure evolution, the industrial structure has shifted from the primary industry to the second industry and the third industry. Specifically, the economic growth mainly depends on the national share(N) and the industrial mix(P), which means the economy of each city is greatly influenced by the development of the province and its own industrial structure quality. In addition, the regional share(D) of most cities is little or even negative, indicating that the industrial competitiveness of cities in Zhejiang is very weak. To further analyze the secondary industry and the tertiary industry of Zhejiang province, drew the shift-share analysis graph with the industry mix(P) as the abscissa and the regional share(D) as the ordinate, and divided the chart area with the line y = x, as shown in Figure 2.
As shown in Figure 2, all the coordinate points are located below the straight line, the values of the industry mix(P) are much larger than those of the regional share(D) whether it’s for the second or the third industry in all cities. This is because, as mentioned above, the competitive advantages of most industries are not obvious and need further improvement. In terms of the industry mix(P), the tertiary industry is much higher than the second industry, which shows that the tertiary industrial structure is more reasonable than the second industry with the fast growing or promising industrial sector accounting for a sizable proportion. In contrast, the second industry gradually declined with the recession of many industrial sectors.
As shown in Figure 3, the calculation results in Table 1 are shown graphically. Obviously, the gross national product and the share values of Hangzhou and Ningbo are ranked in the first two. Hangzhou, as the capital of Zhejiang Province, is highly developed in service industry especially in new and high technology industries. Ningbo, as a famous port city, has developed heavy chemical industry and equipment manufacturing industry. In the other 4 cities in the northern part of Zhejiang Province, Shaoxing and Jiaxing have similar characteristics with Ningbo, the regional share(D) of the second industry in Ningbo is positive, and the third industry is negative. But the pillar industries in these cities are not obvious enough and the competitiveness of the pillar industries also need to be improved. Unlike Hangzhou and Ningbo, the regional share(D) of secondary and third industries in Huzhou and Zhoushan are both positive, indicating that the competitiveness is rising at the same time. Wenzhou and Taizhou, as coastal cities, have a rapid pace of development with a lot of private enterprises. It is obvious that the third industry in Wenzhou has gradually become the leading industry, and the third industry has a quite rational structure considering the industry mix(P) of the third industry. However, there is excessive pressure on the industrial transformation in Taizhou, the second industry and the third industry of which are both lack of competitiveness. Jinhua, Quzhou and Lishui are in the middle or south of Zhejiang Province, the economic development of these cities is relatively low, and the industrial structure is irrational. It is necessary to pay attention to the adjustment of the industrial structure, and use their own resources to cultivate advantageous industries in the future.

4 Conclusion

The paper takes the coastal province of Zhejiang Province as a case study, and uses shift-share method to analyze the dynamic relationship between the evolution of industrial structure and economic growth, and the main conclusions are as follows:

① The shift share method is more profound than the simple analysis of growth rates analyzing industrial structure, it can separate the factors that affect the development of regional economy and evaluate the strengths and weaknesses of regional economic structure as well as competitiveness of regional industries.

② The economy of cities in Zhejiang is greatly influenced by the development of the whole province and its own industrial structure. In the meanwhile, Zhejiang province has poor industrial competitiveness and needs further improvement. Specifically, the fast growing or promising industrial sector accounting for a larger proportion in the tertiary industry, but the second industry is mainly composed of declining industries.

③ The changes of urban industry structure of cities in Zhejiang varies. The coastal cities in Zhejiang province are more developed with a more reasonable industrial structure, but the competitiveness of industries needs further improvement. The cities in the middle or south of Zhejiang Province are less developed because of the problem of irrational industrial structure and lack of advantageous industries.

References


Characterizing the environmental impacts and their occupational health risks during decorative and renovating projects

Li, X.Y.¹, Zhang, H. ², Gao, H.G.³, Duan, H.B.⁴*, Lei, G.Y.⁵* and Wang, J.Y.⁶

Abstract: With the continuous development of construction and real estate industry, there is a vast amount of building decoration projects, associated with increasing indoor air quality concerns. However, there is relatively little work to evaluate the environmental impacts and associated occupational health risks during the decorative processing. This study investigated on 23 decorative projects in Shenzhen city and collected 1,120 various samples to examine physical pollutions (including noise and particulate matter - PM2.5) and organic pollutants (including formaldehyde and volatile organic compounds -TVOCs), and then evaluate the potential occupational health risks on workers. The results showed that the noise, PM2.5, formaldehyde and TVOC have posed serious environmental risks on workers since the concentrations exceeded relevant controlling values by 62%, 86%, 20% and 12%, respectively. Window ventilation is beneficial to reduce indoor air pollution during indoor decoration. The carcinogenic risk of indoor TVOC is high. Even worse, volatile and PM2.5 pollution has not received sufficient attention by project managers and workers. Therefore, and the long-term engagement and no protective behaviors could significantly endanger workers’ occupational health.

Keywords: Decorative and renovating projects; Pollution; Occupational health risk.

¹ Li, X.Y.
School of Resources and Environmental Engineering, Wuhan University of Science and Technology, China
² Zhang, H.
Department of Civil engineering, Shenzhen University, China
³ Gao, H.G.
Department of Civil engineering, Shenzhen University, China
⁴ Duan, H.B.
Corresponding author, Department of Civil engineering, Shenzhen University, China
E-mail: huabo@szu.edu.cn
⁵ Lei, G.Y.
Corresponding author, School of Resources and Environmental Engineering, Wuhan University of Science and Technology, China
E-mail: leiguoyuanhit@126.com
⁶ Wang, J.Y.
Department of Civil engineering, Shenzhen University, China
1 Introduction

Rapid urbanization has led to a marked expansion of the construction industry, which, in turn, has been accompanied by rapid development of the building decoration industry. From 2011 to 2015, China's building decoration industry showed an increasing trend each year, and the total output value increased from 425.7 billion yuan to 616.15 billion yuan, with an average annual growth rate of 28.7% \[1\]. Shenzhen City is a representative first-tier city exhibiting steady growth in the urban construction and real estate industries. It maintains a large annual housing renovation and transaction area (Urban Planning Land & Resources Commission of Shenzhen municipality, see Fig.1) and this, coupled with a regular renovation period of 4 to 8 years, suggests that the decoration industry will thrive in coming years.

Data source: Urban Planning, Land & Resources Commission of Shenzhen Municipality

**Fig. 1 Shenzhen housing transaction floor areas and decorative and renovating floor areas**

Decorative activities can significantly improve people’s living conditions. However, they generate increasingly prominent noise and indoor air quality problems. Shenzhen received approximately 500 cases of decoration complaints in 2015, revealing a significant upward trend from 2011 to 2015, among which decoration-related pollution constituted the main reason for complaints \[2\]. Indoor environmental pollution caused by decoration has become a hot spot of social concern \[3-6\]. Zhao et al. \[7\] carried out measurements on 550 buildings in Dalian, and found that formaldehyde produced by interior decoration was the main source of indoor air pollution. Lee et al. \[8\] studied floor noise and found that noise affects people's physiology and psychology. Habil et al. \[9\] found that humans exposed to fine particulate matter may exhibit significant health defects related to respiratory and cardiovascular systems.

Currently, the replacement of building materials with ‘green’ alternatives and the use of advanced construction technologies are used to promote the development of green buildings and help mitigate a series of resource and environment problems arising from the decoration industry \[10,11\]. However, the impact of decoration projects such as the harmful effects of airborne dust diffused from smashing the wall during home decoration on indoor air quality (IAQ) has rarely been studied in the field \[12\]. The existing literature contains few studies on comprehensive source analyses, environmental analyses of typical pollutants produced in decoration projects, including pollutant type and concentration, and quantitative investigations of the occupational exposure and carcinogenic risk to decoration workers.
This study focused on the decoration projects in Shenzhen city to analyze the emission characteristics of typical pollutants used in indoor decoration, the health risk of formaldehyde, and TVOC (total volatile organic compounds) emissions for decoration employees with the aim of improving the occupation protection awareness of these workers. The results could probably provide fundamental data for indoor environmental pollution involved in the decoration process, and be beneficial to the occupational protection of renovation workers.

2 Materials and Method

2.1 Questionnaire on construction workers

There were a total of 128 questionnaires have been conducted to investigate on decoration workers at Nanshan District, Baoan District and Luohu District, Shenzhen, and 99% of the questionnaires were recovered. The investigation focuses on the understanding of environmental conditions in the processes of interior decoration, the impacts of decoration on the physical health and the awareness of protection of workers, and obtaining relevant suggestions for improvement.

2.2 Field dataset collection of typical pollutants

Meanwhile, there are a total of 23 representative indoor decoration projects in Shenzhen were selected for field investigation. Decoration activities have been divided into different types of simple decoration and complex decoration. Decoration area is ranging from 100 to 400 square meters, and the construction period ranging from 3 days to one month. Pollutant tracking measurements were performed during the renovation, whereby pollutant samples were taken from five types of decoration processes: demolition work, coating work, painting engineering, wood-related work, and metal engineering; all under the conditions of both open windows and closed windows.

The noise monitoring method was based on "acoustic environmental quality standards (GB3096-2008)". Noise was measured continuously for 1 min, resulting in 60 data points. The minimum, maximum, and average values were calculated, and the average value of three different measurements was obtained, excluding any data with greater errors.

The measurement set-up for sampling indoor formaldehyde, TVOCs, and PM2.5 was based on the national "indoor air quality standard (GB/T18883-2002) ". Each sample was measured for 5 min, as were the blank control groups, and the average value of three different measurements was taken, excluding any data with large errors.
Table 1 Main processes and monitoring tools for interior decoration

<table>
<thead>
<tr>
<th>Sampling sites</th>
<th>Field investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>office buildings, laboratories, teaching buildings, shopping malls, residential areas, villas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decoration processes</th>
<th>Digital Sound Level Meters</th>
<th>Formaldehyde monitor</th>
<th>Portable GC-MS spectrometry</th>
<th>Portable laser particle size spectrometer</th>
</tr>
</thead>
</table>

2.3 Quantitative analysis of typical pollutants

2.3.1 Exposure calculation

Formaldehyde, TVOC and other pollutants mainly have impacts on human health through respiratory, so the effect characterization of formaldehyde, TVOC can be assessed by inhalation exposure, which is shown in equation (1).

$$E_i = \frac{C \times R_i \times D_e \times CF_i}{W_b}$$  \hspace{1cm} (1)

Where $E_i$ represents inhalation exposure (µg.kg⁻¹.d⁻¹); $C$ is the concentration of pollutants (mg/m³); $R_i$ is the inhalation rate (m³/d) [13]; $D_e$ denotes the exposure time (7.55h/d for the survey results); $CF_i$ is conversion factor (1/24); $W_b$ represents the body weight (kg), the average male and female weight values were 66.2kg and 57.3kg of Shenzhen City.

2.3.2 Health risk calculation

The impact of formaldehyde on human health during the indoor decoration process can be assessed by the health risk assessment method proposed by the environmental protection agency of the United States to calculate the carcinogenic risk [14], as shown in equation (2) (3).

$$R_c = C_{di} \times F_s$$  \hspace{1cm} (2)

Note: $R_c$ represents the carcinogenic risk value; $C_{di}$ is the average daily exposure (mg.kg⁻¹.d⁻¹); $F_s$ is the potency factor (kg.d.mg⁻¹). According to the U.S. Environmental Protection Agency IRIS system, formaldehyde $F_s$ value is 0.0455 kg.d.mg⁻¹.

$$C_{di} = \frac{C \times R_i \times D_e \times F_s \times Y_s \times 90\%}{W_b \times L_{at} \times 365}$$  \hspace{1cm} (3)

Where $C$ represents the concentration of contaminants (mg/m³); $R_i$ is the inhalation rate (0.67
\( \frac{m^3}{h} \); \( D_e \) denotes the exposure time (16.5 h/d); \( F_e \) represents the exposure frequency (365 d/year); \( Y_e \) is the exposure duration (2 year for new decoration stage); 90% is the absorption factor; \( W_b \) represents the body weight (kg), the average male and female weight values were 66.2 kg and 57.3 kg of Shenzhen City; \( L_{at} \) is the average exposure time, an average lifetime of 76 years for male and 77 years for female was used as the averaging time for carcinogenic assessment.

3. Results and Discussion

3.1 Environmental management status of decoration activities

The questionnaire results show that on-site decoration not only caused environmental problems, but also generated many occupation health problems for the workers themselves. The major results are as follows.

1) Pollutant release from building materials (furniture, paint, glue, floor coverings, and other decorative materials) is an important factor affecting IAQ. The interior environment of decorated houses was of a substantially lower quality than houses that had not been decorated due to the diversity and complexity of decoration materials.

2) The survey found that 74%, 66%, 84%, and 46% of workers considered that noise, PM2.5, formaldehyde, and TVOC emissions had a negative impact on their health. 92.5% of the workers considered great need for protection and attention to noise, formaldehyde, 96.5% of the decoration companies will provide staff with masks, gloves, and other protective clothing, but there are still 5% of the existing construction personnel protection is not in place. Furthermore, volatile and PM2.5 pollution has not received sufficient attention to enable preventative measures.

3) In order to minimize the impact of the decoration processes, decoration companies have started promoting assembly type construction procedures, which not only reduce the workload of site operation, but also reduce the exposure of workers to pollutants risk.

3.2 Emissions of typical pollutants

Air pollutants were classified into physical pollutants (including noise and particulate matter) and organic pollutants (including formaldehyde and volatile organic compounds), and the monitoring results of noise, PM2.5, formaldehyde, and TVOC pollution levels are shown in Table 2. The influence of window opening on IAQ was also investigated.

Table 2. Emissions of different pollutants

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>Windowing condition</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Mean value</th>
<th>Exceeding standard rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise (dB)</td>
<td>closing</td>
<td>42.6</td>
<td>102.8</td>
<td>61.0±11.4</td>
<td>61.7%</td>
</tr>
<tr>
<td></td>
<td>opening</td>
<td>37.3</td>
<td>94.6</td>
<td>57.4±9.2</td>
<td>51.7%</td>
</tr>
<tr>
<td>PM2.5(μg/m³)</td>
<td>closing</td>
<td>42.6</td>
<td>1712</td>
<td>408.36±427.41</td>
<td>86.1%</td>
</tr>
<tr>
<td></td>
<td>opening</td>
<td>61.2</td>
<td>283</td>
<td>97±31.6</td>
<td>25.5%</td>
</tr>
<tr>
<td>Formaldehyde(mg/m³)</td>
<td>closing</td>
<td>0.00</td>
<td>1.01</td>
<td>0.05±0.09</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>opening</td>
<td>0.00</td>
<td>0.20</td>
<td>0.03±0.04</td>
<td>10.9%</td>
</tr>
<tr>
<td>TVOC(mg/m³)</td>
<td>closing</td>
<td>0.001</td>
<td>1.85</td>
<td>0.183±0.42</td>
<td>11.5%</td>
</tr>
<tr>
<td></td>
<td>opening</td>
<td>0.001</td>
<td>1.354</td>
<td>0.16±0.041</td>
<td>8.5%</td>
</tr>
</tbody>
</table>
The concentration of contaminants under the conditions of open windows is significantly lower than that of window closed, it shows that window ventilation is beneficial to pollutants emission during indoor decoration.

The trace detection results of typical pollutants emission are shown in Table 3.

Table 3. Concentrations of pollutants in different decoration processes

<table>
<thead>
<tr>
<th>Projects</th>
<th>Contaminants</th>
<th>Standards</th>
<th>Minimum value</th>
<th>Maximum value</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Noise (dB)</td>
<td>45</td>
<td>49.9</td>
<td>102.2</td>
<td>88.5</td>
</tr>
<tr>
<td>Demolition project</td>
<td>PM2.5(μg/m³)</td>
<td>75</td>
<td>107.0</td>
<td>1712.0</td>
<td>157.6</td>
</tr>
<tr>
<td></td>
<td>Formaldehyde (mg/m³)</td>
<td>0.08</td>
<td>0.0</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>TVOC(mg/m³)</td>
<td>0.5</td>
<td>0.02</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>Coating engineering</td>
<td>Noise (dB)</td>
<td>45</td>
<td>48.6</td>
<td>102.8</td>
<td>59.3</td>
</tr>
<tr>
<td></td>
<td>PM2.5(μg/m³)</td>
<td>75</td>
<td>81.0</td>
<td>1188.0</td>
<td>106.5</td>
</tr>
<tr>
<td></td>
<td>Formaldehyde (mg/m³)</td>
<td>0.08</td>
<td>0.06</td>
<td>0.69</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>TVOC(mg/m³)</td>
<td>0.5</td>
<td>0.92</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Paint Engineering</td>
<td>Noise (dB)</td>
<td>45</td>
<td>67.1</td>
<td>92.4</td>
<td>81.8</td>
</tr>
<tr>
<td></td>
<td>PM2.5(μg/m³)</td>
<td>75</td>
<td>26.0</td>
<td>645.0</td>
<td>72.0</td>
</tr>
<tr>
<td></td>
<td>Formaldehyde (mg/m³)</td>
<td>0.08</td>
<td>0.10</td>
<td>0.32</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td>TVOC(mg/m³)</td>
<td>0.5</td>
<td>0.93</td>
<td>1.9</td>
<td>1.45</td>
</tr>
<tr>
<td>Wood-related works</td>
<td>Noise (dB)</td>
<td>45</td>
<td>49.9</td>
<td>101.6</td>
<td>79.6</td>
</tr>
<tr>
<td></td>
<td>PM2.5(μg/m³)</td>
<td>75</td>
<td>29.0</td>
<td>1439.0</td>
<td>127.6</td>
</tr>
<tr>
<td></td>
<td>Formaldehyde (mg/m³)</td>
<td>0.08</td>
<td>0.05</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>TVOC(mg/m³)</td>
<td>0.5</td>
<td>0.20</td>
<td>1.4</td>
<td>0.72</td>
</tr>
<tr>
<td>Metal engineering</td>
<td>Noise (dB)</td>
<td>45</td>
<td>85.0</td>
<td>93.1</td>
<td>89.1</td>
</tr>
<tr>
<td></td>
<td>PM2.5(μg/m³)</td>
<td>75</td>
<td>23.0</td>
<td>791.0</td>
<td>105.1</td>
</tr>
<tr>
<td></td>
<td>Formaldehyde (mg/m³)</td>
<td>0.08</td>
<td>0.00</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>TVOC(mg/m³)</td>
<td>0.5</td>
<td>0.004</td>
<td>0.21</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Note: The reference standards in the table are "Environmental quality standard for noise (GB3096-2008)", "Ambient Air Quality Standards (GB3095-2012)" and "Code for indoor environment pollution control of civil building engineering (GB50325-2010)".

According to pollutant tracking monitoring, demolition, metal and painting engineering, and wood-related work generated serious noise pollution; the monitoring value of noise was as high as 102.8 dB. The use of machining tools, such as pneumatic drills, hammers, cutting machines, planes, and chainsaws, was the main source of noise. The most serious PM2.5 pollution was produced from smashing walls and wood cutting, which produced concentrations up to 1429 μg/m³, approximately 20 times the standard value. In addition, grinding as part of coating engineering and spraying can cause higher concentrations of PM2.5. Coating and paint engineering produced serious formaldehyde pollution, with concentrations reaching 0.26 mg/m³, which was 8.6 times the standard value. The concentration of TVOCs was 1.45 mg/m³, which was 3.8 times the standard value, and it was mainly produced by coating, painting and wood-related processes, while TVOC emissions for demolition and metal work processes were in a reasonable range.
3.3 Health risks for decoration workers

3.3.1 Inhalation exposure

The average concentrations of formaldehyde and TVOCs in the decoration process were 50 μg/m³ and 183 μg/m³, respectively. Estimates of indoor formaldehyde and TVOC inhalation exposure were 3.9 g.kg⁻¹.d⁻¹ and 14.3 g.kg⁻¹.d⁻¹, respectively. The reference dose (RfD) refers to the probability of harmful effects during lifetime exposure to the dose level of chemical substances. It was first proposed by the IRIS system of the U.S. Environmental Protection Agency, in which the RfD of formaldehyde was 200 g.kg⁻¹.d⁻¹[15]. Both the formaldehyde and TVOC inhalation exposure values are less than the RfD.

3.3.2 Carcinogenic risk analysis

The carcinogenic risk for decoration workers exposed to formaldehyde and TVOC was 4.6·10⁻⁷ and 1.7·10⁻⁶, respectively.

According to the U.S. Environmental Protection Agency, when the carcinogenic risk value is less than 1·10⁻⁶, it can be considered as no health risk; when the risk value is higher than 1·10⁻⁴, corresponding measures should be taken. The formaldehyde value was below the risk limit, while TVOC values posed a serious health risk, which is 1.7 times the risk limit, additional attention should be paid to painting and painting processes to reduce volatile concentration and use green building materials. In this study, the carcinogenic risk was calculated only for typical pollutants, the measured time span was relatively short, average values of respiratory rate, working time, and body weight were used, and other carcinogens in indoor air were ignored. If other pollutants are taken into consideration, more serious health risks are expected to result from pollutant emissions during the interior decoration process.

4 Conclusions

Extensive research on building decoration industry have shown not only that significant air quality problems exist after decoration or renovation activities, but more serious environmental problems are present in the decoration processes. In this study, the characteristics of physical pollution and organic pollutants during different decorative processes and the related inhalation and carcinogenic risks were analyzed. The following major conclusions were drawn.

(1) Different decoration processes release different degrees of physical and organic pollution. The average values of noise, PM2.5, formaldehyde, and TVOC emissions were 57.4±9.2 dB, 408.36±427.41 g/m³, 0.05±0.09 mg/m³, and 0.183±0.420 mg/m³, exceeding the standard rates by 52%, 86%, 20%, and 12%, respectively. Overall, physical pollution posed a more serious environment risk. Indoor formaldehyde, TVOC inhalation exposure, and carcinogenic risk values were estimated, and the results of inhalation exposure were less than the RfD (US-EPA), while TVOC posed serious potential carcinogenic risks. Therefore, workers must be protected against toxic gases during coating, painting, and wood-related work.

(2) 74%, 66%, 84%, and 46% of workers considered that noise, PM2.5, formaldehyde, and TVOC posed negative health impacts, respectively. To date, volatile and particulate pollution has not attracted sufficient attention to enable preventative measures.
(3) It is urgent to control the pollutions from indoor decorative activities, by using green building materials. Masks, gloves, and protective clothing should be provided for workers. More important, we need to establish effective standards for engineering and environmental supervision and pollution control.

Acknowledgments

This study was supported by the Natural Science Foundation of Guangdong Province (2017A030313438), Shenzhen Science and Technology Plan (no. JCYJ 20150525092941042 and JCYJ20160520173631894), NSFC 51478267, and the Young Faculty Promotion Plan of Guangdong Province (YQ2015139) for funding and support.

References

Analysis of the operation relationship between commercial real estate price and macroeconomic—Take Chongqing city as an example

Gan Yuqing1*, Zheng Xiaoyun2*

Abstract: Commercial real estate, as an important branch of the real estate industry, not only being closely related to macroeconomic development, but also have an important link with the development of all sectors in national economy. Firstly, this paper analyzes the function mechanism between the price of commercial real estate and macro economy from two angles, namely investment and consumption. Then, the impact of the price commercial estate on economy growth and commodity price are analyzed through theoretical and empirical ways. It is found that the price of commercial real estate can reflect inflationary information and have dual-effect on macro economy.

Key words: Commercial real estate prices, Macro economy, Relationship analysis
I Research background
During the "13th Five-Year" period, Chongqing’s economy has been developing persistently and economic power has been increasing rapidly. In the first half year of 2017, Chongqing’s GDP accomplished around 914 billion yuan and increased 10.5% over the same period of last year at comparable prices. Its economy continues to maintain a good momentum of development and steady progress.

In April 20, 2017, the Chongqing municipal government announced the "Office opinion of Chongqing government on promoting the stable and healthy development of the city’s commercial real estate market ", Chongqing officially embraced the spring of commercial real estate. As the promotion of "The Belt and Road" and Chengdu-Chongqing urban agglomeration development plan adopted successfully and so on, Chongqing listed on the Top 40 of commercial real estate city with vitality in china. Moreover, Chongqing’s commercial real estate prices are rising persistently and almost consistent with the growth rate of GDP in recent years in Chongqing.

To sum up, commercial real estate and macro economy in Chongqing both have been developed rapidly in recent years. Here comes the questions that whether there are some relationships between the development of commercial real estate and macro economy, how do they influence and interact with each other? So based on the context mentioned above, this paper will study the above problems.

2 Literature review
According to the qualitative and quantitative research, Su Guoxing found that commercial real estate has positive effect on urban economy. Using concrete data, Mr.Shi proved that commercial real estate development can promote domestic demand and economy growth. And after comprehensively analyzed the industrial model of the commercial real estate and the situation of China’s economy, He Shanzhuang pointed out that commercial real estate is an important power to promote the development of China’s real economy.

Through the empirical study of Britain, Black et al. found that the growth of real estate prices have a significant impact on business activity. Ding Chen and Tu Mei have investigated the impact of real estate prices on investment in China, and found that the growth of real estate prices have a great impact on investment. Considering house assets account for a considerable proportion of all assets in most countries, and the function of real estate price is much greater than the stock price on consumption, Goodhart, Hofmann argued that the wealth effect depends on the percentage of the house or stock in the total wealth. K. Case, J. Quigley, R. Shiller confirmed that the impact of the real estate wealth on consumption is asymmetric. In other words, the increase in real estate wealth has a significant effect on consumption, but the decline almost do not affect consumption. Shiwen and Bei Zhengxin analyzed the influence of commercial real estate on investment and consumption, then pointed out that maintaining the stability of investment growth and promoting consumption are of great importance for the development of commercial real estate, which will directly and indirectly contribute to the growth of economic growth. Using the panel data of 172 prefecture-level cities in China from 2002 to 2006, Du Li, Pan Chunyang, etc. made an empirical test on the impact of real estate prices on the average consumption tendency of residents, and found that the rise in real estate prices restrains residents’ consumption. Xie Jieyu, Wu Binzen etc. found that house prices inhibite consumption significantly, and Xu Liang thought that the
development of commercial real estate have a positive impact on consumption growth.

3 The relationship between commercial real estate price and macro economy

Commercial real estate, as an important part of the real estate industry, is related to national economy and people's livelihood. Its price has a huge impact on the development of itself, the real estate and related industries, as well as the national economic. In this section, mainly, its impact on macro economy is analyzed from the aspects of price and economic growth.

3.1 The relationship between commercial real estate prices and prices

3.1.1 The mechanism of the impact of commercial real estate price on prices

In order to analyze the relationship between commercial real estate prices and commodity prices, simplified model presented by Smets in 1997 and general inflation theory were quoted.

In the traditional macroeconomic model, hypothesize that: (1) assuming that the wealth effect and investment effect caused by changes of the price of commercial real estate in the total demand equation are positive; (2) the total supply equation are formulated based on Phillips curve; (3) the equilibrium conditions of commercial real estate market determine the price of commercial real estate; (4) the central bank responses to the output gap and inflation gap as well as commercial real estate prices based on monetary policy.

Two kinds of impact coming from output and commercial real estate market respectively are analyzed based on the model and hypotheses mentioned above. And different results were presented according to different responses to commercial real estate prices.

Scenario 1: The price of commercial real estate rises and commodity prices fall. This is because the monetary policy is loosed due to the decreasing pressure of inflation.

Scenario 2: The price of commercial real estate rises and commodity prices rise at the same time. Along with the increase in supply, the market of commercial real estate and real economy grow quickly. The price increase in commercial real estate will give pressure to inflation, which, to some extent, can be offset by the expansion of supply, but not fully neutralized. Then, the price of commodity will increase to some degree.

Scenario 3: Stagflation. With the negative impact of output and taken cost into consideration, large amounts of money are attracted to asset sectors such as commercial real estate stocks, causing a significant increase in asset prices. Under this circumstance, inflation and high commercial real estate prices may coexist, but economic growth stagnate or even produce a fall in output, which is called stagflation.

The analysis above shows that the relationship between commercial real estate prices and inflation is uncertain.

3.1.2 An empirical test of the impact of commercial real estate prices on prices in China

3.1.2.1 Variable and data selection and model establishment

In order to further test it, consumer price index (CPI) of Chongqing was taken as the dependent variable and average selling price of the commercial house in Chongqing (Price) as the explained variable. Then the regression model was established. Considering that the main factors influencing the inflation also includes output level and the level of interest rates, money supply, so money supply (M2), the level of output (using GDP instead) and interest rate (r) are still adopted as explained variables, too. In order to reduce the volatility of data, all data are logarithmically
processed except for the interest rate. Considering the long-term nature of commercial real estate loans, loan interest rates of 5 years and above are selected as interest rate indicators and subtract the inflation rate of that year to reflect the real interest rate (RR). When choosing M2 in Chongqing, the following formula is adopted as there is no attainable direct data.

\[
\text{Chongqing year } M2 = \frac{\text{Chongqing GDP of the year}}{\text{national GDP of the year}} \times \text{M2 national supply}
\]

Due to the availability of data, commercial real estate prices are replaced by commercial housing prices, selected from 2000 to 2014. The data above are selected from the Chinese economic and social development statistics database.

According to the multiple linear regression model, the following regression model can be formulated:

\[
\text{CPI} = \alpha_0 + \alpha_1 \text{Price} + \alpha_2 \text{GDP} + \alpha_3 M2 + \alpha_4 RR + \mu + \epsilon
\]

Among them: \(\mu\) means the sum of effect of other factors which have effect on CPI, and \(\epsilon\) means a random perturbation term.

3.1.2.2 Analysis of Empirical Test Results

According to the results of weighted least squares regression, the following regression equation can be obtained:

\[
\text{CPI} = 4.732760 + 0.033540\text{Price} + 0.031022\text{GDP} + 0.004729\text{M2} + 0.948177\text{RR}
\]

The regression results are shown in Table 1. Through the regression results can be drawn as follows:

1. The impact of commercial real estate prices on consumer price index is significant. Considering the coefficient is positive, it can be seen that the price of commercial real estate has a positive effect on the price index, which means that the increase in commercial estate will boost inflation to some extent.

2. The impact of current gross domestic product (GDP) on consumer price index is similar to that of commercial real estate price, which is consistent with the general theory of economic development: Countries with GDP growth generally grow in CPI. Two indicators remain synchronized, indicating that economic growth is reasonable.

3. The coefficient of money supply(M2) is significant and positive, which is consistent with the general economic theory: The more money supply, the more inflation in economy and the higher the price index.

4. The effect of interest rates on prices is negative and the coefficient is significant, indicating that interest rates have a significant effect on curbing price increases, which is consistent with the general economic theory.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>4.732760</td>
<td>0.054166</td>
<td>87.374520</td>
<td>0.000000</td>
</tr>
<tr>
<td>PRICE</td>
<td>0.033540</td>
<td>0.012377</td>
<td>-2.709766</td>
<td>0.021900</td>
</tr>
<tr>
<td>GDP</td>
<td>0.031022</td>
<td>0.021960</td>
<td>1.412630</td>
<td>0.088100</td>
</tr>
<tr>
<td>M2</td>
<td>0.004729</td>
<td>0.022332</td>
<td>-0.211749</td>
<td>0.036600</td>
</tr>
<tr>
<td>RR</td>
<td>-0.948177</td>
<td>0.055255</td>
<td>-17.160060</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

According to the analysis above, it can be concluded that commercial real estate price is a leading indicator of consumer price index and it can be used for consumer price index (inflation) forecast.
From the overall macroeconomic situation, our country’s overall price rise rate is far lower than the growth speed of commercial real estate prices and money supply in recent years. This is benefited from the positive effect of China's economic growth itself has played a cushioning effect on prices rising. However, if the economy changes and the supply level continues to present a negative impact, the combined effect of both may increase the pressure of the rise on commodity prices and the relationship between them may change with the commercial real estate prices rising continually.

3.2 The Relationship between Commercial Real Estate Price and Economic Growth

3.2.1 The mechanism of commercial real estate prices on economic growth

The impact of real estate prices on economic growth mainly reflects in investment and consumption. As commercial real estate is a branch of the real estate industry, so the impact of commercial real estate on economic growth is the same.

Firstly, commercial real estate investment can promote urban economic growth. As commercial real estate is an important component of real estate, the restraint of residence purchase is getting strengthened and the existence of expectations of rising interest rate, the enthusiasm of developers and investors keeps rising and they begin to transfer their funds to commercial real estate, which lead to the promotion of economy development of the city.

Secondly, on the condition of market economy, investment is only the pilot power to increase economy. The sustainable force is the stability of consumer demand. Commercial real estate investment lead to the acceleration of commodity circulation inevitably, which will enlarge commodity consumption, and even the related taxes and fees. Thus consumption has a great pulling effect on urban economy. As the spatial carrier of commodity wholesale and retail, entertainment, catering, leisure services and so many other business activities, commercial real estate has a strong driving effect on other industries, which is achieved through the commercial real estate investment and consumption.

In addition to the above positive impacts, the increase in commercial real estate prices also have a certain degree of hindrance to economic growth. When commercial real estate investment is overheated far beyond the market needs, which will greatly destroy equilibrium of the distribution of market resource, waste a large number of limited resources, and exacerbate the instability of the national economic structure, as well as hinder country's national economy development.

3.2.2 An Empirical Study of Commercial Real Estate Price on Economic Growth

Through literature reading, it is found that the asset price increase mainly affects the investment and consumption of the real economy through four channels. The first one is the Tobin 'Q' theory and the second is through the balance sheet of enterprises. The third channel is the balance sheet of the family and the fourth is the wealth effect of the household sector. The impact of commercial real estate prices on economic growth is summed up in two main channels. First is the direct channel of wealth effect. When the price of commercial real estate rises, the wealth level rises. And when the marginal propensity to consume remain unchanged, consumption increases, output increases simultaneously. Second is the indirect channels of credit. When Commercial real estate prices rise, the collateral of the commercial real estate value also will rise. Based on this, enterprises and investors can use commercial real estate mortgage to obtain more loans to invest, thereby increasing output.
According to Douglas production function and the appropriate mathematical operations, we can get the following measurement model:

$$y_i = \alpha_0 + \sum \alpha_i X_i + \sum \alpha_l Y_l + u_i + \epsilon_i$$

Among them, $y_i$ represents the GDP growth rate of I province, which is explained by the model. $X_i$ represents each explanatory variable that affects economic growth. $Y_i$ is the control variable that affects economic growth. $U_i$ reflects the impact of unobservable other factors. $\epsilon_i$ represent random perturbation terms.

3.2.2.1 Variable selection and data source

1. Explained variable
   Economic growth rate (represented by GDP): use Chongqing's GDP growth rate.

2. Explanatory variables
   Commercial real estate price growth rate (shorted in $P$): Choose the average sales price of Chongqing’s commercial business occupancy.

3. Control variables: To avoid bias caused by the missing variables when conducting the model, a control variable group was introduced. Combined with the general economic growth theory and existing literature researches, this paper mainly chooses the following variables as control variables.

   Inflation factor (CPI): In order to reflect the impact of price fluctuation or macroeconomic uncertainty on economic growth, this paper selects Chongqing consumer price index to measure the inflation factors.

   Level of economic development (PGDP): The level of economic development itself can affect economic growth, reflecting the endogenous economic growth. This paper selects the per capita GDP of the province to measure the level of economic development.

   Infrastructure (INF): As for this indicator, traffic condition is selected as a proxy variable to reflect the condition of infrastructure. Chongqing’s highway mileage is selected as the data.

   Government action(GOV): Government action include consumption and investment behavior. As the incomplete government investment data, the government’s final consumption expenditure is used to measure the impact of government actions on economic growth.

   Openness to foreign economy (OPEN): In this paper, total import and export is token to measure the degree of openness to foreign economy of Chongqing.

   All the above data are from China's economic and social development statistics database and are from 2000 to 2014. All the variables are based on the previous year data, using the relative number of indicators.

3.2.2.2 The setting of the metering model

Through the model settings above, as well as the selection of variables, the following measuring model can be formulated.

$$GDP = \alpha_0 + \alpha_1 P + \alpha_2 CPI + \alpha_3 PGDP + \alpha_4 INF + \alpha_5 GOV + \alpha_6 OPEN + u_i + \epsilon_i$$

Among them: $u_i$ is the sum of other factors that affect the GDP growth rate, and $\epsilon_i$ is a random perturbation term.

3.2.2.3 Analysis of empirical results

From the regression results, except for the government action factor (GOV), the t-statistics of all parameters are significant.

1. The price growth rate ($P$) of commercial real estate is positive and significant, indicating
that the increase in the price of commercial real estate has a positive and promoting effect on economic growth. As the price of commercial real estate rises, the GDP will also get some growth, which conforms to the general economic theory.

(2) Infrastructure (INF) has a positive contribution to GDP growth, not merely because it is conducive to investment and employment. Taking location selection of commercial real estate, they usually locate in the place with intensive population and convenient transportation. It can be speculated that the infrastructure will promote commercial real estate prices while promoting GDP growth.

(3) Degree of openness to foreign economy (OPEN) can promote GDP growth. The increase in openness will contribute to the increase in the number and quality of commercial real estate, then contributing to GDP growth.

(4) The coefficient of inflation (CPI) is positive and significant, indicating that moderate inflation will promote good economic development. When economic development is good, people’s demand and consumption will increase, while promoting the development of commercial real estate and GDP growth.

(5) The regression coefficient of economic development level (PGDP) is positive, indicating that it has played a certain degree of positive effect on economic development. The increase in productivity usually mean the increase in income followed by the increase in desires to consuming. So, the economy will be boosted.

(6) The coefficient of government action (GOV) is positive but not significant, implying that the government behavior will promote economic growth but it has a certain degree of "crowding out" with the poor significance. If excessive government action is carried out, economic growth may be damaged.

Table 2. Model regression results of commercial real estate prices on economic growth

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>0.1129</td>
<td>0.0241</td>
<td>4.6817</td>
<td>0.0000</td>
</tr>
<tr>
<td>INF</td>
<td>0.0262</td>
<td>0.0052</td>
<td>-4.9893</td>
<td>0.0000</td>
</tr>
<tr>
<td>OPEN</td>
<td>0.0055</td>
<td>0.0028</td>
<td>1.9863</td>
<td>0.0500</td>
</tr>
<tr>
<td>GOV</td>
<td>0.0097</td>
<td>0.0211</td>
<td>0.4616</td>
<td>0.6454</td>
</tr>
<tr>
<td>CPI</td>
<td>0.4945</td>
<td>0.1276</td>
<td>3.8763</td>
<td>0.0002</td>
</tr>
<tr>
<td>PGDP</td>
<td>0.0663</td>
<td>0.0298</td>
<td>2.2240</td>
<td>0.0286</td>
</tr>
<tr>
<td>C</td>
<td>9.8644</td>
<td>0.4310</td>
<td>22.8891</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

According to the analysis above, it can be draw that the price of commercial real estate can promote economic growth. However, it is not clear that commercial real estate price growth has a negative effect on economic growth.

4 Conclusion

Through the analysis of Smets' model and the general theory of inflation, it is found that the relationship between commercial real estate prices and inflation is not so clear. By constructing the economic model of commercial real estate prices and commodity prices and the regression of the model, it is found that the price of commercial real estate can provide the information of future price increase as well as inflation.

Meanwhile, this paper studied the relationship between commercial real estate price and
economic growth. Being a carrier of consumer goods circulation, commercial real estate is closely related with investment and consumption. Commercial real estate will drive economic development by promoting investment and consumption. However, if the investment and consumption are irrational, the commercial real estate price changes will be detrimental to economic growth, leading the national economy into a wrong development -- "bubble economy". Moreover, on the basis of regression analysis, the empirical study of the relevant data proves that the price of commercial real estate can promote economic growth, but fail to prove that changes in commercial real estate prices have an adverse effect on macroeconomic growth.

References


Achieving Sustainable Construction in South Africa Through Digitalization: An Exploratory Study

Bankole Awuzie, Thabiso Monyane

Abstract: The construction industry seeks to transform its existing business model from an overtly physically oriented one into a digitally driven one. This move is predicated on benefits associated with a similar transition in industries such as manufacturing, media, etc. According to some scholars, the adoption and implementation of digitalization in construction supposedly make a significant contribution towards boosting sustainable construction practices therein. However, a paucity of empirical studies supporting this assertion has been observed, hence the need to explore stakeholder perceptions concerning this nexus. It is anticipated that the level of digitalization uptake in the industry will improve significantly if the existence of such a relationship is established. This is the case in South Africa where stakeholders often decry the high cost of digital technologies. Therefore, this study explores the relationship between digitalization and sustainable construction. This qualitative study relied on a phenomenological research design for data elicitation. Interviewees were purposively selected from stakeholder groups within the construction industry. Subsequently, data from the interviews were transcribed and analyzed using thematic analysis. Findings indicate a nexus between the adoption and implementation of digitalization and the achievement of sustainable construction practices. It is expected that this study will increase awareness among relevant stakeholders about the utility of digitalization in engendering sustainable construction practices across different stages of the project delivery lifecycle.

Keywords: Digitalization, Phenomenology, Sustainable Construction, South Africa,

1. Introduction

The attainment of sustainability through equitable resource usage continues to occupy centre stage in contemporary development discourse. Consequently, various economic sectors are modifying their operations to reflect a shift to sustainable practices. Such movement within the construction industry has been described as slow[27]. The nature of the industry as a fragmented, temporary multi-organization replete with a diverse array of stakeholders each pursuing different goals, has been blamed for the slow uptake[11]. However, advocacies for the adoption and implementation of sustainable construction (SC) practices have continued unabated[26]. Such advocacies result from the legendary reputation of the industry to undermine the sustainability aspirations of the society[15]. According to[23], the construction industry utilizes a significant portion of the earth resources to deliver projects. Also, assets emanating from the industry such as buildings and civil engineering works contribute to unsustainable consumption patterns being witnessed in contemporary times.

Gradually, the construction sector appears to be coming to terms with the need to heed to society’s quest for sustainability. This notion is supported by the plethora of attempts aimed at changing the industry’s mode of operation. Stakeholders have become fixated with the need to deliver projects in a sustainable manner[16]. As a result of this, new business models are evolving on a continuing basis in the industry. In hindsight, this has led to new taxonomies such as green construction, green supply chains, collaborative procurement, concurrent engineering, responsible sourcing, and lean construction among others. Proponents for the adoption of SC practices maintain that practices associated with the taxonomies above are capable of supporting the attainment of sustainability[26]; [7].

Another school of thought opines that these practices cannot achieve the stated objective without the effective and efficient management of information flows and communication in an integrated manner as to enable collective decision making within the project delivery environment[34]. The pivotal nature of information is buttressed by scholars who insist that the success or otherwise of any given project delivery exercise is premised on the management of information flows among stakeholders[30]. Yet, the management of such
information flows within the project delivery environment remains an onerous task. Since the presentation of relevant information in 2D has continued to pose a challenge to seamless dissemination, a transition towards digitalization based on digitization of such information is suggested\[14\]. They insist that this transition would be pivotal to the successful actualization of practices like lean construction, design automation etc which in turn engenders SC.

Existing literature indicates that the South African construction industry has shown signs of embracing the process of digitalization\[13\],\[4\],\[12\]. Nevertheless, the successful nature of such uptake remains underreported hence the prevailing uncertainty regarding benefits derived by the South African construction industry and the prospects that it holds for SC practices therein. This is the gap which this study seeks to fill. Accordingly, this study proceeds to examine the validity of assertions made by several scholars in the developed country context concerning the utility of digitalization in the attainment of sustainable construction, within a developing country context -South Africa.

To achieve its objectives, this study will be presented in the following format; a review of extant literature on digitalization, highlighting the relationship between digitization and digitalization as well as identifying various construction activities which can benefit from digitalization, an adumbration of the research methodology adopted in the elicitation and analysis of data, the presentation of the study’s findings and the discussion of these findings, and; concluding remarks.

2. Digitization vs Digitalization- A Clarification of terms

A review of the state-of-the-art reveals some degree of confusion concerning the meaning of digitization and digitalization. Perhaps this is responsible for the interchangeable use of both terms oftentimes. Considering the centrality of this term to the study, there is need to provide clarity at this point. Digitization refers to the conversion of information from the analogue format into a digital format\[28\]. Besides enabling effective and efficient storage of such information, it allows for seamless integration of the digitized information into multi-modal sharing platforms. Conversely, digitalization connotes an improvement or transformation of an organization’s business model through a holistic adoption and implementation of digital technologies across every facet of its operations\[15\]. Often times, such organizations need to leverage on digitized information and processes to achieve this feat. Digitalization holds certain benefits for organizations, namely: development of business models for improved service delivery; improved productivity; increased opportunities for automation of hitherto physically-oriented processes; improved decision making; competitive advantage among other benefits\[28\],\[35\]. Maintain that certain digital technology attributes like reprogrammability and homogenization of existing data engender conducive atmosphere for flexibility and openness thus bringing about an increase in the level of innovation within the organization.

Digitalization is not new to the construction industry as several digital solutions have been proffered for the industry, yet its uptake remains dismal\[11\]. Yet, digitalization proponents assert that the industry’s drive for sustainability can be boosted by optimal digitalization\[1\],\[2\]. They opine that waste caused by poor design processes, conflicting information emanating from diverse stakeholder groups, inefficient material/resource usage on construction sites, etc. all contribute to undermine industry-wide sustainability aspirations. And they argue that the adoption of digital technologies would undoubtedly ameliorate the occurrence of these challenges as well as boost productivity.

2.1 Utility of digitalization in engendering sustainable construction

Ineffective resource/material utilization across the project lifecycle has been identified as being capable of undermining society’s sustainability aspirations. Overt reliance on digitalization is presented as a potential medium for resolving this challenge\[33\]. Sustainable construction practices will benefit from the integration of digital technologies across the project delivery lifecycle\[31\]. Pointing to instances where business models of hitherto physically oriented industries such as automobile manufacturing have adapted towards the digital
technologies, \cite{10}, observe that what is required in bringing about this digital transformation is the need to adapt to the increasingly digitalization of the final users’ lives and businesses. The same applies to the construction industry. If this were to be the case, the advent of the smart homes, smart campus, intelligent building concepts amongst others should drive the construction industry towards optimal mainstreaming of digital technologies into the industry’s mode of delivery and management of assets. Also, it has been posited that the adoption of digital technologies engenders improved productivity in various sectors \cite{10}, \cite{14}.

The use of digital technologies in construction is all encompassing and applies to every facet of the project delivery lifecycle. Therefore, the World Economic Forum report \cite{27} in proposing an industry transformation framework, suggest that digitalization be made the pivot of this endeavour as it enables the development of new processes, performances and competencies across the construction value chain throughout the project lifecycle, a claim supported by \cite{32}. The report provides a picture of benefits accruable from the digitalization of non-residential construction wherein it mentions that such scenario will inadvertently lead to a cost savings of between $0.7 - $1.2 trillion (13-21\%) during the construction phase and a further $0.3 - $0.5 trillion during the operations phase of such assets. \cite{17}, assert that the adoption of Building Information Modelling (BIM) and Virtual Design and Construction (VDC) was capable of delivering cost savings of AUD12 billion whilst boosting productivity levels by 9\%. Besides cost savings and improved productivity, digital technologies are also capable of enhancing safety levels during the construction process through a reduction in the workforce \cite{19}. Figure 1 highlights how aspects of digitalization are being applied on construction projects and assets to bring about such savings.

As shown in Figure 1, there are various types of digital technologies that can be applied across the entire project delivery and operation lifecycle to support sustainable construction practices. Delving further, \cite{29} make a case for the adoption of design automation technologies by the construction industry. They opine that design automation will provide clients, final users and other stakeholders the impact of the design on variables like project cost, equipment use and availability, capabilities of staff as well as the buildability of the proposed asset, given contextual conditions.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Digital Technologies Applied in the Engineering and Construction Value Chain (Renz and Solas, 2016)}
\end{figure}

Also, design automation ensures the development of alternative solutions to meet stakeholder expectations in effective and efficient manner. Instances of design automation in the construction industry include building
information modelling (BIM), knowledge-based engineering, master models, modularization, simulations etc. [26]. Yet, BIM is described as the platform for integrating other aspects available in the design automation field. Volk et al. (2014) observe the growing relevance of BIM beyond the preplanning, design and construction phases of the project lifecycle into the operations maintenance, refurbishment, deconstruction and end-of-life phases.

Rapid prototyping is another aspect of digitalization with the potential to support sustainable construction practice. This mode of modelling emanates from the seminal work of Pegna on the adoption of additive manufacturing (AM) in construction [24]. Pegna’s prognosis derived from the successful integration and utilization of rapid prototyping in the aeronautical and robotic fields, predicting that the adoption of this technology in construction will attract a 30% reduction in construction costs. AM in construction (AMC) involves the production of shaped parts through an automated procedure. It is also referred to as 3-dimensional printing (3-Dp) [25]. According to them, the use of AMC has the potential of leading to a reduction in the construction labour and resource wastage whilst increasing the speed of project delivery. Various types of AMC are available to construction industry stakeholders however the contour crafting remains the most popular as it is being used in the delivery of low-cost/mass housing units given its support for design uniformity [18]. Four benefits pursued by the adoption and implementation of AMC comprise of improved functionality of the end product, a significant reduction in the number of parts being used, customization, and improved aesthetics [3]. However, the jury is still out on the sustainable nature of AMC enabled built assets and the processes through which they were delivered [21]. [20]. [8].

There seems to be a consensus amongst the scholars that the integration of digital technologies (digitalization) in the construction space will lead to a reduction in waste, efficient resource utilization, cost-effectiveness, timely delivery and improved safety conditions in construction sites. Whilst there is no explicit relationship between digitalization and sustainable construction in the literature reviewed, these benefits mentioned are identical to the expected deliverables from the adoption of sustainable construction practices. This observation leads to the main crux of this study- to determine the relationship between the adoption and implementation of digital technologies and sustainable construction, especially within the South African context and also to determine the stages of the project delivery lifecycle where such relationships exist.

3. Research Methodology

This phenomenological study sought to explore the views of construction industry stakeholders who have been involved with construction projects in the Free State province of South Africa. It forms part of a wider study seeking to explore the degree of technology acceptance in the South African construction industry by stakeholders. The choice of the phenomenological research design was predicated on the designs usefulness in eliciting views about the worldviews as well as shared experiences of individuals concerning a particular phenomenon [9]. In this instance, the phenomenon being understudied was the determination of the impact of digitalization on the attainment of sustainable construction practice in the South African construction industry. This understanding of the phenomenon enabled the researchers to carefully select the interviewees based on a mixture of purposive, snowballing and convenience sampling techniques [10]. Care was taken to select only interviewees who had participated in the delivery and management of construction projects where an appreciable level of digital technology uptake has been observed. Furthermore, knowledge concerning what constitutes sustainable construction practices was deemed paramount during the selection process. Suffice to say that the interviewee sample comprised of a select group of experts on sustainable construction and digital technology in construction. In all, 16 interviewees were recruited, 4 interviewees each were drawn from the construction management, architecture, civil engineering and quantity surveying cohorts respectively. Interview sessions lasted for an average of 30 minutes each. Questions asked followed a semi-structured interview format, hence enabling the interviewers to skew their questions slightly to suit the professional role of the interviewee as it is believed that their roles on projects would affect the manner in which they engage with digital technologies. The choice of semi-structured interviews was considered apposite as it enabled the use of similar questions instead of identical questions as would be the case if structured interviews were adopted [8].
The interviewees were asked to discuss their engagement with technology and to affirm the presence of a nexus between the adoption of digital technologies and the proliferation of sustainable construction practices or otherwise.

The interview sessions were recorded and transcribed with permission of the interviewees. The transcripts originating from the transcription exercise were then read and re-read by the researchers independent of each other to make sense of the data. Themes which were aligned to the research question were developed and used as pre-set themes. Relevant data in the transcripts were coded according to these pre-set themes manually by the researchers after which they jointly reviewed the themes and the associated codes therein. This procedure, usually referred to as multi-investigator triangulation is necessary to ensure trustworthiness of the emergent data [23].

**Discussion of Preliminary Findings**

Findings from the interviews are presented concurrently with the discussions for the sake of brevity. These findings will be presented to depict the research questions which the study sought to answer: the establishment of the presence of a nexus between digitalization and SC practice or otherwise.

### 4.1 Nexus between Digitalization and Sustainable Construction

Upon commencement, the interviewers sought to ensure that the interviewees shared a common ontology concerning the terms ‘digitalization’ ‘digital technologies’ and ‘sustainable construction’. It was observed that whereas a common ontology existed on digitalization and digital technologies, the same could not be said of sustainable construction. Whereas the researchers had viewed sustainable construction practices as those practices that were capable of delivering on an integration of the three pillars of economic, social and environmental sustainability, a majority of the interviewees (13) opined that sustainable construction practices were those practices responsible for bringing about benefits associated with environmental sustainability alone. The interviewers sought to correct this impression during the interviewees.

It can be noted that whereas mention has been made of the benefits accruing from the optimal adoption of digital technologies across various facets of the construction project delivery lifecycle, it appears that no explicit mention has been made of the contributions of such disruptive technologies towards the entrenchment of sustainable construction practice. It should however be noted that the benefits mentioned are synonymous with the expected benefits from optimal sustainable construction practice. When interviewees were asked to discuss their respective engagement with digital technologies, all interviewees gave positive narratives of such interaction. Furthermore, there appeared to be a consensus among the interviewees on the existence of a directly proportional relationship existing between the adoption and effective implementation of the digitalization agenda and the sustenance of sustainable construction practices in the construction projects they have been involved with. They reiterated the notion that most of the sustainable construction practices such as management of material usage on site and just-in-time delivery of goods to the site were actually dependent on digital technologies which have the capacity of sustaining the push and pull arrangement. One interviewee (a construction manager) affirmed that the existence of such digitalization-enabled push and pull arrangement on her site led to space usage optimization within the site hence resulting to minimal injuries among the workers. It also led to improved conditions pertaining to egress and ingress therein. Another interviewee, an architect, acknowledged the utility of digital technologies in driving sustainable construction practices particularly during the design stage. The use of the computer assisted design software (CAD) according to him, led to a reduction in the time spent on design and allowed for client changes made during the construction process to be incorporated with ease.

Interviewees took turns to explain how digitalization had improved their working environment. Consultants (architects and quantity surveyor interviewees) explained that they now experienced minimal disputes relating
to the design and cost estimation on projects, given the in-depth details conveyed by 3D drawing plans when compared to 2D drawing plans thus engendering comprehensive estimation of materials and its effective utilization by the construction team. The use of virtual design modelling was identified as bringing about increased stakeholder collaboration at the early stages of the project hence bring about a collective buy-in by the design and project delivery teams in the client’s objective. Other interviewees (Civil engineers) made mention of their usage of the energy modelling techniques- a disruptive technology which allowed them to decide on a veritable energy supply mix for the proposed building project. This information was subsequently passed on to the design team for incorporation into the final design.

Summarily, the interviewees noted that there was indeed a nexus between digital technology adoption and implementation, and SC. Furthermore, from the narratives rendered previously, it can be seen that the utility of digitalization transcends all stages of a project’s lifecycle and supports the implementation of SC practices, therein. However, they decried the slow uptake of such technologies and mentioned factors such as high cost of technology acquisition as a deterrent to its uptake.

4. Conclusions

The construction industry’s commitment to the attainment of society’s sustainability aspirations is currently on the rise. Visible efforts are being made by the industry to leverage on successfully tested methodologies in other industries to bring about the needed transformation of the construction industry’s business model. The utilization of digital technology has been identified as one of such methodologies that has been routinely cited as efficacious in engendering the actualization of this goal. However, whilst extant literature has applauded the potential of digitalization to boost productivity within the construction, a paucity of empirical studies elucidating the methodology’s contribution to fostering sustainable construction practice in the industry was observed, hence this exploratory study.

Based on a plethora of interviews with purposively selected construction industry stakeholders, a consensus was arrived at pertaining to the pivotal nature of digitalization in driving sustainable construction practices in the South African construction industry. It is expected that the findings of this study will contribute to increasing the awareness of industry stakeholders concerning the instrumentality of these technologies in the attainment of sustainable construction. Such increased awareness may lead to an improvement in its uptake within the industry. Furthermore, this study provides the platform for the further studies into the reasons for the slow uptake of digital technologies amongst stakeholders in the South African construction industry.

5. Acknowledgement

The corresponding author will like to acknowledge the National Research Foundation (NRF), South Africa for the travel grant which they provided to facilitate the presentation of this paper at the CRIOCM 2017 conference in Melbourne. This support was provided through the instrumentality of the Knowledge Interchange and Collaboration (KIC) travel grant for individuals #110131.

Reference


Organisational Attributes that Determine Design for Occupational Safety and Health Capability

Mahamadu, A.-M.¹, Manu, P.¹*, Poghosyan, A.¹, Mahdjoubi, L.¹, Gibb, A.² and Behm, M.³

Abstract: Design for occupational safety and health (DfOSH) is increasingly becoming prominent in construction. In the UK, DfOSH is a legal requirement under the Construction Design and Management Regulations 2015 (CDM 2015). Amongst other requirements, the CDM 2015 regulations require organisations to have the appropriate organisational capability in respect of occupational safety and health (OSH), which is described as the policies, systems, resources and people an organisation has in place to set acceptable OSH standards and to ensure the standards are delivered. Regarding design firms, it is unclear within the academic literature which organisational attributes are important for ascertaining DfOSH organisational capability. This study sought to address this through two expert focus group discussions involving seven experienced construction, design and OSH professionals within the UK construction industry. The focus group discussions revealed that organisational attributes that determine DfOSH organisational capability include: design quality management; project review to capture lessons and improve; physical work resources that support design work and DfOSH; design risk management; company reputation/experience; ability to innovate or to be creative in addressing OSH hazards in design; organisational leadership and strategy that promotes DfOSH within the organisation; design staff capability (i.e. skills, knowledge and experience); human resources development; information and communication technology (ICT) resources; and collaboration ability. These attributes could assist design firms to better understand their own DfOSH capability, and they could similarly help organisations that appoint design firms to understand design firms’ DfOSH capability.

Keywords: design; design for occupational safety and health; prevention through design; safety in design.

¹Department of Architecture and the Built Environment, University of the West of England, Frenchay Campus, Bristol, BS16 1QY, United Kingdom.
*Corresponding author E-mail: Patrick.manu@uwe.ac.uk
²School of Civil and Building Engineering, Loughborough University, Loughborough, Leicestershire, LE11 3TU, United Kingdom.
³College of Engineering and Technology, East Carolina University, Greenville, NC 27858-4353, USA.
1 Introduction

According to the International Labour Organisation (ILO), about four percent of the world’s gross domestic product (GDP) is lost due to work-related accidents and diseases [1,2]. In the UK, the construction industry was responsible for 31% of all industrial fatalities in 2012/13, despite accounting for only 5% of the total workforce [3]. The estimated cost of these construction work-related injuries and illnesses is GBE1.1 billion (circa US$ 1.7 billion) [3], an amount comparable to the GDP of many countries in the world (see [4]). Due to the socio-economic impacts of the poor occupational safety and health (OSH) situation, several improvement initiatives have emerged over the years. Prominent amongst these initiatives has been the promotion of early consideration of OSH in the project lifecycle, especially during the design phase [5]. This concept is referred to as design for occupational safety and health (DfOSH) and also known as “Prevention through Design” (especially in the USA). This study investigates organisational attributes that determine an organisation’s (e.g. design firm’s) capability to implement DfOSH. The next section presents a brief review of DfOSH and capability maturity literature to provide the underpinning for the empirical facet of the study. Findings, discussion and concluding remarks are presented subsequent to a description of the research methodology.

2 The Role of Design in Occupational Safety and Health

The emergence of DfOSH is largely due to research findings that design contributes significantly to the occurrence of accidents and injuries in construction [5,6]. According to OSH studies in construction, some accidents are linked to pre-construction decisions (e.g. design and client requirements) that result in design features that may be inherently dangerous to build or operate [7,8,9]. Haslam et al. [6] found causal links between permanent works design and accidents in nearly 50 out of 100 cases of accidents they examined. Similarly, studies in the USA found that 42% (out of 224) of construction fatality cases were linked to design [5]. Another study of 27 incidents on USA construction sites revealed that design contributed to up to 30% of accidents [10]. In a more recent survey of UK practitioners (n=184), complex design (i.e. design with intricate aesthetic qualities) was perceived to influence construction accident occurrence [9]. From these studies, it is clear that design remains an important factor in accident causation in construction. Consequently, DfOSH is growing as part of efforts to improve OSH performance in construction.

3 Design for Occupational Health and Safety (DfOSH) Capability

DfOSH requires that designers (e.g. architects and engineers) give careful consideration to the implications of their design decisions on the OSH of builders and maintenance workers. In the UK, DfOSH is mandatory under the Construction (Design and Management) Regulations 2015 (CDM, 2015) [11]. The CDM 2015 requires that designers (organisations/individuals) reduce foreseeable risk as much as possible through the design decisions they make about the facilities they design. The CDM 2015 further requires the appointment of designers with the organisational capability for DfOSH. However, conspicuously missing in the growing body of academic DfOSH literature is an in-depth understanding of what constitutes DfOSH capability of a design organisation or an organisation with design responsibility on a project. Furthermore, no studies have sought to identify and categorise DfOSH organisational capability attributes to aid objective assessment of
the DfOSH capability maturity of firms.

3.1 Towards DfOSH Capability Modelling in Construction

One of the prominent methodologies for assessing the maturity of organisations in the performance of tasks is capability maturity model (CMM) \([12,13,14,15]\). CMM is a methodology used to assess and refine organisational systems, processes or competencies on an evolutionary path towards attainment of specific goals \([13]\). CMM principles have been applied in the construction industry for assessing capability in areas such as building information modelling (BIM) \([15,16,17]\), e-readiness \([18]\) and supply chain management \([19]\). Within OSH, maturity modelling has been applied for assessing construction site safety management (e.g. AC2E model by Carillion Plc), safety culture \([20]\) and also for design in the offshore sector \([13,14]\). However, no CMM exists for assessing a design organisation’s capability to implement DfOSH in construction. Before a CMM can be developed for DfOSH, there is a need to identify attributes that will serve as the key criteria in assessing capability. The application of CMM is reliant on the identification of key attributes referred to as key process areas (KPA) which represent performance indicators for benchmarking capability and process improvement areas across organisations and systems \([12]\). These capability attributes refer to distinct clusters of related activities, competencies or resources that are required or performed to achieve a set of goals \([21]\). They broadly include processes, people, policy, systems and resources required to execute relevant functions \([11,12,15,21]\). This study therefore explored the attributes required for assessing organisation’s DfOSH capability as a precursor for developing a DfOSH CMM.

4 Research Methodology

Two expert focus group discussions (FGD) with experienced construction industry professionals were used to generate a list of attributes that can be relied on in assessing the DfOSH capability of organisations. The FGDs were used to draw on participant's experience and expertise in relation to DfOSH. A total of 7 experts were engaged in the two FGDs. Collectively, participants had vast experience in DfOSH and procurement (including selection of design firms). The participant’s organisations are reputable industry organisations that are partners in the delivery of the research. Most importantly their level of expertise meet the requirements for selecting participants in expert group methods (see \([22]\) e.g. membership of a nationally recognised professional institution; a senior professional or academic in the subject area; and a minimum of five years of experience. The background information of FGD participants is presented in Table 1. The number of experts in FGDs is recommended to be small in order to ensure effective management by researchers \([23]\). Furthermore, research methods that rely on expert opinion are more concerned with the depth and relevance of knowledge rather than quantity \([22]\). Expert group methods have become popular as a result of their effectiveness for deep exploration of phenomena \([23,24]\). The FGD allowed the experts to draw from each other's expertise and experience regarding DfOSH, thereby creating rich and in-depth discussions. The first expert FGD (FGD-1) provided a brainstorming forum for the generation of a list of organisational capability attributes necessary for DfOSH. The second expert FGD (FGD-2) then focussed on reviewing the attributes to ensure their validity and applicability as well as identifying examples of indicators for the attributes. The FGD participants comprised of senior construction industry practitioners with extensive DfOSH and procurement
experience. Participants had an average of 25 years of experience in construction. The thoughts of the experts regarding the capability attributes were captured on designed open-end feedback sheets. The recorded attributes were subsequently categorised into thematic areas of DfOSH organisational capability.

Table 1. Background of Experts

<table>
<thead>
<tr>
<th></th>
<th>FGD-1</th>
<th>FGD-2</th>
<th>Professional Role</th>
<th>Experience in Role (Years)</th>
<th>Experience in Construction (Years)</th>
<th>Professional Body Affiliation/Qualifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>√</td>
<td></td>
<td></td>
<td>Senior Design Manager</td>
<td>12</td>
<td>30</td>
<td>Member of CIOB</td>
</tr>
<tr>
<td>√</td>
<td></td>
<td></td>
<td>Architect</td>
<td>31</td>
<td>31</td>
<td>Member of RIBA</td>
</tr>
<tr>
<td>√</td>
<td></td>
<td></td>
<td>OSH Manager</td>
<td>5</td>
<td>17</td>
<td>Chartered Member of IOSH</td>
</tr>
<tr>
<td>√</td>
<td></td>
<td></td>
<td>OSH Advisor</td>
<td>10</td>
<td>15</td>
<td>Chartered Fellow of IOSH, Fellow of RSPH,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fellow of IIRSM, Member of APS, Certified</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Generalist OHS Practitioner of the Safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Institute of Australia, and European</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Occupational Safety and Health Manager</td>
</tr>
<tr>
<td>√</td>
<td></td>
<td></td>
<td>Civil/Structural Engineer and OSH</td>
<td>28</td>
<td>28</td>
<td>Member of ICE, Member of IStructE, and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Professional</td>
<td></td>
<td></td>
<td>Incorporate member of APS</td>
</tr>
<tr>
<td>√</td>
<td></td>
<td></td>
<td>Civil Engineer and OSH Professional</td>
<td>27</td>
<td>40</td>
<td>Member of ICE and Member of IOSH.</td>
</tr>
<tr>
<td>√</td>
<td></td>
<td></td>
<td>Senior Quantity Surveyor</td>
<td>20</td>
<td>28</td>
<td>Member of RICS</td>
</tr>
</tbody>
</table>

Notes: OSH = Occupational Safety and Health; CIOB = Chartered Institute of Building; RIBA = Royal Institute of British Architects; RICS = Royal Institution of Chartered Surveyors; IOSH = The Institution of Occupational Safety and Health; RSPH = Royal Society for Public Health; IIRSM = International Institute of Risk and Safety Management; APS = Association for Project Safety; ICE = Institution of Civil Engineering; IStructE = Institution of Structural Engineers

5 Findings and Discussions

The DfOSH capability attributes are shown in Table 2. The attributes are: Design Quality Management; Design Risk Management; Project Review; Physical Work Resources; Information Communication Technology; Experience/Reputation; Collaboration; Leadership and Strategy; Personnel (i.e. design staff capability); Human Resource Development; and Research and Innovation. The attributes share similarities with the criteria proposed by Strutt et al, [14] for the assessment of offshore safety and environmental design maturity. One notable difference, however, is the reliance on 12 assessment criteria areas in comparison with the 11 attributes that emerged in this study. Unsurprisingly, several conventional measures of organisational capability (e.g. experience, leadership, reputation, physical resource availability and personnel/human resources) were proposed albeit specifically defined in terms of DfOSH. Attributes such as ‘design quality management’ and ‘design risk management’ have not been previously considered in the generic safety CMMs currently available [14,20]. Furthermore, the descriptions of the DfOSH capability attributes reflect recent industry developments, especially the role of digital and virtual technologies such as BIM (i.e. theme 5-‘Information Communication Technology’) as well as
competencies in design for manufacture, assemble and disassembly (i.e. theme 11- ‘Research and Innovation’).

<table>
<thead>
<tr>
<th>Capability Attributes</th>
<th>Description / Example of indicators of attributes</th>
<th>Related Key Process Area Category [11,12,15, 21]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Design Quality Management</td>
<td>Systems, processes and procedures for design quality review to capture and rectify errors and to ensure conformance of design to proposed DfO SH solutions e.g. ISO 9001 certification.</td>
<td>Process</td>
</tr>
<tr>
<td>2  Design Risk Management</td>
<td>Systems, processes and procedures for identification and mitigation of OSH hazards in design as part of design workflow e.g. design risk register.</td>
<td>x</td>
</tr>
<tr>
<td>3  Project Review</td>
<td>Systems, processes and procedures for capturing lessons learnt in order to facilitate future improvements e.g. knowledge management systems.</td>
<td>x</td>
</tr>
<tr>
<td>4  Physical Work Resources</td>
<td>Conducive workspace, environment and equipment that support design and DfOSH e.g. workstations and workspace.</td>
<td>x</td>
</tr>
<tr>
<td>5  Information Communication Technology (ICT)</td>
<td>Computing and information technology facilities that support DfO SH and communication or sharing of design information e.g. BIM software, advanced visualisation and virtual prototyping tools.</td>
<td>x</td>
</tr>
<tr>
<td>6  Company Experience/Reputation</td>
<td>Company track record in design for occupational safety and health on specific type of project or similar types of project e.g. portfolio of past projects.</td>
<td>x</td>
</tr>
<tr>
<td>7  Collaboration (intra and inter-organisational)</td>
<td>Ability of various design units/sections/departments within the organisation to collaborate to promote DfO SH as well as the</td>
<td>x</td>
</tr>
</tbody>
</table>

Table 2. Summary of Organisational Capability Attributes for Design for Occupational Safety and Health
The emergent attributes were further reclassified in line with widely used categorisation of attributes in capability maturity modelling \(^{[12,15,21]}\) as well as the descriptions of organisational capability in the CDM 2015 guidance \(^{[11]}\). The re-classification adopted are: `process` for required activities and workflows; `systems` in place to ensure these processes work; `people` for describing human capital; `technology` for specific technological tools and artefacts required; `policy` for strategic organisational directives, guidance and benchmarking to achieve objectives; and `resources` for describing attributes related to other physical resources needed for delivery of DfOSH functions effectively. From the review, the majority of the DfOSH organisational capability attributes are either related to `systems` or `process` followed by `people` and then `resources`. The categories associated with the least number of the main DfOSH capability attributes are `policy` and `technology`. The high number of `systems` and `process` related criteria is unsurprising and supports the primary ethos of CMMs which is premised on a philosophy that

| Related Key Process Area Frequency | 6 | 5 | 3 | 2 | 4 | 7 |

The emergent attributes were further reclassified in line with widely used categorisation of attributes in capability maturity modelling \(^{[12,15,21]}\) as well as the descriptions of organisational capability in the CDM 2015 guidance \(^{[11]}\). The re-classification adopted are: `process` for required activities and workflows; `systems` in place to ensure these processes work; `people` for describing human capital; `technology` for specific technological tools and artefacts required; `policy` for strategic organisational directives, guidance and benchmarking to achieve objectives; and `resources` for describing attributes related to other physical resources needed for delivery of DfOSH functions effectively. From the review, the majority of the DfOSH organisational capability attributes are either related to `systems` or `process` followed by `people` and then `resources`. The categories associated with the least number of the main DfOSH capability attributes are `policy` and `technology`. The high number of `systems` and `process` related criteria is unsurprising and supports the primary ethos of CMMs which is premised on a philosophy that

| 8 | Leadership and Strategy | Leadership and strategic management that supports and promotes DfOSH and recognises DfOSH as a key organisational goal e.g. company policy. | x | x |
| 9 | Personnel | Individual design staff capability i.e. skills, knowledge and experience (SKE) e.g. staff qualifications. | x |
| 10 | Human Resource Development | Provision of accredited/appropriate training/professional development including support for OSH in general and DfOSH specifically. E.g. design staff training records. | x |
| 11 | Research and Innovation | Organisation’s investment into, conduct of, or exploitation of research to enhance DfOSH, as well as organisational ability to be creative in eliminating or mitigating OSH hazards through design e.g. application of design for manufacture and assemble. | x | x | x | x | x |

ability of the organisation (as a unit) to collaborate with other organisations to deliver safe designs and projects e.g. in-house design co-ordinator for various workpages, and company involvement in routine design review meetings.
key ‘process’ improvement leads to sustained and repeatable attainment of goals. According to Strutt et al.,\textsuperscript{[14]} DfOSH CMM requires shifting the focus from the safety of the final product of design towards assessing the “process” that delivers the safe product. Thus, process elements are widely regarded as an important aspect of DfOSH organisational capability, though the systems, resources, people and policy that facilitates the processes also need full consideration. Furthermore, the domination of particular types of attributes does not necessarily indicate their importance during assessment, thus, the relative weight (importance) of attributes need to be determined separately through further research.

6 Conclusion

The consideration of DfOSH is increasingly becoming a pre-requisite in design practice in construction. In other to shift the focus of OSH consideration to the early stages of projects, there is a need for understanding what constitutes an organisations ability to deliver DfOSH. The study explored the DfOSH capability attributes of organisations as a precursor for identifying metrics for the development of a bespoke DfOSH CMM. The findings highlight the relevance of process and system maturity in the attainment of DfOSH goals. The findings also acknowledge the role of digital and people capability and the relevance of research and innovation to improve DfOSH organisational capability. Overall, the research findings could assist design firms to better understand their own DfOSH capability, and they could also assist organisations that appoint design firms (e.g. clients and project management firms) to understand design firms’ DfOSH capability. Future work will ascertain the relative importance of the attributes and also define maturity levels and a scoring method for the capability attributes.

Acknowledgement

This research is funded by the UK Engineering and Physical Sciences Research Council (grant number: EP/N033213/1). Industry partner organisations involved in the delivery of the project are: Bam Construction Limited, Health and Safety Executive, Heathrow Airport, ISG, Mott MacDonald, Nick Bell Risk Consultancy, GCP Architects, and Safety in Design.

References


An analysis of Stakeholder Management in Design & Build projects in South Australia, from a client’s perspective.

Hutchinson, N.J.¹, O’Leary, T.R.² and Ma, T.³

Abstract: Although the quality standards of construction projects are increasingly complex, less time and cost is allotted to designing, procuring, planning and construction. Clients are also endeavouring to minimise their risk exposure.

The research presented in this paper in a mainly qualitative study of the South Australian construction industry examines industry perspectives on several key aspects of stakeholder management. Firstly to understand the shift away from traditional construction contracts to Design and Build procurement; understand how stakeholder management methodologies might affect Design and Build project outcomes; and finally to undertake a gap analysis from the client perspective (up front expectation vs delivery satisfaction).

In order to understand any shift away from traditional contracting and the impact it might have upon project outcomes and client satisfaction, a literature review was undertaken and quantitative and qualitative methods were used to collect data.

A questionnaire survey was developed to collect a substantive amount of information for analysis, with questions based upon information garnered from the literature review. Questionnaire surveys were forwarded to persons in the construction industry known to the researchers together with professional bodies. Of the 485 direct emails, 101 responses were received equating to 20.81%. Additionally, LinkedIn, Facebook and Twitter call outs were made and further anonymous responses were received, providing an instructive 109 responses. Stakeholders in the construction industry were approached and included Project Managers, Contractors, Consultants, Engineers and Clients.

The key findings from the survey are presented here and indicate some common agreement around the need for engagement with PMBOK principles and the need for improvement in stakeholder management practices. There is significant disagreement on both the utilisation and actual success of stakeholder management on projects. However a surprising finding was that each interviewee felt that there was a project management position to be created to liaise between client, and builder, and builder and design team through the D&B process. How this would be implemented in a project hierarchical environment was not considered and warrants further research.

Keywords: Construction projects; Stakeholder Management; Design & Build; Traditional Contracting; Construction Procurement.

¹* Hutchinson, N.J.
Corresponding author, c/- School of Natural and Built Environments, University of South Australia, Australia
E-mail: nerolihutchinson@built.com.au

² O’Leary, T.R.
School of Natural and Built Environments, University of South Australia, Australia

³ Ma, T.
School of Natural and Built Environments, University of South Australia, Australia
1 Introduction

Although the quality standards of construction projects are increasingly complex, less time and cost is allotted to designing, procuring, planning and construction. Clients are also endeavouring to minimise their risk exposure. In a South Australian context Ma, et al. [1] support this contention, stating that,

‘The South Australian construction industry is experiencing high demand for new construction and meanwhile increasing project complexities in terms of schedules and budgets. These pressures are driving the need for changes in contracting procedures.’

It is proposed that South Australia is moving towards a continued growth of the Design and Build (D&B) procurement method, driven in part by the State Government as a major client stakeholder. This research considered how a change from traditional procurement to D&B procurement in the construction industry might affect stakeholder management and project outcomes in South Australia.

In order to understand any shift away from traditional contracting and the impact it might have upon project outcomes and client satisfaction, a literature review was undertaken and quantitative and qualitative methods were used to collect data. The literature review considered the following areas considered foundational to the topic: construction procurement systems and trends; stakeholder management methodologies in construction procurement; and impact of Stakeholder management on project outcomes.

All literature reviewed placed high importance upon relationships in construction contracting, and therefore upon the relevance of stakeholder management. Forgues and Koskela [2] state ‘Building trust is also an essential component in building the team dynamic.’ Yang, et al. [3] further identified four key gaps regarding critical success factors, stakeholder management process, methods for stakeholder management and stakeholder relationship management.

It was found that there is a trend away from traditional contracting methods with a shift towards D&B procurement. Whilst this divests risk away from client to contractor, clients need to be more involved in this procurement process. The questionnaire survey was developed to collect a substantive amount of information for analysis, with questions based upon information garnered from the literature review. Stakeholders in the construction industry were approached and included Project Managers, Contractors, Consultants, Engineers and Clients.

2 Stakeholder Management

Although there are prescribed and clear requirements for project managers to carry out stakeholder management, they are often not easy to apply on construction projects which are by nature, one-off and unique. From the literature reviewed, it is held that the most successful D&B project delivery has had a single point of contact within the client organisation, and one single point of ownership/control across the project (a project manager) [4], [5], [6], [7], [8].

All literature reviewed places high importance upon relationships in construction contracting, and therefore upon the relevance of stakeholder management. This view has not altered from the 1990s until the time of writing. Stakeholder management is considered difficult even in a traditional contract as discussed by Yu and Shen [9]. An emotional intelligence approach towards project management in construction projects is considered by Zhang and Fan [10], indicating that a better understanding between parties is necessary to enhance project outcomes.

Furthermore, the literature points to a worldwide gap between client expectations and the reality of project delivery. Procurement types which may or may not be fit for the project also play a part in the stakeholder management methods engaged. Stakeholder management is caught up in the contractual agreements that currently drive construction relationships. Clients are also endeavouring to minimise their risk exposure [11].

Following completion of the literature review, a number of barriers to stakeholder management were discovered. Some of these related to the procurement type and others appeared to be common to all construction contracts.
The authors utilised the literature review findings to create a questionnaire survey to collect data for analysis from construction project practitioners in Australia, and particularly in South Australia. Questionnaire surveys were forwarded to persons in the construction industry known to the research team together with professional bodies. Of the 485 direct emails, 101 responses were received equating to 20.81%. Additionally, LinkedIn, Facebook and Twitter call outs were made and further anonymous responses were received, providing an instructive 109 responses. Respondents had significant experience within the construction industry. Half of respondents were equally spread across the 5-12 years and 12-20 years grouping, with a significant 41% with more than 20 years of experience. A significant majority responded with their construction experience within the commercial sector occurring within South Australia.

The focus of the first section of questions was to discover any gap in Stakeholder Management in the D&B contracting method. The initial survey question was designed to obtain primary information on stakeholder agreement with PMBOK[12] guidelines as follows:

‘According to the Project Management Body of Knowledge Guide (PMBOK), to engage stakeholders you should:

- Engage stakeholders to ensure commitment to the success of the project;
- Manage stakeholders’ expectations to ensure project goals are met;
- Anticipate future problems that may be raised by stakeholders by listening to concerns when raised. Identify and resolve to ensure they do not escalate to project risks; and
- Address and rectify issues uncovered.

Do you agree?’

Responses were overwhelmingly in agreement with this excerpt from PMI [12] about Stakeholder Management and engagement, with 97% in agreement, 3% stating they didn’t know. No respondent disagreed with the excerpt.

2.1 Success and utilisation of Stakeholder Management

Further, the survey asked if Respondents felt that stakeholder management methods were properly considered, integrated and utilised in both Traditional and D&B contract scenarios.

![Utilisation of Stakeholder Management](image)

*Figure 1 Survey response Utilisation of Stakeholder Management methods*

There were smaller differences between the two procurement types than anticipated by the authors.
Further to the understanding of utilisation of stakeholder management methods, the notion of success was queried, asking “Did the Respondents believe that stakeholder management methods were successful across the two contract types?”

![Success of Stakeholder Management methods](image)

**Figure 2 Survey responses: Perceived Success of Stakeholder Management methods**

It can be seen from Figure 2 that there are similar values across the two types of contract. Interestingly, the highest value of ‘highly successful’ and ‘highly unsuccessful’ responses both relate to the Traditional procurement route.

### 2.2 Improvement in Stakeholder Management

The survey addressed the notion that there could be room for improvement to stakeholder management in project procurement. The Respondents overwhelmingly said ‘Yes’ with 79% believing there could be improvements made.

![Could there be improvements to stakeholder management within project procurement](image)

**Figure 3 Survey responses: Improvements to Stakeholder Management within project procurement**
Respondents were then asked to select which of the methods set out they might apply. The results are set out in Table 1 Stakeholder Management: areas for improvement below.

### Table 1 Stakeholder Management: areas for improvement

<table>
<thead>
<tr>
<th>Areas of improvement in stakeholder management in Traditional + Design and Build procurement</th>
<th>Traditional</th>
<th>D&amp;B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ensuring total commitment of all parties to the project and its outcomes (from CEO level)</td>
<td>51%</td>
<td>53%</td>
</tr>
<tr>
<td>2. Formalise the process for briefing and scoping</td>
<td>36%</td>
<td>52%</td>
</tr>
<tr>
<td>3. Clients to be made aware of impact of poor scoping and assisted with same</td>
<td>48%</td>
<td>53%</td>
</tr>
<tr>
<td>4. Clarify the time required for client involvement through the project</td>
<td>46%</td>
<td>56%</td>
</tr>
<tr>
<td>5. Link initial capital cost considerations with operational costs in use</td>
<td>44%</td>
<td>41%</td>
</tr>
<tr>
<td>6. Clients to allow enough time for staff to be available throughout the project</td>
<td>39%</td>
<td>45%</td>
</tr>
<tr>
<td>7. Have a ‘go to’ advocate who speaks plain English:</td>
<td>24%</td>
<td>23%</td>
</tr>
<tr>
<td>(a) within Client team</td>
<td>42%</td>
<td>39%</td>
</tr>
<tr>
<td>(b) within Contractor group</td>
<td>37%</td>
<td>42%</td>
</tr>
<tr>
<td>(c) Project Manager</td>
<td>41%</td>
<td>40%</td>
</tr>
<tr>
<td>(d) Stakeholder Engagement Manager (that is, a Project Manager who is solely responsible for communication and understanding between stakeholders)</td>
<td>38%</td>
<td>43%</td>
</tr>
<tr>
<td>8. Choosing correct procurement for the project</td>
<td>46%</td>
<td>50%</td>
</tr>
<tr>
<td>9. Clarity about risk and risk allocation (develop a weighted risk matrix)</td>
<td>34%</td>
<td>40%</td>
</tr>
<tr>
<td>10. Combine breakthrough thinking with intelligent risk taking to achieve exceptionally good project outcomes, that is, allow for:</td>
<td>14%</td>
<td>17%</td>
</tr>
<tr>
<td>(a) Building innovation</td>
<td>39%</td>
<td>39%</td>
</tr>
<tr>
<td>(b) Design innovation</td>
<td>32%</td>
<td>39%</td>
</tr>
<tr>
<td>(c) Value Management</td>
<td>38%</td>
<td>43%</td>
</tr>
<tr>
<td>11. Make project interests paramount over stakeholder interests</td>
<td>24%</td>
<td>28%</td>
</tr>
<tr>
<td>12. Updating standard contracts to encourage team relationship arrangements, not litigation</td>
<td>33%</td>
<td>39%</td>
</tr>
<tr>
<td>13. Contractor Project Manager to be focused on relationships not just hard dollars</td>
<td>42%</td>
<td>50%</td>
</tr>
<tr>
<td>14. To integrate staff from all parties on a 'best for job' basis</td>
<td>39%</td>
<td>45%</td>
</tr>
<tr>
<td>15. Engender enthusiasm for the project with social activities and other team building exercises</td>
<td>28%</td>
<td>31%</td>
</tr>
</tbody>
</table>

Again, in alignment with the literature review research, most areas of improvement were considered to be equally applicable to the two contract types. However, two areas of distinct differences were identified.

First, scoping was considered by Respondents to be more problematic in D&B than in Traditional. The suggestion that the process of briefing and scoping be formalised (item 2 above) had 36% responses for Traditional contracting and a significant 52% for D&B. This was supported by Fleming [13] and Greenhalgh and Squires [14].
This response could also relate to the idea that in the Traditional scenario, the client brief evolves across the design and documentation process by the Architect/Designer. The scope is then bedded down for the Contractor at this time and is less risky for pricing. Conversely, the D&B contract requires the Contractor to work with a written brief which can be lengthy, technical but not innovative. This means that there is a risk to the Contractor for fixing a price at this early stage of the client’s thought processes [8].

Secondly, the area of client time application to the project was highlighted for D&B with items 4 and 6 in Table 1 Stakeholder Management: areas for improvement suggesting that clients and their staff should have more availability resourced for D&B than required under a Traditional model. Also for further investigation was the agreement by many respondents that a ‘go to’ advocate who could assist in communication between teams should be available within the; (a) client team, (b) contractor group, and (c) Project Manager.

2.3 Respondent comments on Stakeholder Management

Some further insights were offered by Respondents of the Questionnaire Survey and many follow similar themes. Some key points have been provided to ensure good stakeholder management:

- Client to have a clear understanding of the time, cost, quality triangle.
- Respect everyone’s part in the process and provide the time required to do the work.
- Identify all project stakeholders as early as possible. A large stakeholder group is not conducive to good outcomes.
- Stakeholder discussions should be held with the whole design team (not just a few).
- The promotion and management of collaboration across all disciplines and between all parties to design and build will lead to better outcomes for all, there is too much adversity in the industry.
- The success of the project depends on the skills of the stakeholder manager.

3 Interview outcomes

Semi-structured interview participants included a Building Contractor, a Quantity Surveyor and a Client representative with an Architectural background. Each individual had over 20 years of experience in the construction industry.

The interview comprised five directed questions and one open question with interviews taking around 30 minutes. Although the interview was mostly structured, interesting discussions ensued from all questions. Comments from the interview are set out in with a common goal, whilst maintaining positive relationships. Having the right people on the project was considered important by all.

Table 2 Results from Face to Face Interviews on the page following.

Amongst the interviewees, there was a mix of formal and informal stakeholder management processes with all relying on existing relationships and two on intuition. It is suggested that the use of intuition is really based upon experience of previous poor outcomes. All felt that it was important that the builder have an understanding of design and design processes in the D&B contract.

Each interviewee agreed there was a gap in stakeholder management in both traditional and D&B contracting. All identified some in the South Australian market who were better at D&B than others, but none felt that any were doing it well. Most noted that Managing Contractor procurement was the most common method aside from Traditional. This was also identified from the questionnaire survey.

They all suggested there was a project management position to be created to liaise between client, and builder, and builder and design team through the D&B process. The aim of this project manager as a stakeholder manager would be to ensure all are continuing to work towards the end result, and are all clear on their roles and responsibilities. This role needs further research, but it could be considered a person to guide clients, consultants and builders through the D&B process.
with a common goal, whilst maintaining positive relationships. Having the right people on the project was considered important by all.

Table 2 Results from Face to Face Interviews

<table>
<thead>
<tr>
<th>Q</th>
<th>Building Contractor</th>
<th>Quantity Surveyor</th>
<th>Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1 - Does your business have any</td>
<td>Yes. High level,</td>
<td>No. Due to</td>
<td>No. General information gathering, working with end users in early</td>
</tr>
<tr>
<td>processes/checklists or methodology for</td>
<td>political. Includes</td>
<td>engagement on</td>
<td>phases of feasibilities. Consultation levels depend upon project. Often</td>
</tr>
<tr>
<td>stakeholder management?</td>
<td>user groups and</td>
<td>projects and</td>
<td>also intuitive.</td>
</tr>
<tr>
<td></td>
<td>consultants.</td>
<td>existing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Utilises a</td>
<td>relationships.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>structured process.</td>
<td>Contractual and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Also use ‘gut feel’.</td>
<td>personal.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acting between</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>client and</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>designers</td>
<td></td>
</tr>
<tr>
<td>Q2 - Do you believe there is a gap</td>
<td>Traditional – Yes</td>
<td>Traditional – Yes</td>
<td>Traditional – Yes at post documentation. Change management to contract.</td>
</tr>
<tr>
<td>o Traditional Contracting?</td>
<td></td>
<td>understanding of</td>
<td>but need to constrain consultant. Difficult to determine cut off</td>
</tr>
<tr>
<td>o Design and Build</td>
<td></td>
<td>roles and</td>
<td>point (ie 75% completion). Value management a priority. Not all</td>
</tr>
<tr>
<td>Contracting?</td>
<td></td>
<td>responsibilities.</td>
<td>builders good at D&amp;B. Client communication important.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technical abilities</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>lacking. Who</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>signs off?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>D&amp;B – Yes -</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dissipation of</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>roles from</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Traditional. Who</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>is engaged for</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>what? Who is</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>delivering what?</td>
<td></td>
</tr>
<tr>
<td>Q3 - If so, is this particular to</td>
<td>Problem everywhere</td>
<td>Worldwide problem.</td>
<td></td>
</tr>
<tr>
<td>South Australia in your view?</td>
<td>but especially D&amp;B</td>
<td>D&amp;B - Some</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>contractors good</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>at design control</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>and management,</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>but some are not.</td>
<td></td>
</tr>
<tr>
<td>Q4 - Why do you think this is</td>
<td>Subcontractors can't</td>
<td>External Project</td>
<td>Smaller pool. Lack of exposure and therefore lack of experience.</td>
</tr>
<tr>
<td>particular to South Australia?</td>
<td>support D&amp;B.</td>
<td>Manager doesn’t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Builders don’t know</td>
<td>take responsibility.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>how to do it.</td>
<td>Internal client</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clients lack of</td>
<td>Project Manager</td>
<td></td>
</tr>
<tr>
<td></td>
<td>understanding.</td>
<td>doesn’t have</td>
<td></td>
</tr>
<tr>
<td>Q5 - What methods /strategies do</td>
<td>Builder to have</td>
<td>- Project Manager</td>
<td>Must have the right people. Good client</td>
</tr>
<tr>
<td>you believe should be considered/</td>
<td>design expertise in</td>
<td>to manage the</td>
<td>relationships to be maintained. Have a Liaison/Design Manager or</td>
</tr>
<tr>
<td>adopted to assist with design and</td>
<td>their team.</td>
<td>delivery team.</td>
<td>Project Manager with emotional intelligence. Liaise through the</td>
</tr>
<tr>
<td>build contracting stakeholder</td>
<td>Understand design</td>
<td>D&amp;B Builder to</td>
<td>business for the Builder. Be a “plain English” translator for the</td>
</tr>
<tr>
<td>management?</td>
<td>office &amp; consultant</td>
<td>continue with</td>
<td>client to Builder. Consider this a specific role.</td>
</tr>
<tr>
<td></td>
<td>methods.</td>
<td>design team.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manage requirement</td>
<td>Need to understand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>for document</td>
<td>process to call it</td>
<td></td>
</tr>
<tr>
<td></td>
<td>progress in</td>
<td>out.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>packages.</td>
<td>- Project Manager</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>for User</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>management. Client</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>interface team -</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>internal or</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>external.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Project Manager</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>for Public</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>interface.</td>
<td></td>
</tr>
<tr>
<td>Q6 - What else should the researcher</td>
<td>Banks are tightening</td>
<td>Most common in</td>
<td>Clients to inform themselves by knowing the market – what is</td>
</tr>
<tr>
<td>be aware of or consider?</td>
<td>controls. Risks</td>
<td>Adelaide Traditional/</td>
<td>contractor capacity. Who can do D&amp;B – builders &amp; consultants</td>
</tr>
<tr>
<td></td>
<td>for companies –</td>
<td>Managing Contracting / Early Contractor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bank guarantees</td>
<td>Involvement and D&amp;B.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>holding up cash.</td>
<td>D&amp;B should be</td>
<td>Client reality check – budget for delivery.</td>
</tr>
<tr>
<td></td>
<td>Clarify that can</td>
<td>simplest due to</td>
<td></td>
</tr>
<tr>
<td></td>
<td>have certainty</td>
<td>relationship</td>
<td></td>
</tr>
<tr>
<td></td>
<td>around end cost</td>
<td>hierarchy. Doesn’t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>with Guaranteed</td>
<td>seem to be working</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maximum Price for</td>
<td>that way.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D&amp;B</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5 Conclusion

A questionnaire survey was developed to collect a substantive amount of information for analysis, with questions based upon information garnered from an initial literature review. Stakeholders in the construction industry were approached and included Project Managers, Contractors, Consultants, Engineers and Clients.

Some questionnaire survey data has been analysed with mean and standard deviation figures extrapolated for further review and consideration. It was discovered that there was a mix of formal and informal stakeholder management processes mostly reliant on existing relationships and intuition. It is suggested that the use of intuition is really based upon experience of previous poor outcomes. Research held it important that the builder have an understanding of design and design processes in the D&B contract.

An outcome of the research was that a project management position be created to liaise between client, and builder, and builder and design team through the D&B process. The aim of this project manager as a stakeholder manager would be to ensure all are continuing to work towards the end result, and all are clear on their roles and responsibilities.

The purpose of this thesis research was to respond to the question, ‘Is there a gap in stakeholder management methodologies in design and build procured construction projects in South Australia from a client’s perspective? ‘The answer is ‘Yes’.

References


Lessons and Revelations of Sino - Thai Railway Project

Luo, W.Z.1*, Jin, Z.G.2

Abstract: In the context of One Belt, One Road (OBOR), the government took the lead and the company responded positively to the call, and the number of overseas railway investment projects has gradually increased, but they have encountered many obstacles. As an important part of OBOR, Sino - Thai railway has suffered setbacks and has a profound impact on OBOR. This study systematically analyzes the lessons of the implementation process of Sino - Thai railway project and puts forward the corresponding improvement measures to provide inspiration for overseas railway investment projects in China.

Key words: One Belt, One Road; Sino - Thai railway; lessons; revelations

1* Luo, W.Z.
Corresponding author, Department of management engineering and science, Chongqing University, China
E-mail: 276243429@qq.com

2 Chan, I.Y.S.
School of construction management and real estate, Chongqing University, China
1 Introduction

In the OBOR background, the government took the lead and the company responded positively to the call, the scale of overseas investment projects gradually expanded. China's enterprises have directly invested 49 countries relative to OBOR in 2015, which total investment of 14.82 billion dollars, increased by 18.2% [1]. China's overseas railway investment projects as an important part of China's overseas investment projects, their size has gradually expanded. Since the OBOR was put forward in 2013, the western express high-speed railway, Yavan high-speed railway, London to Manchester high-speed rail, Sino - Thai railway, Laos railway, Russia Moscow - Kazan high-speed railway and so on caused widespread international attention.

However, the progress of overseas investment projects in China is not smooth, for example, the Thai government unilaterally announced that Sino - Thai railway is no longer to look for Chinese enterprises loans in April 2016. Only two months later, the Western Express Company unilaterally announced the termination of the western express high-speed railway. Sino - Thai railway as a Pan-Asian railway network, it suffered setbacks compared to the western express high-speed railway which have more far-reaching implications for OBOR, So the study takes Sino - Thai railway as an example. Sino - Thai railway has undergone ups and downs, during the reign of yingluck, two countries reached a plan to exchange rice for high-speed rail. At one time, the domestic political unrest in Thailand failed to proceed as scheduled, until 2014, when the sino-thai railway project resumed, and during the period of Japanese disruption, our government responded positively. But Thailand has unilaterally changed its mind as the railway project is officially finalised. This study analyzes the lessons learned from the development of sino-thai railway project, and puts forward the corresponding improvement measures to provide inspiration for the overseas railway investment projects.

2 Overview of Sino-Thai Railway Project

The Sino-Thai Railway Project is about 873 km of complex railway construction, including Kan Gui - Bangkok, Kan Gui - Ma Ta Bu, Nakhon Ratchasame and Nakhon Ratchasima four lines, across the north, middle and south of Thailand. After its completion, it is conducive to improving the infrastructure construction in Thailand and improving the transportation network system. The departure railway line at the north end is connected to the Laos railway.

In December 2015, China and Thailand signed a framework document on inter-governmental railway cooperation. The Sino-Thai Railway cooperation project will begin the groundbreaking ceremony in December 2015, and strive to achieve the full construction of the project by May 2016 [2]. While the outside world have thought that the Sino-Thai Railway project has been settled, the bad news came. In March 25, 2016, Thai Minister of Transport Ding Pisiye Shi said that Thailand decided to self-financing investment in the Sino-Thai Railway project, no longer to look for Chinese loans, and the line shortened by more than two-thirds line. Now the construction section is a section of Bangkok - korat, a total length of 250 km, the design speed of 250 km. Although Thailand has not changed the policy of introducing Chinese technology, the cooperation plan that the two countries have already reached has been greatly reversed. Thailand government shortened the railway line by more than two-thirds, and did not build the northern section of the
departure railway line, unable to connect with the Laos Railway, so that the economic value of the railway has shrunk dramatically.

Prior to that, the international loans for the sino-thai railway project were mainly from the export-import bank of China. The source of funding is shown in Figure 1. Thailand and China intends to set up a project company. The contract stipulates that the two parties shall be responsible for the land requisition, basic civil construction and power supply in Thailand. While China is responsible for the design, high technology infrastructure, equipment, providing all tracks, signals and vehicles. The first phase of the project, Kan Kwai - Bangkok, Nakhon Ratchasima - Kan Kwai Road, started in early 2016 and is expected to be completed and opened in 2019. The remaining two phases will commence at the beginning of 2017 and is expected to be completed by 2020.

![Figure 1 Sino-Thai Railway project funding sources](image)

### 3 Lessons from the Sino - Thai Railway Project

Through the case analysis, interview and literature research, this study analyzes the root causes of the frustration of Sino - Thai Railway, including the loan interest rate between China and Thailand, and a dispute over the contribution of the project company, Thailand thinks China's total investment is high, Thai people distrust China's manufacturing, the influence of Chinese and Thai public opinion. Ultimately, these factors can be divided into two levels: economic and social. As shown in Table 1.

<table>
<thead>
<tr>
<th>the first level factor</th>
<th>the second level factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic level</td>
<td>The loan rate won't hold up</td>
</tr>
<tr>
<td></td>
<td>There is a dispute over the contribution of the project company</td>
</tr>
<tr>
<td></td>
<td>Thailand believes that China's total investment estimate is higher</td>
</tr>
<tr>
<td>Social level</td>
<td>Thai people do not trust Chinese railway technology</td>
</tr>
<tr>
<td></td>
<td>The Influence of Public Opinion in China and Thailand</td>
</tr>
</tbody>
</table>

#### 3.1 Economic factors

##### 3.1.1 Loan interest rates to compete

In recent years, Thailand's infrastructure is in urgent need of improvement, and there are many infrastructure projects to be built. However, the economic development of Thailand is relatively low and the construction fund gap is large, so they hope that every project can compress the cost as much as possible. Previously, China had issued a "2 per cent dollar loan interest rate" for Yavan high-speed rail project, with no government guarantee. In view of the precedent of Yavan
high-speed rail, Thailand expects China to offer equal terms for the Sino-Thai Railway project, and Thailand insists on a 2 percent interest rate on U.S. dollar loans. For China, the US dollar loan rate of 2.5 percent for overseas rail investment has been low, showing China's great sincerity, and China has stuck to its 2.5 percent interest rate.

In terms of project level, first of all, the current China's domestic railway project loan interest rate is usually about 3% ~ 4%, and overseas investment projects, the export-import bank of China usually dollar lending rates to 3% as the bottom line. Yavan high-speed rail project belongs to the special case, not each project can provide Yavan high-speed rail project equal or even more favorable conditions. China should also consider the investment risk and return. Second, China thinks that Sino-Thai railway project can improve the current situation of Thailand's poor infrastructure, can make Thailand asean's transportation hub, and brings to the economic and social development in Thailand, transport costs not only fell between the two countries and the railway project will increase 2 million Chinese tourists to Thailand every year, at the same time also provide more convenience for Thai agricultural exports. In terms of strategic significance, China should strictly prevent the bottom line of lending rates, lest other developing countries follow suit. Many countries along the OBOR are same as Thailand's domestic economic situation and infrastructure construction situation. Their infrastructure constructions and economic are poor. Therefore, they not only need to increase the domestic infrastructure construction, and hope to get a lower lending rates. If China offers such a favourable offer to Sino-Thai Railway, other countries could follow suit, leading to China's disadvantage. The leaders of the two governments have been unable to agree on loan rates during the talks, and the final project financing consultation failed, and Thailand changed its mind unilaterally.

3.1.2 A dispute over the proportion of the project company

China and Thailand are not only competing on loan interest rates, but also in the structure of the project company's share structure, which is a dispute over the cost-sharing of total investment. China and Thailand are planning to set up a project company, and they negotiate a 60% or 70% of China's different plans for the contribution of it. In Thailand's view, the China-Thailand railway project is an important part of China's OBOR strategy, and China should shoulder most of the investment. However, in the request of China to undertake greater investment, Thailand is reluctant to sell along the development rights of the railway, and are unable to provide other favorable conditions in China, so China does not agree to Thailand inequality conditions is put forward, and compromise, if China railway projects in China and China in the future overseas railway investment projects will be at a disadvantage situation. China and Thailand have not agreed on the contribution of the project company due to their respective considerations. The final project financing consultation failed and the Thai side changed its mind.

3.1.3 Thailand thinks China's total investment is high

According to relevant information, China has taken into account all aspects of the impact of factors, the estimated total investment of more than 500 billion baht (about 14.2 billion dollars), Thailand estimated 400 billion baht (about 11.36 billion dollars), Thailand thinks China's total investment estimate is higher. It is clear that Thailand's estimated total investment in China is higher than Thailand's estimated $2.84 billion, suggesting that China is profitable. The Thai side not only wants China to offer discounts on loans, but also expects lower total investment in the
railway.

3.2 Social factors

3.2.1 Thai people do not trust China's railway technology

Thai people do not trust China's railway technology. Sino-Thai railway was planning a total of 12 across Thailand mansion, since the second half of 2015, the Thai ministry of transportation and the Chinese authorities along the joint in 4 ~ 5 fu held much 12:00p.m, played a role in the answer. But so far, in addition to korat mansion of people, several other province mistrust of China railway technology, held in the presentation of 4 ~ 5 provinces in the proportion of 4/5 or 3/4 distrust of China railway technology. This mistrust may be due to the low visibility of China's railway brands, the Thai people's image of China's lower evaluation and so on.

China's railway technology started late and brand awareness is low. Taking China's high-speed rail technology as an example, Our country first introduced the high-speed rail technology of Germany Siemens, alstom of France, bombardier of Canada and kawasaki of Japan, then digestion, absorption and re-innovation, which have obtained our high-speed railway technology.

3.2.2 The influence of public opinion in China and Thailand

There is a voice in Thailand's public opinion that says "China is making more money", arguing that China needs the railway more than Thailand itself. In 2006, 18 Asian countries signed the Intergovernmental Agreement on the Asian Railway Network, which established the Pan-Asian Railway Network Program in Korea. The starting and ending points for Kunming and Singapore, of which Thailand is the only way which must be passed, whether it’s eastern and western lines, have to go through Thailand. In addition, after the railway is opened to traffic, Thailand will become a connecting point for maritime transport between China and asean countries. China's exports can be effectively transported through the maritime silk road. Therefore, Thailand believes that China needs the railway to build the pan-asian railway. Therefore, Thailand has argued that the railway is very important to China, and China has money and technologies, so China should bear more, such as concessions to 2% of the dollar loan interest rates, a higher investment proportion of the project company; China's public opinion has also given Thailand the illusion that "the railway is a necessary route for the pan-asian railway, which is more needed than Thailand", which deepens Thailand's misreading.

4 The inspiration from the Sino - Thai Railway

China Railway project as an important part of the OBOR, its implementation process is hindered which is more profound for OBOR. This study aiming at the lessons of it’s implementation process puts forward the corresponding improvement measures to provide enlightenment for China's overseas railway investment projects.

4.1 Measures to improve economic factors

4.1.1 Let the host Government understand the intentions of OBOR

For China to have the money and technology, China should take more of it, and China can give
more preferential ideas, and China should let the host country understand the intention of OBOR. OBOR is the cooperation between the two countries, the process of sharing risk, the sharing of benefits, and ultimately achieve a win-win effect, rather than unilateral foreign aid [3], the Chinese government can provide aid funding which is limited [4]. OBOR is a common cause of the two countries. It’s cooperation is led by the Chinese government. The Chinese enterprises are actively responding. The host country actively cooperates with the host country to invest in construction and develop the economy. The two countries work together to achieve win-win cooperation.

The implementation of OBOR, China should adhere to the following three principles. First, with the OBOR to establish a particularly good faith in the image. When Chinese government, enterprises and host governments, enterprises discuss projects, if necessary, the terms of the contract can be preoccupied. After signing the contract, the two sides must be strictly in accordance with the contract agreed to earnestly, in case of difficulties to overcome, can not breach of contract behavior. This is to ask Chinese government, enterprises to establish their own business practices and commercial credit. Second, China should adhere to the bottom line, can not be dominated by the host country. Chinese enterprises in the process of going out, China and other countries of the game is essential. Chinese government and enterprises should try to give preferential policies, but China should adhere to the bottom line, can not be dominated by the host country, if it happens, the future of other countries may follow, China is facing an unfavorable situation. Third, in cooperation with developing countries, China should stand in their point of view to consider the problem [5]. OBOR is the key to cooperation with developing countries rather than with developed countries. Developing countries economic is lag and relatively poor, they can't afford the loss of the failure of the project, China should convey itself to developing countries also can't bear such a loss, is sincerely want to cooperate with you in China, and is holding the determination to success, the two countries will eventually become common winners.

4.1.2 The risk of investment in railway projects is Shared by many countries

China's overseas railway investment project has a long construction period, high technical content requirements, large investment scale and so on, determines the investment risk of overseas railway investment projects in China. In this regard, we should build investment risk sharing, so that more countries share the risk.

Take advantage of the Asian Infrastructure Investment Bank (AIIB). Memorandum to Prepare The AIIB shows that AIIB to the statutory capital of 100 billion US dollars, China's initial subscription capital target of 50 billion US dollars, or 50% of China's contribution, the other interested parties to co-funded the remaining 50% [6]. AIIB aims to finance the construction of infrastructures in Asia's poor areas and make up for the lack of financing capacity for multilateral development of financial institutions such as the World Bank and AIIB [7]. In the future, the railway projects of Asian countries can be financed by AIIB. Since AIIB is a multilateral development financial institution jointly funded by various countries, the investment risk of the project is shared by multiple countries. According to the data show that by the end of 2016, AIIB member countries will be more than 90 [8], the future will be more and more countries to jointly bear the project investment risk.
4.2 Improvements to Social Factors

4.2.1 Host country news media strengthened the propaganda of the railway

China's railway technology started late, it’s brand awareness is low. In view of the above situation, China should invite the host country news media to visit our railway industry companies, such as China Railway Group (CREC), China Railway Construction Corporation (CRCC), CRRC and so on. Visit China Railway and China Railway Construction Company’s engineering equipment and spare parts manufacturing workshop. Visit CRRC’s locomotive, general electromechanical, orbital engineering equipment production workshop, all-round understanding of product production lines and product products. Visit CREC and CRCC’s construction site of the contracted project.

Inviting the host country's news media, we should invite the railway-based news media. Focused on the mainstream news media to invite the host country, the mainstream news media authority, highly influential, issue is big enough, use newspapers big platform, page views, in favor of the propaganda of railway technology in China. Invite the reporter to visit the interview, the cameraman to record video, the photojournalist to take the photograph, should coordinate carefully, ensure the interview, the video, the shooting efficiency; To provide the accurate foreign language information of the company, as an aid to the interview.

If the interview has omissions, some news media sent back after the fax asked to supplement or verify some of the contents of the interview, chinese company shall, according to the request of the media, use the fastest speed to make up the material of the reporter, and send it in written form.

4.2.2 focus on China's railway brand to build

Japan Shinkansen is brilliant because of its extraordinary safety record, high transport density and stable, on-time operating records. Chinese Railway should take this as the goal and continue to carry out technical research and development. At the same time, maximizing safety is the most important theme of the railroad, and it is also important to keep it on time. China's railway technology started late, the rapid development, now has a proud result. In the rapid development of the same time, the Chinese parties should do the corresponding work. Railway construction projects, construction companies should pay attention to the quality of the project, pay attention to control the cost of the project, the local railway supervision and management of the railway project, the local railway bureau should do a good job in the operation and management work, the local railway supervision and management Bureau to do security supervision; Bureau to do the project supervision. The parties to work together to build China's fine railway projects.

At the same time, we should promote China's railway standards in the international application. The current European railway standards are more used by the world, especially in the third world [11]. At present, China's railway standards are not in the stage of understanding by many countries [11]. The Railway Cooperative Organization (RCO) and the International Railway Alliance (IUR) are the two major international railway organizations. IUR has a Class A contact membership of the International Organization for Standardization (ISO). China should strengthen communication and exchanges with these two organizations, attach importance to regional railway alliances, establish regional railway standards, make China's standards in the RCO scope to become a common standard, and then extended to other areas; China should prepare the introduction of China Railway Standard Of the international version, to eliminate the language
5 Conclusion

China Railway as an important part of the strategy of OBOR, its process has been hampered by a far-reaching impact on the OBOR strategy. This study systematically analyzes the root causes of the setbacks, from the economic point of view, including the loan interest rate contention, the proportion of the project company capital dispute, Thailand believes that China's total investment estimate is high. From the social level, including the Thai people The distrust of China's railway technology, the influence of public opinion in China and Thailand. The improvement measures include the intention of the host government to understand the OBOR, the multi-country share the railway project investment risk. For the social level factors, the improvement measures include the host country news media to promote the promotion of China Railway, pay attention to China's railway brand to build. With a view to providing inspiration for China's overseas railway investment projects, the development of our country's OBOR strategy will be promoted smoothly.

References

[5] Xing Houyuan. With the five development ideas to lead the "one way all the way" construction thinking [J]. International Economic Cooperation, 2016 (6): 4-6.
An overview of multi-project scheduling problems in India with resource constrained and unconstrained settings

Marimuthu K1*, Benny Raphael2, Ananthanarayanan K3, Ekambaram Palaneeswaran4, and Behrooz Bodaghi5

Abstract: Companies keep minimal resources such as equipment, labor, and non-renewable materials to maintain productive working capital. This means that resources are constrained, and a multi-project environment adds further complexity since resources have to be shared among projects. Existing project management approaches such as critical path method (CPM), program evaluation and review technique (PERT) etc. are mainly suitable for the unconstrained resource situation. However, industry practitioners are required to handle resource constrained situations and multi-project priorities. Hence, it is important to identify the best practices and systematic approaches used in resource constrained multi-project environment. The objective of ongoing research is to determine the industry practices under resource unconstrained and constrained multi-project settings. An interview with experts and a questionnaire survey were conducted to determine the current industry practices followed for solving project scheduling problems. This research has revealed that resource unconstrained multi-project environment is rare, whereas resource constrained multi-project environment models the real nature of actual projects. When modelled as an unconstrained resource problem, underutilization of resources might occur. On the other hand, in a resource constrained problem, limited resources are shared among project sites, resulting in efficient utilization of resources. The decision process can follow either centralized or decentralized model. A decentralized model is recommended for handling small size projects in a multi-project environment. However, the systematic centralized model is recommended for the large size multi-project environment to optimize the multiple objectives. This study brings out that the current industry practices in India to manage multi-project scheduling problems use experience based heuristics to accommodate the practical challenges which may not be replicated in other project instances.

Keywords: Resource scheduling; Multi-project scheduling; centralized model, decentralized model.

1*IITM-Swinburne Joint PhD Student, Corresponding author
Department of Civil Engineering, Indian Institute of Technology, Madras, India
Department of Civil and Construction Engineering, Swinburne University of Technology, Australia
E-mail: marimuthukan@gmail.com

2 Associate Professor
Department of Civil Engineering, Indian Institute of Technology, Madras, India

3 Professor
Department of Civil Engineering, Indian Institute of Technology, Madras, India

4 Associate Professor
Department of Civil and Construction Engineering, Swinburne University of Technology, Australia

5 PhD Student (Centre for Sustainable Infrastructure)
Department of Civil and Construction Engineering, Swinburne University of Technology, Australia
1 Introduction

Timely delivery of services is critical for the success and survival of organizations. Many organizations are simultaneously managing the execution of a portfolio of projects under tight time and resource constraints (Pennypacker and Dye 2000). However, construction management research is dominated by a single project model, which does not reflect the actual nature of multi-project portfolios (Blismas et al. 2004). The ability to manage multiple projects in competitive environments becomes an essential competence (Araszkiewicz 2017). Projects vary in size, importance, required skills, and urgency, at various stages of completion, yet use the same pool of resources (Fricke and Shenhar 2000). Multi-project scheduling is a fundamental crisis faced by enterprises which require to reasonably allocate the limited resources among multiple projects thereby optimizing all the projects’ multiple objectives (El-Abbasy et al. 2017). Herroelen (2005) has mentioned that even a small improvement in multi-project management will yield a large benefit. Additionally, more than 90% of all international projects are executed in a multi-project environment (Payne 1995), and 84% of firms handle multiple projects in parallel (Lova and Tormos 2001).

An important issue discussed in the multi-project management literature is resource allocation among simultaneous projects. The resource-constrained project scheduling problem (RCPSP) presents an extension to the standard CPM and PERT techniques by including the availability of resources during scheduling (Engwall and Jerbrant 2003). This extension is known as the resource constrained multi-project scheduling problem (RCMPSP), and multi-mode resource constrained multi-project scheduling problem (MRCMPSP) (Geiger 2017). Scheduling and allocation of resources to multiple projects is a non-deterministic polynomial (NP) hard problem and more complex than that for a single project (Singh 2014). Yang and Sum (1993) have used the dual level management structure for managing multiple projects: project managers are responsible for operational level project activities, whereas the upper-level manager operates on a more tactical level and is in charge of all the projects and project managers.

Traditionally, the RCMPSPs were solved with the assumption of centralized decision making in which the resource allocation and scheduling decisions were made centrally in an integrated manner (Adhau et al. 2012). Centralized planning model requires full information about all the projects so that it could get a satisfactory scheme more quickly. However, in practice, the resource allocation and scheduling functions are performed in a decentralized manner. Decentralized model and solutions are advantageous in multiple project scenarios since it helps in better coordination and fairness among multiple projects, and they are more realistic (Zheng et al. 2014).

Many theoretical approaches have been proposed with unrealistic assumptions. However, the industry has been operating in a resource-constrained multi-project setting. This study is intended to identify the industry practices in resource unconstrained and constrained multi-project scheduling situation. The rest of the paper is organized as follows. In Section 2 we describe the relevant literatures on traditional project management specific to resource unconstrained and constrained multi-project situations. Section 3 outlines the proposed methodology to recognize the practices under resource unconstrained and constrained multi-project scheduling problems, and Section 4 discusses the results. Finally, Section 5 describes the concluding remarks and possible future research possibilities.
2 Literature review

Project time and cost overruns persisted for decades, despite numerous advances in the field of project management (Anderson and Tucker 1994). Starting with the critical path method (CPM) and the project evaluation and review technique (PERT), network techniques have continued to evolve and advance. Advances include resource-constrained scheduling, resource leveling, and trade-off problems (Schwindt and Zimmermann 2015a; b). Most of the business organizations deal with the issue of running multiple projects simultaneously and sharing a common pool of limited resources between them (Tam and Palaneeswaran 1999). In multiple project management (MPM), projects are managed concurrently which are diverse in size and importance, and may not necessarily be interdependent. Those projects can be parts of programs or portfolio. Program management is a centralized and coordinated approach that is used to manage a group of goal-related projects (PMBOK Guide 2013). Project portfolio management (PPM) involves the selection and management of the collection of projects and programs. PPM has a strategic focus, whereas MPM focuses on tactical issues. MPM emphasizes on the allocation of resources to multiple projects, the assignment of project managers, and the use of project management processes, tools, and techniques (Blismas et al. 1999). In recent years, project scheduling has attracted ever-growing attention both from the fields of science and practice (Xu and Zhang 2012). Given below is the detailed review of project management techniques having two subsections. The first subsection deals with the resource unconstrained multi-project scheduling problems, while the second subsection focuses on the resource constrained multi-project scheduling problems.

2.1 Resource unconstrained multi-project scheduling problems

The most widely used techniques for project planning and management are Gantt, Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). CPM and PERT are concerned with time aspect only (Kelley 1961). It has some serious limitations: (1) assumption of unlimited resources and (2) application to only one project at a time (Goncalves et al. 2008). Besides, Fondahl (1961) introduced the precedence diagramming method (PDM) to represent a realistic relationship between the activities. However, inability to perform resource scheduling is the main drawback of the network scheduling methods. Gantt, CPM, and PDM are incorporated in most popular project scheduling software packages such as MS Project, Primavera, and Time Line. Neither of the aforementioned techniques - Gantt, CPM, PERT or PDM addresses the decisions required in dynamic, multi-project setting (Ash 1999). Although these models are still applicable in some real-world projects, a deterministic assumption and single-project applicability issues make it unsuitable for multi-projects and uncertain environments. In multi-project environment resources are constrained, but the methods above did not cover this situation. Hence, the resource constrained multi-project scheduling should be used which is discussed in the next section.

2.2 Resource constrained multi-project scheduling problems

Project scheduling is a complex decision-making process which involves resources. Two types of resources including renewable and non-renewable resources are considered in project scheduling problems (Bodaghi and Palaneeswaran 2016). Initially renewable resources are assigned to the various activities with limited availability. However, additional limited amounts of the resources are supposed to be rented, to catch up with the deadline of activities, which causes high penalty costs.
when not met with. A supply chain provides the non-renewable resources available for the projects. Typically, multiple projects share common resource pools, whose capacities are not sufficient to support all project activities at the same time, leading to the resource constrained multi-project scheduling problem (RCMPSP). Although RCMPSP plays a vital role in project management, there are not much fruits on the topic as those on single project scheduling. The main reason behind this is due to its high complexity, which is affected by many factors such as the vast solution space, conflicting objectives, the inter-project dependency and priority, and the high level of uncertainty (Zheng et al. 2013). The aim is to prioritize the project's activities to optimize an objective function without violating both intra-project and inter-project resource constraints. Choosing between alternative optima makes the changes in the scheduling easier and faster than re-scheduling. Exact algorithms are limited to solving small problems due to its complexity. Another alternative is the heuristic approach which can be divided into four groups: priority rule-based heuristics, classical meta-heuristics, non-standard meta-heuristics such as agent-based, and different heuristics (Kolisch and Hartmann 2006). There is not a single priority rule that performs well all the time (Browning and Yassine 2010; Marimuthu et al. 2017). Many different exact, heuristic and meta-heuristic approaches have been developed to solve the resource-constrained multi-project scheduling problems. However, the numerous challenges in the multi-project environment makes it difficult to reflect the realistic nature of dynamic multi-project settings. But, in practice, organizations do perform in a multi-project context. Hence the objective of this paper is to identify those industry practices in resource unconstrained and constrained multi-project environment setting.

3 Research methodology

Research methodology used in this study involves expert interviews and a questionnaire survey conducted in various cities in India. The main goal is to identify current practices used in the Indian construction industry.

3.1 Expert interview and survey

Face to face interviews and a questionnaire survey have been conducted in various Indian cities. Expert interviews were employed for collecting historical information, tacit and explicit project knowledge sets which are relevant to the research. Both interviews and questionnaire surveys employed in this research were useful to compile current industry practices on handling the resource unconstrained and constrained multi-project scheduling problems. An inductive approach based on grounded theory is used for this study to analyze the data systematically. The sample size recommended for grounded theory is twenty to thirty (Creswell 2014). Semi-structured interview and a questionnaire survey based protocol are chosen because it enables a subjective evaluation of the concerned problem. Interviews were audio-taped and then transcribed for further data analysis. In addition, survey data are used for analysis. The questionnaire consists of two sections.

In section 1, each respondent is asked to provide the critical factors or challenges faced in handling the multi-project environment. This is followed by a general opinion on resource unconstrained and constrained multi-project scheduling situations, and how these cases are being handled today, existing unsolved issues and reasonable solutions adopted. Next, the different kinds of approaches used, objectives and constraints, solution methods, tools, and techniques are also recognized.
Section 2 consists of respondents’ demographic information.

3.2 Characteristics of respondent’s

The respondents’ demography includes project engineer (PE), assistant manager (AM), project manager (PM), construction manager (CM), project control manager (PCM), deputy project manager (DPM), general manager (GM), head portfolio (HP), head project management (HPM), head planning and contracts (HPC), architect (A), and environment engineer (EE). So far, the total number of valid responses received through face to face interview and questionnaire survey were 25 and the key summary is presented in this paper. The distribution and characteristics of the respondents were tabulated in Table 1.

<table>
<thead>
<tr>
<th>Characteristics (n=25)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PE</td>
</tr>
<tr>
<td>Experience</td>
<td></td>
</tr>
<tr>
<td>&lt;5 yrs</td>
<td>3</td>
</tr>
<tr>
<td>5-10 yrs</td>
<td>2</td>
</tr>
<tr>
<td>&gt;10 yrs</td>
<td>1</td>
</tr>
<tr>
<td>Region</td>
<td></td>
</tr>
<tr>
<td>Chennai</td>
<td>2</td>
</tr>
<tr>
<td>Hyderabad</td>
<td></td>
</tr>
<tr>
<td>Bangalore</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
</tr>
</tbody>
</table>

4 Results and Discussion

The top 10 challenges faced in the multi-project environments in the Indian context are derived based on the frequency of occurrence, i.e., (1) resource allocation, sharing, and tracking capabilities, (2) shortage of skilled labor, (3) project manager skills and the performance of individual project team, (4) external factors i.e., environmental issues, political influence, external stakeholder management, (5) coordination, (6) communication, (7) prioritization of projects, (8) cash flow management, (9) quality control and safety, (10) real time monitoring and proactive decision making. It has been identified that resource management is one of the critical challenges for the success of multi-project environment.

Resource unconstrained multi-project environment rarely exists in reality. The general opinions about the unconstrained resource situations are that it: (a) costs more as sharing of resources is not practiced, (b) causes underutilization of resources and wastages, (c) hinders acceleration of the
project, (d) is easy to manage but it doesn't replicate the real nature. Resource unconstrained condition is handled through divide-and-rule principle, engaging more supervisors and hierarchy management. The unresolved issues in the resource unconstrained situation are: (a) pertaining to monitoring and controlling of various projects, (b) resource lead-time cannot be predicted correctly which can upset the assumptions made, (c) sudden scarcity of resources, (d) awareness of different management techniques is very less or limited, (e) reuse of resources is less, (f) improper maintenance and control of resources hence there is a big loss to the firm, and (g) lavish use of resources lead to underutilization. The possible solutions to the above mentioned problems would be maintaining proper centralized documentation, maintaining clear communication channel, using ERP software system, optimization of resources by implementing efficient productivity tracking, periodic tracking of issue log which can be shared among all stakeholders, enabling the effective interpersonal and decision making skills of project manager, training programme, creation of common resource pool and charging the projects on rental basis, strict planning and organized execution (“even when throwing in the river, measure how much you throw”).

Unlike the resource unconstrained multi-project environment, resource constrained is more realistic because organizations keep limited resources to maximize the wealth. Resource constrained condition is handled through: (a) proper resource planning and scheduling, (b) use of optimization concepts, (c) managing procurement, risk and scheduling strategies, and (d) sharing of resources based on priority. The unresolved issues in resource constrained situation are, (a) as there is no scientific approach there is always a 'fire-fighting' condition where resources are allocated based on pull-based contingencies, (b) the culture of practices, (c) uncertainty in terms of productivity assumption which depends on several tangible & intangible factors, (d) effects on the timeliness in multiple projects lead to more errors and high level of stress. The possible solutions would be augmentation of the resources from private players, scientific and digital/automated solutions for resource allocation, resource optimization, assigning resources to key result area (KRA), providing an additional overtime payments on shift basis when resources are limited, responsibilities and liabilities to the various level of employees, training programme at all levels, proper planning through adhering best resource management practices, use of alternative resource options to execute the activities and prioritizing the activities for resource smoothening.

The decentralized model is recommended for the single-project approach of multiple project environment, whereas centralized model is recommended for the multi-project approach. Decentralized decisions are not in favor of effective resource sharing, unlike centralized decision model. Centralized system will be more efficient when managers are skilled, knows the practical implications, and effective communication systems are in place. Resource allocation is dynamic in a multi-project environment. The schedule should be incorporated with vendor based, location based, activity based, client based, procurement and project based schedules. Activities can be executed in multiple modes with the varied construction methods, materials, equipment, and crew size to achieve the multiple objectives, i.e., time, cost, quality, and safety under precedence and resource constraints. The solution methods used under resource constrained multi-project environment is heuristic in nature. The various project management tools and techniques that have been used to overcome the situation are customized excel spreadsheets, Primavera and MS Project but fails to promise the requirements due to built with only heuristic rules.
5 Conclusions

Resource unconstrained multi-project scheduling approaches fail to address the actual nature of the construction work. Resource constrained multi-project scheduling approaches more closely model actual construction projects. In this scenario, previous researchers have proposed many approaches and solution procedures. But such previous studies failed to add to the framework various attributes such as activity preemption, stochastic activity duration, dynamic project arrivals, efficient algorithms to handle larger size projects, scheduling projects with multiple objectives, resource transfer times and costs, multiple project networks and multiple activity execution modes, precedence relations between projects, penalty and bonus costs, resource sharing, dedicating and substituting policy etc. There is a great need for resource constrained multi-project scheduling algorithms since many companies work in the multi-project context with limited resources in hand. This study brought out that unconstrained resource situation is rare, unlike the resource constrained environment. Under resource unconstrained multi-project environment, there is a great possibility of firms losing wealth. However, in resource constrained environment, by keeping limited resources and also trying to share it with other projects, the resource utilization can be maximized. This study also suggests that systematic centralized model is recommended over decentralized ones while handling larger size multiple projects. Further research in this area involves developing a scientific approach to managing the dynamic resource constrained multi-project environment to optimize the multiple objectives.

References


Building Information Modelling within the Australian Prefabrication: Findings of Opportunities and Barriers

Mostafa, Sherif1*, Kim, Ki2, Rahnamayiezekavat, Payam3

Abstract: Prefabrication has the potential to minimise total project duration and improve the quality of a project. Despite the potential, the uptake of prefabrication in the Australian construction industry is limited due to the dispersed locations of designers and manufacturers, clients’ preferences and builders’ capability. Recently, Building Information Modelling (BIM) has been recognised as a possible solution to eliminate the barriers as BIM can enhance the coordination of construction information and facilitate an informed decision at the early design stage. This research aims to investigate the opportunities of and barriers to integrating BIM within the Australian prefabrication context. Through a questionnaire survey of designers, managers, engineers and manufacturers, the design stage is revealed as the most vital stage in which to adopt BIM capability. The 18 survey respondents emphasised the main opportunities of BIM integration as being increasing mass customisation, and reducing project duration and schedule risks. The identified BIM challenges were centred on changing the business practices, replacing the existing computer-aided drafting (CAD) system and the upfront cost of BIM integration, for example, investment in BIM tools and training. The survey results document the opportunities of and barriers to BIM integration, and provide professional insights on how BIM can benefit prefabrication. Some limitations are acknowledged as the study reports on these findings from the Australian context. Future studies could employ case studies and be conducted in other countries to enhance the generalisation of these research findings.

Keywords: Australian construction, BIM, prefabrication, BIM–prefabrication integration

1* Dr Sherif Mostafa
Corresponding author, College of Engineering and Science, Victoria University, Melbourne, Australia
E-mail: sherif.mostafa@vu.edu.au

2 Dr Ki Kim
School of Natural and Built Environments, University of South Australia, Adelaide, Australia

3 Dr Payam Rahnamayiezekavat
Faculty of Humanities, School of Built Environment, Curtin University, Perth, Australia
1 Prefabrication in the construction industry

Prefabrication has been recognised as one of the key visions for improving the Australian construction industry as it provides the following benefits: a) waste minimisation; b) reduced project duration; c) reduced construction costs and reworks; d) safety improvement; e) and reduced needs for skilled labour on the construction site [1]. Researchers have emphasised that prefabrication is capable of enhancing overall project performance by providing the means to cope with a compressed project schedule, unorganised site conditions and a shortage of skilled labour. Furthermore, researchers have asserted that prefabrication has become a global-scale strategy to minimise construction costs and maximise the return on investment by improving design and construction processes in construction projects [2]. Consequently, prefabrication has been introduced to the Australian construction industry as a general term, namely, off-site manufacturing (OSM), to achieve better quality with fewer costs in construction projects.

Despite the identified benefits, the use of OSM is not widely practised in the Australian construction industry due to the lack of skilled personnel, the low level of technical knowledge and the low perceived value of adopting OSM [3]. In [4], insights from construction professionals were collated to identify the possible solution to overcoming the current barriers to OSM adoption in the Australian construction industry. As a result, they identified the most critical barriers to be tackled as being poor information coordination across the supply chain and the freezing of the design at an early stage of the project. Researchers have emphasised that effective and collective efforts to integrate information in terms of design and construction should be coordinated and integrated from the outset of prefabrication to increase its adoption. In relation to the coordination barriers, [5] highlighted the importance of timing to correct design errors and a defect-proofing process by asserting the need for an effective information management process or an information management tool. Indeed, [6] suggested Building Information Modelling (BIM) as an integration process and an information management tool to control the design process of industrialised building systems (IBSs). The arguments that BIM can be a solution to minimise design and coordination errors as well as being a methodology to enhance OSM processes are supported by recent researchers [7].

Although the potential for and benefits of BIM adoption in the prefabrication industry are recognised, the industry is still slow in its adoption of BIM as approximately 50% of project stakeholders including architects, engineers and contractors are not using BIM in conjunction with prefabrication [8]. Furthermore, only 30% of construction professionals acknowledge that BIM has the potential to improve efficiency in the prefabrication industry. While research has indicated that BIM is recognised as either relevant or irrelevant in improving efficiency in the prefabrication industry, the fundamental reasons contributing to its slow adoption and low perception in the prefabrication industry have not been fully identified. Therefore, this research aims to shed light on the fundamental causes of the low perception of BIM and its low rate of adoption in the prefabrication industry.

2 Implications of BIM in prefabrication

In response to the current barriers in the prefabrication industry, BIM has been introduced as one of the alternatives for productivity improvement. In particular, BIM has been recognised as a potential solution to achieve effective information integration between the construction and manufacturing industries. The reason is that BIM is an information management system that integrates and manages
various construction information throughout the entire construction project and product life cycles based on a 3D parametric design to facilitate effective communication between project stakeholders [9]. Indeed, BIM has been recognised as a methodology and a technology to facilitate process improvement in the prefabrication modular construction sector. It has the capability to enhance construction personnel’s understanding of the design intent and to provide more accurate dimensional information and specifications of building materials based on the instant and timely feedback loop between stakeholders [10]. Researchers have identified that the integration of a BIM tool and OSM can render improved visualisation of building components, effective clash detection and more accurate shop drawings at the early design stage of a construction project [11]. According to a case study integrating BIM in a prefabrication project (total cost $44 million), a total cost saving of 1% ($440,000) was achieved by minimising design and mechanical, electrical and plumbing (MEP) coordination errors at the early design stage [11].

More importantly, managerial benefits have been recognised when BIM is adopted as a methodology to facilitate effective information exchange and decision making on any changes via effective communication between stakeholders [12]. The identified managerial benefits were mainly associated with proactive design change management with fewer delays and reworks. In addition, having more accurate dimensions of building components can enhance cost estimation and resource planning which, in turn, can minimise the unnecessary waste of resources [10]. It was asserted by [13] that BIM has the potential to automate the processes of prefabrication and component assembly in the modular construction industry. In the current research, BIM is identified as an information exchange platform for implementing the automated processes for modular building projects, with further research studies having been conducted to confirm the potential of BIM in the precast concrete manufacturing industry [14]. As a result, the capability of BIM to improve all project processes including design, fabrication and construction has been confirmed.

In alignment with the concept of BIM as an information flow management platform, various efforts have been undertaken to develop a BIM system or a BIM framework for prefabrication construction to support informed decisions by stakeholders. A web-based BIM platform using the building components’ object library in a BIM system has been developed to facilitate stakeholders’ timely decision making [15]. Similarly, [21] proposed a BIM object library so appropriate design decisions could be made and more accurate design information for prefabrication could be provided. In addition, an automated design process map based on an algorithm system has been proposed for selecting the most suitable designs for prefabrication [12]. In a recent study aimed at integrating prefabrication in a BIM system for housing projects [10], a BIM platform has been used to facilitate informed decision making at the design phase. Thus, it is evident that BIM can be used as both an effective design management tool and as an information management methodology to integrate diverse construction information in the prefabrication industry.

3 Research method

The objective of this research is to examine the opportunities of and barriers to the integration of BIM within the Australian prefabrication context. For data collection, this study employed a literature review and a questionnaire survey. A review of the related literature on OSM and BIM in Australia assisted with the establishment of an information base on OSM and the implications of BIM in off-site manufacturing (OSM). This facilitated the design of the survey questions. The questionnaire survey was conducted to obtain specific insights on the status of BIM adoption and
the integration of BIM capabilities within the Australian prefabrication industry. The survey questions adopted a 5-point Likert scale as this is the most popular method among researchers and is easy to communicate to respondents [17]. The questionnaires were distributed through PrefabAUS, the professional affiliated association of the OSM/prefabrication industry in Australia, to obtain valid and relevant research findings. This research employed purposive sampling to obtain individual responses from professionals specifically involved in integrating BIM in OSM practice across Australia. The survey was circulated to 35 members employed in a nationwide construction company, who had attempted to use BIM or had been involved in a prefabrication project using Building Information Modelling (BIM). In total, 18 members responded and completed the questionnaire (approximately 51% response rate). This response rate was deemed adequate for the purpose of data analysis. In [18], it was argued that a 20–30% response rate is the norm in questionnaire surveys of the construction industry. The web-based questionnaire comprised 15 questions designed to explore the following three key aspects: a) awareness and current uptake of BIM; b) perceived advantages of and barriers to BIM adoption; and c) potential advantages to the prefabrication industry of BIM integration. A pilot questionnaire survey was conducted before the main questionnaire survey to eliminate misleading questions, ambiguity and any difficulty in responding. A statistical analysis tool, IBM SPSS Statistics, was used to conduct a statistical analysis, for example, standard deviations, correlations and cross-tabulation analysis, in order to render more specific insights from the research findings.

4 Research findings and discussion

4.1 Respondents’ background information

This section presents respondents’ background information including their organisation, position and primary role in the prefabrication industry. In terms of positions held and length of experience, all respondents were in managerial positions with an average of 10 years of experience in the prefabrication industry across Australia. The primary roles of respondents comprised Consultant (60%), BIM Manager (20%), Managing Director (10%) and Project Manager (10%). Within the prefabricated building project life cycle, they had significant levels of participation in the planning and design, engineering and procurement, construction and building services stages. Based on respondents’ organisations, the primary markets for prefabrication were identified as educational facilities; office, retail and industrial facilities; health care facilities; and commercial buildings.

4.2 Awareness and uptake of BIM within the prefabrication industry

Survey respondents were asked to identify their level of understanding about BIM in the prefabrication industry. All respondents were fully aware of BIM as a coordination tool and only two respondents mentioned that BIM is a methodology, although the current usage of BIM is mainly focused on 3D visualisation and design coordination. Respondents were asked to specify the BIM uptake in their organisations, with 80% of respondents utilising Autodesk Revit Structural and MEP for the design stage. Other respondents (20%) highlighted the usage of BIM 360 Glue and Integrated Environmental Solution Virtual Environment (IES VE) for structural and architectural component design. Survey respondents specifically emphasised the seamless data exchange and integration of design intent at the early design stage as a means to effectively cope with any changes before a design is finalised. Consequently, BIM 360 Glue was identified as an information management
platform, with this being highly aligned with the implications of BIM in the prefabrication industry for better work and information management flow. Based on the identified BIM tools, it can be extrapolated that a broad level of knowledge regarding BIM fundamentals and applications is present in the prefabrication industry, as responses ranged from basic BIM tools such as Revit Structural through to BIM 360 Glue which is the cloud-based BIM system that facilitates collaboration and communication between key project stakeholders.

4.3 Advantages of integrating BIM in the prefabrication industry

This study identified the advantages of integrating BIM within the prefabrication industry. The benefits indicated by survey respondents are presented in Table 1.

<table>
<thead>
<tr>
<th>BIM benefits</th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early identification of long completion time</td>
<td>18</td>
<td>1</td>
<td>4</td>
<td>1.4</td>
<td>1.04</td>
</tr>
<tr>
<td>Shortening procurement schedule</td>
<td>18</td>
<td>2</td>
<td>4</td>
<td>2.3</td>
<td>0.66</td>
</tr>
<tr>
<td>Exploring design constraints for fabricators</td>
<td>18</td>
<td>1</td>
<td>3</td>
<td>1.1</td>
<td>0.47</td>
</tr>
<tr>
<td>Reducing differences between design and manufacturing models</td>
<td>18</td>
<td>2</td>
<td>3</td>
<td>2.8</td>
<td>0.38</td>
</tr>
<tr>
<td>Reducing fabrication cycle time</td>
<td>18</td>
<td>1</td>
<td>3</td>
<td>1.2</td>
<td>0.54</td>
</tr>
<tr>
<td>Reducing coordination errors</td>
<td>18</td>
<td>1</td>
<td>3</td>
<td>1.2</td>
<td>0.51</td>
</tr>
</tbody>
</table>

As shown in Table 1, the most critical benefit is the reduction in differences between designers and manufacturers in the final model, with this benefit of BIM integration being highly relevant to overcoming the current barriers identified in the literature. Based on the small numeric value of the standard deviation (SD=0.4), all respondents were in agreement that this benefit is realistic and achievable. The second most important benefit is the shortening of the procurement schedule as an integrated BIM system can facilitate design collaboration from the outset of a project. Any necessary changes or alterations on a model can be implemented before the actual manufacturing stage without compromising the duration and/or quality of a project and a product. It should be noted that the two most important benefits stemming from BIM integration into the prefabrication industry are directly related to the seamless information exchange and effective collaboration based on better communication through a BIM tool or system.

To investigate further regarding the relationship between the benefits of BIM implementation, Spearman’s rho analysis was used. As shown in Table 2, a strong positive correlation was found between the early identification of long completion time and shortening of the procurement schedule ($rs=0.994, p<.01$), and reducing the fabrication cycle time ($rs=0.847, p<.01$). Moreover, a strong correlation existed between exploring the design constraints and reducing the coordination errors ($rs=0.889, p<.01$), and reducing the fabrication cycle time ($r=0.809, p<0.1$).

Table 2. Correlation of BIM benefits within prefabrication industry
The results shown in Table 2 provide evidence that the benefits of BIM integration are mainly related to reducing the length of time of the prefabrication project through early identification of long completion time, reducing the fabrication cycle time and shortening the procurement schedule. The benefits are also highly related to exploring the design constraints and enhancing coordination between the stakeholders involved in the design and planning stage of a prefabrication project. Respondents indicated that BIM integration should be considered as a way of improving prefabrication processes and enhancing information flow between stakeholders based on a collaborative industry culture. Thus, the findings are highly aligned with the findings of the literature review and, consequently, BIM adoption can be considered as providing an opportunity to improve productivity in the prefabrication industry.

### 4.4 Potential outcomes of integrating BIM

Respondents were asked to rate the potential advantages of integrating BIM with prefabrication. Most survey respondents (60%) showed a high level of agreement that reducing the project duration and increasing mass customisation were the top two potential outcomes arising as benefits from BIM integration. The reduction in project duration is due to the following four main benefits: early identification of long completion time, exploring design constraints, reducing the fabrication cycle and reducing coordination error. Furthermore, mass customisation is the result of three BIM benefits: early identification of long completion time, exploring the design constraints and reducing the fabrication cycle. This means that BIM uptake within the prefabrication industry in Australia would result in positive outcomes for clients as well as for builders.

### 4.5 Barriers to integrating BIM in prefabrication

Respondents identified the following three major barriers to integrating BIM into the prefabrication
industry, as listed in Table 3. The main challenge, identified by 43.3% of respondents, is embedded in the business practices needed to support BIM implementation. More planning for the use of prefabricated assemblies in a project would need to take place in the design phase. Building Information Modelling (BIM) requires the use of integrated project delivery (IPD) and various forms of design–build for effective coordination and collaboration in the early stages of the project. The other two challenges are replacing computer-aided (CAD) technologies with BIM, and the investment required in BIM software, training and hardware. These challenges could be overcome with Australian Government support.

Table 3. Challenges of BIM integration within prefabrication construction

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business change practices to support BIM</td>
<td>18</td>
<td>1</td>
<td>4</td>
<td>2.7</td>
<td>0.46</td>
</tr>
<tr>
<td>Replacing CAD technologies with BIM</td>
<td>18</td>
<td>1</td>
<td>4</td>
<td>2.3</td>
<td>0.74</td>
</tr>
<tr>
<td>Investment required in software, training and hardware</td>
<td>18</td>
<td>1</td>
<td>4</td>
<td>1.8</td>
<td>0.80</td>
</tr>
</tbody>
</table>

The National BIM initiative report recommended that the Australian Government should mandate full collaborative BIM based on open standards for information exchange. The report further recommends that the Australian Government encourage the State and Territory Governments, through the Council of Australian Governments (COAG), to commit to using BIM for a full collaborative industry culture. Thus, proper financial and technical support from the government could be expected shortly which would ameliorate the barriers of replacing the current CAD system and meeting the upfront financial burden required to prepare the appropriate hardware and software for a BIM system.

5 Conclusions

This research identifies the benefits and potential outcomes of, and the barriers to, adopting BIM within the prefabrication industry. The research findings designate the potential to achieve improved productivity by integrating prefabrication with a BIM system to coordinate the design plan and to communicate effectively. In addition, the findings recognise reduction in the differences in a final model between the designer and the manufacturer, and shortening of the procurement schedule as the most significant benefits of BIM integration in the Australian prefabrication industry. It is also identified that seamless and timely data exchange via a BIM system is essential in the prefabrication industry. As soon as reliable building components are constructed within a BIM system, these components can be built digitally and physically, and the information about them can be disseminated and shared over the project lifecycle. Therefore, key project stakeholders can make informed decisions on design changes and the fabrication of building components. The synergy of integrating BIM and prefabrication minimises unnecessary and costly reworks and conserves resources. Building information modelling (BIM) enables the early involvement of project stakeholders, thus improving design and prefabrication processes and identifying design errors earlier compared to the traditional workflow. Hence, the low perceived value of prefabricated buildings will be improved, and a more open and collaborative project team culture could be established. This research contributes to the identification of potential outcomes of BIM integration within the Australian prefabrication context. For a comprehensive realisation of the benefits of BIM and the outcomes for Australia’s prefabrication industry, more studies could be developed to further categorise these benefits and outcomes from the perspectives of clients and builders. Moreover, these benefits and outcomes should be studied in relation to the types of prefabricated project (e.g.
commercial buildings and health care facilities). The identified outcomes could lead to the future development of prefabrication practice in Australia.

References


Research on the Efficiency of Commercial Real Estate Development from a TFP Perspective

Huang, Ying.,* Zheng, Shuai.2

Abstract: This article examines the commercial real estate production efficiency based on the Total Factor Productivity (TFP) perspective and the Malmquist Index method. Based on the provincial panel data from 2008 to 2015, this paper analyzes the trend and regional differences of commercial real estate production efficiency in China. It has been found that the commercial real estate total factor productivity (CRETFP), the performance of Accumulative Area of commercial business Completed, showed a V-trend from the national perspective, mainly caused by the technological change. It has also been found that the performance index of eastern region is highest in the three regions in China, and the scale efficiency index firstly felt in 2015. The study also found that commercial land input has promoted the growth of CRETFP and the national commercial land performance index, the ratio of the average of provincial Malmquist index containing land over the one without land, is greater than 1 on the whole.

Key words: Malmquist Index; commercial real estate; efficiency

1*Huang,Ying.
Corresponding author, School of Economics&Management, Shenyang Institute of Engineering, China
E-mail: huangying@sie.edu.cn

2 Zheng,Shuai
School of Economics&Management, Shenyang Institute of Engineering, China
E-mail: shuaishuai1206@sie.edu.cn
1 Introduction

The rapid urbanization in China, not only has changed the urban forms and space structures startlingly, but also led to the old industrial land being replaced by office and commercial land [1], which has caused a vast need for commercial real estate investment. From 2001 to 2016, the investment in commercial properties had maintained a high growth rate with an annual average growth of 22 percent in China, but in the past two years, the rate felt back. Thus, it is important to scientifically plan the development of commercial land in order to maximize the utility of existing commercial land and promote sustainable land development. It is also necessary to improve the efficiency of commercial land by consuming the least amount of land and resources to satisfy the needs of business services and to promote the progress of the tertiary industry [2].

There are a lot of researches about land use efficiency [3,4,5], agricultural land use [6,7], industrial land use [8], but the studies about commercial real estate production efficiency and related land use efficiency are relative.

The objectives of this study are to explore the commercial real estate production efficiency through building the Malmquist Index model to reveal the trend of commercial real estate development from the TFP perspective, analyzes the influence of commercial land to the total factor productivity by calculating the performance index of commercial land and reveal the trend and regional differences of commercial real estate production efficiency in order to provides a scientific basis for the related policies for the commercial real estate development.

2 Methodology

2.1 DEA Malmquist Index Model

Data envelopment analysis (DEA) is a non-parametric method often used to measure the total factor productivity. It uses linear programming to combine production units and construct a mapping of production frontier to assess the relative performance of any unit. Malmquist Index Method based on DEA is now the most widely used method to study the dynamic change trend of efficiency. Essentially, the Malmquist productivity index means the change of the productivity by using the ratio of distance function in two different time [9]. The Malmquist productivity index is defined as the ratio of the estimates of distance function [10]. The distance function and its parameters are defined as follows:

\[ M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \left[ \frac{D_{t+1}^0(x_{t+1}, y_{t+1})}{D_{t+1}^0(x_t, y_t)} \times \frac{D_t^0(x_{t+1}, y_{t+1})}{D_t^0(x_t, y_t)} \right]^{1/2} \] (1)

\( D_0^t(x_t, y_t) = \) the distance function that accounts for the maximum change in outputs using a set of given inputs with the technology at \( t \).

\( D_0^{t+1}(x_{t+1}, y_{t+1}) = \) the distance function that evaluates the maximum change in outputs using a set of given inputs compared with the benchmark technology at time \( t+1 \).

\( D_0^t(x_{t+1}, y_{t+1}) = \) the mixed-period hyperbolic distance function that evaluates the maximum change in outputs using a set of given inputs compared with the benchmark technology at time \( t \).
\[ D^r_{t+1}(x_t, y_t) = \text{the mixed-period distance function that maximizes the change in outputs using a set of given inputs with the benchmark technology at } t+1. \]

Malmquist Index was used to measure the change of productivity efficiency and being decomposed into efficiency change and technical change [11]. The function is defined as follows:

\[
M_t(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{S^r_t(x_t, y_t)}{S^r_0(x_t, y_t)} \times \frac{D^r_t(x_{t+1}, y_{t+1})}{D^r_0(x_t, y_t)} \times \left[ \frac{D^r_t(x_{t+1}, y_{t+1})}{D^r_{t+1}(x_{t+1}, y_{t+1})} \right]^{1/2}
\]

On the right hand side of the above equation, the first portion which consists of functions denoted by \( \frac{S^r_t(x_t, y_t)}{S^r_0(x_t, y_t)} \) is defined as the changes of the scale efficiency; the second portion, \( \frac{D^r_t(x_{t+1}, y_{t+1})}{D^r_0(x_t, y_t)} \), is defined as the changes of pure technical efficiency; and the last portion, \( \left[ \frac{D^r_t(x_{t+1}, y_{t+1})}{D^r_{t+1}(x_{t+1}, y_{t+1})} \right]^{1/2} \), is defined as technological process changes.

Malmquist productivity index is calculated by multiplying the three parts together. If the scale efficiency index is greater than 1, it means the scale efficiency is enhanced by the change in commercial real estate investment. When pure technical efficiency is greater than 1, it indicates the efficiency of social resources allocation and utilization is improved. If the technological change is greater than 1, it means there is an improvement in production technology. If TFP is greater than 1, it indicates that the comprehensive productivity has been improved. On the contrary, if the above indicators are all less than 1, it means that the corresponding efficiency indices are deteriorated [12].

### 2.2 Commercial land performance model

In order to analyze the impact of commercial land investment on the total factor productivity of commercial real estate development, this paper use similar method that used to study industrial and land efficiency [8] Firstly, propose and build the commercial land performance index model, then use the ratio of the Malmquist indexes including land as input and without land as input to explore the contributions of the land to the commercial real estate total factor productivity. The commercial land performance model is defined as follows:

\[
W = \frac{ML_{t+1}}{M_{t+1}}
\]

where \( W \) indicates the land performance index; \( ML_{t+1} \) indicates the Malmquist index containing land; and \( M_{t+1} \) indicates the Malmquist index without land input.

The performance index of commercial land is the ratio of \( ML_{t+1} \) and \( M_{t+1} \).

### 2.3 Variables Choice and Description

Usually, the land use efficiency is mainly measured by the indexes of intensity of capital, labor and technology input, as well as the average output value to evaluate the degree of land intensive use [13]. The inputs usually include land, capital and labor. The input variables consist of a
number of factors: such as the accumulative and developed areas, the fixed asset investment, the transferred total amount of foreign capital, the remaining number of staff and workers by the end of the year[14], the urban population density[3], the number of labor in the second and third industries and the town-constructed areas[15]. The outputs mainly refer to the benefits that commercial real estate contribute to the economy, the government and the society such as tax revenues and the aggregate consumer goods value [3]. In addition to the benefits described above, the national GDP [4] and the added value of the second and tertiary industry[15] are also considered as a part of outputs.

Based upon the above study, this paper chooses three input variables: the total areas of completely developed commercial land, the labor population in the tertiary industries and the investment in commercial premises to represent the commercial land, labor and capital input respectively; selects the added value of tertiary industrial and the aggregate consumer goods value as output variables to reflect the economic benefits of commercial real estate development.

3 Empirical Results

In this paper the commercial real estate means the property used for commercial facilities, including retail, catering, entertainment, leisure, and fitness, etc.. The research object consists mainly of large shopping malls, large supermarkets, businesses in the community (i.e., bottom merchandise). All data used in this study came from the China Statistical Year Book 2008-2015 and China Real Estate Information (http://www.realestate.cej.gov.cn). The software used to do calculation is DEAP2.1.

3.1 Malmquist Index of Commercial Real Estate Development Based on Input-oriented Perspective

This paper takes 31 provinces and cities in China as samples. Firstly, calculate the Malmquist index of commercial real estate development including the land investment factor (completed area); then explore the trend and regional differences; finally, analyze the efficiency from the input-oriented perspective.

Analysis of National Malmquist Index

This study uses the panel data of 31 provinces and cities from 2008 to 2015 to calculate the Malmquist index of commercial real estate development from 2009 to 2015. The results are showed in Figure 1.

![Figure 1](image-url)
As shown in Figure 1, except the declining in 2012 and 2013, the overall trend of Malmquist index that indicating commercial development over the period of 2008 and 2015 has a V-shape, and the overall average value is 1.013. The commercial real estate total factor productivity (CRETFP) had an increasing trend over the research period from the national perspective, while the index of Technological change had touched bottom in 2013, and the index of scale efficiency dropped in 2015. On one hand, the declining trend obeys the general law in economic operation that the growth slows down after many years’ rapid development. On the other hand, the declining trend is bounded by the decline in efficiency when the development scale is too large. In addition, as the traditional retail trade encounter the challenge from E-commerce, the development of commercial real estate has acted crazy for extending and wasting a lot in some sense from the outlook of the development of commercial real estate.

Since 2010, due to the implementation of a series of residential real estate control policies, more and more real estate developers turned to commercial real estate and its influence will appear gradually in the next 2-3 years. The growth rate of investment in commercial premises encountered a big drop in 2015, which drives the rebound of the commercial real estate total factor productivity. However, the cumulative effect of extensive expansion over years made the scale of commercial real estate development arrived at the threshold, and the scale efficiency of national commercial real estate development declined in 2015. Furthermore, the index of Technological change has increased since 2013. With the progress of China's commercial real estate development technology, the developers begin to think creatively to build clear business model and business philosophy in order to deal with the impact of the internet. In other words, the land supply, business model and the adverse effect of internet have caused the bottleneck of the development of commercial real estate, which drives the V-shaped trend of CRETFP.

**A Comparative Analysis of Malmquist productivity of Commercial Development in Different Provinces**

The Malmquist indexes of 31 provinces and cities are showed in Table 1. Table 1 showed that more than half of the provinces in China, its Malmquist index is more than 1 over the study period, which means that the total factor productivity of commercial real estate is increasing. The Mongolia’s Malmquist index is highest in these provinces and cities with a 10.2 percent increase rate, mainly due to the lower development level of commercial land and Western Development Strategy. In contrast, Tibet, Qinghai, Xinjiang and Gansu have rather lower Malmquist indexes. The reasons are constraints of natural condition, geographical location and lower economic development. The attraction for capitals and talented people has more influence than land input.

The technical efficiency index varied over a much wider range than the scale efficiency for most of the provinces and cities, indicating that the expansion of the frontier for the production led by the technological change having the most effect on the total factor productivity. The scale efficiency of Shanghai, Beijing, Liaoning and Heilongjiang are all less than one, to some extent, reflecting the results of blind expansion and excessive investment.

**Table 1. The mean of Malmquist productivity (including land factor) and its decomposition in commercial real estate development of the provinces ranking, 2008-2015.**

<table>
<thead>
<tr>
<th>Province</th>
<th>M Productivity (tpch)</th>
<th>Technological change (techch)</th>
<th>Scale of efficiency change (sech)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mongolia</td>
<td>1.102</td>
<td>1.051</td>
<td>1.003</td>
</tr>
</tbody>
</table>
3.2 Index of Commercial land performance based on completed area

Analysis of the National Commercial Land Performance Index

The land performance index is defined as the ratio of the Malmquist index containing land over the one without land input. The larger the land performance index is, the more influence of the land-use has on the commercial real estate total factor productivity. The National Commercial Land Performance Index is showed in Figure 2.
As Figure 2 shows the national commercial land performance index is greater than one on the whole from 2008 to 2015, meaning that the Malmquist index containing land is larger than the one without land input. However, the index turned dramatically after 2014 owning to the disadvantages of the effect of crazily extended commercial land. The result suggests that commercial land input plays a key role in the changes of the commercial real estate total factor productivity.

A Comparative Analysis of Commercial Land Performance Index in Different Provinces and cities

The commercial land performance index of 31 provinces and cities are showed in Figure 3.

Figure 2: Plot of the national commercial land performance index.

Figure 3: Plot of the national commercial land performance index of 31 provinces and cities.
characteristic and geographical environment, the commercial land input has no prominent effect on the commercial real estate total factor productivity in Tibet, Jilin, Beijing, Hebei and Liaoning. The indexes for these provinces are all less than 0.99, showing the commercial land input has little effect on the growth of commercial real estate total factor productivity. The main reason for this, for instance, in Hebei and Liaoning, is that the increasing speed of urban population growth and the development of purchase power cannot keep up with the speed of expansion of commercial real estate development. While for Beijing, the reason is different. In Beijing, the situation is that business inventories are low and yet stable in recent years; therefore, the effect of commercial land input on commercial real estate total factor productivity index is lower than the effect of capital and technology especially in the core business district due to the shortage of land supply caused by scarcity of land.

4 Conclusions

In general, the trend of Malmquist index of commercial real estate development is V-shaped in China. The overall average of the index is 1.013 over the period of 2008 to 2015 with almost years’ indexes being greater than one except 2012 and 2013. The result shows that CRETFP is increasing from the national perspective but the index of scale efficiency decreased in 2015. From the provinces perspective, the Malmquist indexes of more than half of them are greater than one over the-eight-year study period, which indicates that the total factor productivity of commercial premises is mostly on the rise. In particular, the increase of total factor productivity of commercial development in the East area is the largest, followed by the Western and middle regions. The national commercial land performance index is greater than one overall from 2008 to 2015, which indicates that commercial land input plays a key role in the variety of the commercial real estate total factor productivity. There are significant regional differences in commercial land performance. Hainan is the highest, followed by Shaanxi, Yunnan, Qinghai and Guizhou. Meanwhile, Jilin, Beijing, Hebei and Liaoning fall at the back of the list.

The result of this study demonstrates that the most provinces in Eastern area are going to the stage of diminishing return to scale after many years of developing, where should change the way of commercial real estate development from the initially extensive growth mode to the economically intensive growth mode. The government should encourage innovation and fund raising by developers at the management level. The Western region should adopt the three-pronged approaches to enhance the development of commercial real estate: commercial area planning, capital operation and business operation. It should also efficiently take advantages of the great Western development policy to strategically adjust the commercial real estate development and basic facility sets and give priority in commercial land-use under scientific planning and rational development.

As the limitation in accessibility of data collection, the study uses the data from the complete area of commercial real estate to analyze the input of commercial land, rather than the pure commercial land. As the result of differences in plot ratio, different provinces may encounter measurement error in commercial land performance. Since the paper emphasizes on the trends and regional differences of commercial real estate production efficiency in China, measurement errors can be accepted. The further research will be aimed at collecting and using more accurate data of actual commercial land based in cities.
References

Ensuring Teams Integrate Better: Views from Malaysian Construction Builders

Che Ibrahim, C.K.I., Rahmat, A. and Belayutham, S.

Abstract: The diffused and fragmented nature of the construction industry has long been recognised around the world and is no exception in Malaysia. Although extensive research has been undertaken on team integration practices for construction projects, research that focuses specifically to the local context still remains elusive. Therefore, the main objective of this study was to provide an overview of the key determinants of team integration, based on an online survey of an award-winning construction builders in Malaysia. A literature review was initially conducted to review the concept of team integration in construction projects and, from this, twenty-three key determinants were identified. A set of questions were designed to confirm and rank the determinants, which was included in the online questionnaire survey. The research findings revealed that internal and external determinants have direct influence in determining the success of team integration practice. The analysis further revealed that the top-ranked determinants are commitment from top management, team leadership, trust and respect, communication, trust and respect and focusing on goals and objectives. The determination of these determinants provides the foundations for organisations to ensure the project team integrate better over time and stimulate an environment of collaboration amidst the widespread adversarial culture in the construction industry.

Keywords: Integration; Collaboration; Builders; Malaysia.
1 Introduction

The fragmentation of the construction industry has been influenced by inability of multi organisations to collaborate and integrate successfully when delivering construction projects [1]. Numbers of well-known construction reports have evidenced that the traditional procurement approach inhibit effective integration, resulting in organisations unable to achieve successful outcomes. The probable cause of this disintegration was due to the nature of temporary organisation within traditional project based industry (i.e. construction) which they operate beyond their own organisational boundaries where diverse organisations collaborate and cooperate to achieve common goal [2].

This phenomenon has long been recognised around the world and is no exception in Malaysia. A lack of understanding of what is required to embrace the integration practice among the construction organisations exists within the current Malaysian construction industry [3,4,5]. Also, there is great concern within the industry for the organisations to improve their integration practice throughout the construction project. Such concerns have a direct link to the nature of temporary organisations in which a multitude of different disciplines and functions do not exhibit stable boundaries within a project [2] due to issues such as cross-culture issues [6], lack of coordination due to separation of design and construction [1], individuals with opportunistic behaviours and adversarial relationships [3], lack of trust and insufficient communication [7]. In fact, the features of the bilateral contract in the traditional approach are believed to inhibit effective integration. Liu and Chan [8] indicated that different value propositions among organisations could resulted in tensions that affect the collaboration.

Integration practice has been acknowledged as one of the promising panacea to foster collaborative culture among the organisations in the construction project [9,10]. Despite the extant of construction literature tends to contribute understandings on the elements of integration practices in construction projects, research that focuses specifically to the local context still remains elusive. CIDB [5] in their latest report on Malaysian Construction Industry Transformation Plan (CITP) 2016-2020 emphasised the importance of construction organisations to understand and embrace the integration practice towards achieving high level of collaboration. As part of wider study on construction organisations integration practice in Malaysia, this paper aims to provide an overview of the key determinants of successful team integration, based on an online survey of an award-winning construction builders in Malaysia.

2 Team Integration in Construction Literature

The subject of team integration has received widespread attention in construction management literature due the potential of panacea to the fragmented relationships and adversarial nature of traditional procurement approaches [11]. Several scholars highlighted the increasing research interest in understanding the concept, features and elements of team integration practices in construction projects as a way to embrace collaborative environments. Consequently, examples of studies are reported here to provide insight into the extent of team integration research that has been undertaken.

Particular attention has been given to Baiden et al. [9] who made one of the first attempts to assess the extent of team integration in design-build and construction management procurement approaches. They found that that the level of integration among project teams could differ due to
the characteristics of the procurement model. In another study, Mollaoglu-Korkmaz et al.\textsuperscript{[12]} focused on measuring the level of integration in affecting sustainability goals in the DB procurement approach. The findings indicated that attributes such as early collaboration of the project’s participants, method and timing of communication, the chemistry among participants, owner commitment and team characteristics influence the level of integration. Che Ibrahim et al.\textsuperscript{[13]} conducted a study to identify the most significant key indicators (KIs) of team integration in alliance projects. Their findings indicate that alliance team members must possess different attributes from those involved in business as usual in order to strengthen the sources of integrated practice. In another study on team integration by Che Ibrahim et al.\textsuperscript{[14]}, a framework for influencing relationship indicators of team integration was proposed based on four elements: team formation; contractual model; teamwork principle; and operational monitoring. In a study of two green building projects, Senaratne and Hewamanage\textsuperscript{[15]} found that team integration practice and team leadership for both projects was at a higher level compare to typical building projects. They also emphasized that not only team integration, but also shared team leadership, is required for achieving LEED certification in a green building project, specifically in Sri Lanka.

It is worth highlighting that the findings from these studies indicate that the current perceptions of team integration practice are largely built around individuals, peer relationships, collaborative environments and skill-based practice. By its very nature, team integration is characterized by tangible and intangible elements. In addition, although numerous sets of elements, indicators or factors have been derived in the literature to cover most aspects of team integration practice, an insight of these elements within the local context is remain significant as local environment could influence how these elements are perceived.

2.1 What Makes Teams Integrate Better

Team integration in this paper should be viewed in the context of the definition suggested by Baiden et al.\textsuperscript{[9]} as the introduction of working practices, processes, methods, attributes and behaviours that create a culture of efficient and effective collaboration by project teams in achieving the project objectives. A conceptual framework, based on Che Ibrahim et al.’s\textsuperscript{[14]} key indicators (KIs) of team integration and Relationship-Based Procurement (RBP) taxonomy developed by Walker and Lloyd-Walker\textsuperscript{[16]}, have been studied in an effort to better understand what makes project teams integrate better. In addition, literature relevant to team integration in construction projects published in leading construction management journals (e.g. Journal of Construction Engineering and Management, Construction Management and Economics, Construction Economics and Building and International Journal of Construction Management) were also considered to further understand the determinants that influence the integration practice. This resulted in a set of twenty-three determinants that contribute to team integration practice as identified in Figure 1.

From the observation of the existing literature, these twenty-three determinants exhibit some important similarities in terms of their characteristics. For example, the determinants can be considered as either internal or external determinants. Determinants such as team leadership, single team focus, trust and respect, collective understanding, and communication are identified as internal determinants that are to some extent influenced and controlled within the team, whereas determinants such as single team location, governance structure, integrated risk and incentivization are considered as external determinants due to the use of systems or processes in influencing the relationships within the team. Consequently, it is proposed that to influence the team integration
practice both internal and external determinants are required. For a detailed discussion and evaluation of these determinants the reader is referred to Che Ibrahim et al.’s [16] and Walker and Lloyd-Walker [18].

![Figure 1. Determinants of Successful Team Integration Practice](image)

### 3 Research Methodology

The research methodology for this study included the development and distribution of a questionnaire survey for data collection purposes. Award-winning Malaysia construction builders of Malaysian Construction Industry Excellence Awards (MCIEA), was selected to participate in this study. The annual awards that celebrate excellence in Malaysia’s construction industry are a regular feature by the Construction Industry Development Board (CIDB) Malaysia since 2000. Consequently, it was considered extremely useful to draw on the award-winning members’ experience, knowledge and expertise regarding the subject of team integration. This survey had the following objectives: (1) to validate the key determinants of team integration identified from the construction literature; and (2) to rank the top 5 key determinants in terms of their importance in assessing team integration in construction projects.

The questionnaire comprised of both closed-ended and open-ended questions and was divided into two parts. The first part of the questionnaire (SECTION A) sought background information on each participant’s level of experience, how many years they have been in the industry and the type of contracting arrangements that they have been involved in over the years. The second part (SECTION B) focused on what key determinants they considered important for assessing the success of team integration in construction projects, as well as their views on methods to improve team integration in construction projects.

The survey was administered online. An email with a brief introduction about the survey was sent to the participants with the help of CIDB representative, along with the survey hyperlink, and an attachment of the survey summary for their reference. Based to the list of MCIEA recipients from 2000 until 2016 (provided by CIDB), the survey was sent to 103 recipient representatives’ email accounts. From the invitation, 34 responded, which is equivalent to 33% as the response rate.
4 Survey Results and Discussions

4.1 Section A: Profile of Respondents

The summary of respondent’s profile to this survey are included in Table 1. Twenty-one of the respondents (61.8%) identified themselves as managers, two respondents (5.9%) were directors, seven respondents (20.6%) held other positions such as executives, and the remaining four respondents (11.7%) did not reveal their current designations. It is clear that the majority of respondents belong to senior and top management decision makers, with the balance predominately in middle management. Overall, there was a fairly good mixture of designations and years of experience of respondents with almost 68 per cent of the respondents holding upper level management positions in their organisations.

Respondents were asked for their involvement in the construction industry in terms of type of sector and project delivery systems. Referring to Table 1, the majority (52.9 per cent) of the respondents were involved (at some stage of their career) in the infrastructure sector. The building sector comes behind with 47 per cent.

<table>
<thead>
<tr>
<th>Respondent Characteristics</th>
<th>No. of respondents (Total = 34)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directors</td>
<td>2</td>
<td>5.9</td>
</tr>
<tr>
<td>Managers</td>
<td>21</td>
<td>61.8</td>
</tr>
<tr>
<td>Executive</td>
<td>7</td>
<td>20.6</td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
<td>11.7</td>
</tr>
<tr>
<td>Years of experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>15</td>
<td>44.1</td>
</tr>
<tr>
<td>11-20</td>
<td>11</td>
<td>32.4</td>
</tr>
<tr>
<td>21-30</td>
<td>6</td>
<td>17.6</td>
</tr>
<tr>
<td>31 and above</td>
<td>2</td>
<td>5.9</td>
</tr>
<tr>
<td>Sectors in Industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrastructure</td>
<td>18</td>
<td>52.9</td>
</tr>
<tr>
<td>Building</td>
<td>16</td>
<td>47.1</td>
</tr>
<tr>
<td>Type of Delivery Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional</td>
<td>4</td>
<td>11.8</td>
</tr>
<tr>
<td>Design &amp; Build</td>
<td>14</td>
<td>41.2</td>
</tr>
<tr>
<td>Others</td>
<td>9</td>
<td>26.4</td>
</tr>
<tr>
<td>Unknown</td>
<td>7</td>
<td>20.6</td>
</tr>
</tbody>
</table>

The most prevalent project delivery system that the respondents had been involved was the design & build with 41.2 per cent. Traditional system follows behind with 11.8 per cent. The respondents were also involved with other types of project delivery approaches, notably private finance initiative (PFI) / public private partnership (PPP) and joint ventures.

4.2 Section B: Significance of Key Determinants of Team Integration

In this section, respondents were asked to rate the twenty-three determinants of team integration on how significant they thought each was for determining the success of team integration in construction projects. They were asked to rate the determinant based on the selection of a score
according to the 5-point Likert scale, ranging from 1 = Not Significant, 2 = Least Significant, 3 = Neutral, 4 = Significant, to 5 = Highly Significant. Results are shown in Table 3.

Table 3. Mean rating of key determinants of team integration

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Significance (Mean Rating)</th>
<th>Ranking (Top 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creation of single team location</td>
<td>4.24</td>
<td>-</td>
</tr>
<tr>
<td>Commitment from top management</td>
<td>4.74</td>
<td>1</td>
</tr>
<tr>
<td>No Blame culture</td>
<td>4.35</td>
<td>-</td>
</tr>
<tr>
<td>Trust and Respect</td>
<td>4.53</td>
<td>4</td>
</tr>
<tr>
<td>Client Care team</td>
<td>4.12</td>
<td>-</td>
</tr>
<tr>
<td>Seamless operation with no-organisational boundaries</td>
<td>3.91</td>
<td>-</td>
</tr>
<tr>
<td>Team flexibility and responsiveness to change</td>
<td>4.15</td>
<td>-</td>
</tr>
<tr>
<td>Team leadership</td>
<td>4.79</td>
<td>2</td>
</tr>
<tr>
<td>Collective understanding</td>
<td>4.38</td>
<td>-</td>
</tr>
<tr>
<td>Encouraging initiative</td>
<td>4.41</td>
<td>-</td>
</tr>
<tr>
<td>Effective management of Health and Safety</td>
<td>4.53</td>
<td>-</td>
</tr>
<tr>
<td>Focusing on Goals and Objective</td>
<td>4.79</td>
<td>5</td>
</tr>
<tr>
<td>Communication</td>
<td>4.68</td>
<td>3</td>
</tr>
<tr>
<td>Predictability of Overall Cost/Schedule</td>
<td>4.41</td>
<td>-</td>
</tr>
<tr>
<td>Integrated Risk</td>
<td>4.35</td>
<td>-</td>
</tr>
<tr>
<td>Accountability and Transparency</td>
<td>4.03</td>
<td>-</td>
</tr>
<tr>
<td>Innovation &amp; improvement</td>
<td>4.12</td>
<td>-</td>
</tr>
<tr>
<td>Integrated ICT System</td>
<td>4.03</td>
<td>-</td>
</tr>
<tr>
<td>Sharing of Information</td>
<td>4.15</td>
<td>-</td>
</tr>
<tr>
<td>Incentivization</td>
<td>4.06</td>
<td>-</td>
</tr>
<tr>
<td>Consensus decision making</td>
<td>4.06</td>
<td>-</td>
</tr>
<tr>
<td>Governance structure</td>
<td>4.32</td>
<td>-</td>
</tr>
<tr>
<td>Best for project culture and mindset</td>
<td>4.15</td>
<td>-</td>
</tr>
</tbody>
</table>

Overall, the indicators “Focusing on Goals and Objectives” and “Team Leadership” received the highest mean rating of the team integration determinants with a 4.79. This is followed by “Commitment from Top Management” and “Communication” which received a 4.74 and 4.68 mean rating respectively. Determinants of “Trust and Respect” and “Effective management of Health and Safety” both received a 4.53 mean rating. These six highest rated determinants can be classified as “Highly Significant” in determining the success of team integration in construction projects.

Determinants such as “Encourage Initiative” and “Predictability of Overall Cost/Schedule” with a mean rating of 4.41, “Collective Understanding” with a mean rating of 4.38, “No Blame Culture”, and “Integrated Risk” which shared the same mean rating value of 4.35 and “Governance Structure” which received a mean rating of 4.32, can be classified as “Significant” in terms of determining the successful team integration. The least significance according to the rating is “Seamless operation with no-organisational boundaries”, with a mean rating of 3.91. Overall, the survey results confirm
that all the twenty-three determinants, which received average responses ranging from “towards significant” to “highly significant”, are needed to determine the success of team integration practice. The findings indicated that majority of internal determinants were significant in determining the success of team integration as these determinants had direct influence on shaping the culture of diverse team.

It is worth highlighting that although such rating (see Table 3) can be extremely helpful in pointing out areas of relative strength and weakness, it is believed that attention to open-ended questions on ranking is important to present a clear view of the prime contributors to the success of team integration. Subsequently, the respondents were asked to identify and rank the top five determinants (see Table 3). The ranking of the determinants was calculated based on the highest cumulative percentage received for each rank. The determinants which appear to have the greatest effect on determining the team integration success based on the ranking were: (1) commitment from top management; (2) team leadership; (3) communication; (4) trust and respect; and (5) focusing goals and objectives. As for the validation of the findings, the results (top key determinants) presented are supported by a study published by Che Ibrahim [14]. Although the aforementioned study focused on different location, the findings in the current study triangulate with the specific findings in their elements of determining successful team integration practice. Thus, the findings in this study strengthen the fact that the relationship behaviour and collaborative culture have direct influence on successful team integration practice.

5 Conclusion

The research presented in this paper attempts to provide an overview of the key indicators of team integration in construction projects from award-winning Malaysian construction builders point of view. Based on online survey responses from thirty-four construction builders, it has shown that all twenty-three determinants are important and the results of the analysis also revealed that they have a strong influence towards determining the success of team integration in construction projects. The findings also revealed that the top-ranked determinants contribute towards successful team integration are mainly influenced by the internal factors; commitment from top management, team leadership, trust and respect, communication, trust and respect and focusing on goals and objectives.

The present study contributes new insights to the team integration literature by providing an insight of determinants for successful team integration within the Malaysian context. As part of wider study on construction organisations integration practice in Malaysia future research should focus more on enhancing our understanding on how these determinants could directly measure the team integration practice over project lifecycle. Finally, since the key determinants were assessed from a Malaysian organisations’ perspective, it is suggested that further research should be conducted in other countries with different type of procurement approaches for comparative purposes.

Acknowledgements

The work presented herein was undertaken under the aegis of An Assessment Framework of a Multi-Organizational Team Integration Performance in Construction Projects, funded primarily by Ministry of Education Malaysia (Grant No. FRGS/1/2015/TK06/UITM/02/2) through the Faculty
of Civil Engineering, Universiti Teknologi MARA, Malaysia.

References


Quantification of Carbon Emissions of Air Conditioners in Buildings: A Case Study of Shenzhen, China


Abstract: An increasing quantity of household air conditioners (HACs) in cities has led to high-level energy consumption and refrigerant leak during their service periods, which results in significant environmental impacts. However, very few studies have been undertaken to investigate the environmental impacts of HACs at the city level. This is particular the case in Shenzhen, a megacity with rapid development in South China. This paper, therefore, is designed to assess the carbon emissions from the usage stage of air conditioners in residential buildings, including energy and refrigerants effects. The results show that the total carbon emissions from the service stage of HACs in Shenzhen have generally increased in the past decade. The main contributor is electricity consumption, which accounts for nearly 80% of the total emissions, followed by refrigerants leak (20%). Meantime, the electricity consumption of HACs takes up nearly 30% of the total residential electricity consumption, which should be taken as the critical issue for building energy efficiency. Besides, the refrigerants leak and associated impact should not be overlooked due to significant impact on emission reduction. To summarize, these findings provide a valuable basis for energy conservation and emission reduction in the HACs sector in cities.

Key words: Household air conditioners (HACs); Carbon emissions; Electricity; Refrigerant leak.

1 Wang, H.Y.
School of Civil Engineering, Shenzhen University, China

2*Duan, H.B.
Corresponding author.
School of Civil Engineering, Shenzhen University, China
E-mail address: huabo@szu.edu.cn

3 Zuo, J.
School of Architecture & Built Environment, The University of Adelaide, Australia

4 Dong, D.
School of Civil Engineering, Shenzhen University, China

5 Zillante, G.
School of Architecture & Built Environment, The University of Adelaide, Australia
1. Introduction

Shenzhen, a megacity with subtropical marine climate in southern China, has an increasing number of HACs. Statistically, as shown in Figure 1, in 2016, the quantity of household air-conditioners reached 10.04 million units, or twice as much as that in 2005. In addition, according to the climate data of Shenzhen, the number of days with daily average temperature higher than 26°C is around 180 days every year. This means HACs are used at least 6 months annually in Shenzhen. Accordingly, the HACs in Shenzhen has consumed massive amount of electricity and released a great number of refrigerants (such as HCFCs and HFC, with high global warming potential rates) during the usage phase. It is therefore necessary to characterize the global warming impact of the HACs at the city level to achieve lower carbon emissions.

So far, a lot of studies indicate that HACs, as the main driver for domestic environmental impacts, directly or indirectly consume a large amount of energy and have a variety of negative environmental effects. From the perspective of whole life cycle assessment, a number of studies have been undertaken. For example, Li (2015) analyzed various influencing factors for the residential packaged conditioners via life cycle climate performance (LCCP) and material life cycle assessment (LCA). Among those emission contributors, the energy consumption accounts for more than 70% of the total emissions, followed by the annual refrigerant leak. Sun (2014) calculated the carbon footprint of a typical household air conditioner in China via the life cycle assessment, and found that 90% of carbon emissions were generated during the usage stage. In sum, the service stage of a household air conditioner, including electricity usage and refrigerant leak aspects, contributes greatly to the carbon emissions in their whole life cycle. Therefore, some studies focused on energy consumption of HACs through field surveys and analog calculations. For example, Zang (2013) analyzed the electricity consumption of HACs in Shanghai in the last decade. Li (2008) investigated the energy consumption of HACs of five residential buildings in Beijing, and analyzed the energy consumption characteristics of different types of residential air conditioning systems. In addition, Hou (2008) simulated the energy consumption of per household air conditioner in Shenzhen under different scenarios by using DeST software, and they believed that reducing the energy consumption of HACs was the key factor of building energy efficiency in Shenzhen.

However, there are still gaps in those previous studies. First, those studies mainly focused on the energy consumption of HACs while few relative works had examined the whole impacts at the city level. Second, those researches about the environmental impacts of HACs in their service stage did not cover the annual leakage of refrigerants which has certain impacts. In addition, Shenzhen, with massive HACs, generates vast amounts of carbon emissions by using HACs and shows serious impacts on global warming. Therefore, assessing the carbon emissions of HACs in the usage stage of Shenzhen from both energy and chemical effects provides a valuable basis for energy conservation and emission reduction in the HACs sector.

Thus, this study attempts to calculate the carbon emissions from HACs in their service life at the city level due to the electricity consumption and refrigerant leak.
2. Methods

2.1 Scope

The HACs generate environmental impacts (measured by carbon dioxide in this study) directly and indirectly in their usage stage. On the one hand, a great deal of fuels combusted from power generations emit the indirect carbon emissions through electricity consumption. On the other hand, the directly emissions derive from the annual refrigerant leak of HACs. Both effects were concerned in this analysis.

2.2 Calculation

2.2.1 Indirect Emissions

In this process, the indirect carbon emissions mainly caused by electricity usage. Therefore, we obtained the annual electricity consumption per unit area of HACs in Shenzhen through literature reviews and on-site surveys, and then we calculated the indirect carbon emissions of HACs in the usage stage of Shenzhen by Eq.1.

\[ E_{RE,i} = W \cdot q_E \cdot A_{R,i} \quad \text{Eq.1} \]

Where \( E_{RE,i} \) (kg CO\(_2\)-eq) is the indirect emissions from the usage stage of HACs in the year \( i \), \( W \) (kwh/m\(^2\)) is the annual electricity consumption from the usage stage of HACs in per unit area, \( q_E \) (kg CO\(_2\)-eq/kwh) is the grid emissions factors of southern electricity, \( A_{R,i} \) (m\(^2\)) is the residential floor space of Shenzhen.

2.2.2 Direct Emissions

Due to the long-term outdoor exposure of the compressors, the refrigerants in the HACs leak into the atmosphere and emit carbon emissions directly during the usage phase. We considered all types of refrigerants used in the residential HACs and their substitution process. Then, the direct emissions can be obtained by Eq.2.

\[ E_{RF,i} = \sum R_{r,i} \cdot L_r \cdot GWP_r \cdot Q_{RA,i} \quad \text{Eq.2} \]

Where \( E_{RF,i} \) (kg CO\(_2\)-eq) is the direct emissions from the usage stage of HACs in the year \( i \), \( R_{r,i} \) (kg/unit) is each HAC’s average content of refrigerant \( r \) in the year \( i \), \( L_r \) (%) is the annual leak rate of refrigerant \( r \) during the usage stage, \( GWP_r \) (kg CO\(_2\)-eq/kg) is the global warming potential of refrigerant \( r \), \( Q_{RA,i} \) (Million unit) is the quantity of HACs in the year \( i \).
2.3 Data Inventory

In this study, the basic data were mainly derived from literature reviews and on-site surveys. For instance, the annual electricity consumption of HACs in per unit area was obtained from the summary of Hou (2008), Wu (2010), Li (2014) and the objects of our on-site surveys. In our on-site survey, we acquired the annual electricity bills of our objects in two neighborhoods, then calculated the annual electricity consumption of HACs by deducting the average monthly electricity consumption of those non-air conditioners usage months from the yearly electricity consumption. The annual residential floor space and the annual quantity of HACs were drawn from the analysis of Shenzhen Statistical Yearbook (2009-2016). The refrigerant content of each air conditioner was gained by summarizing the studies of MEP (1999), CHEAA (2015), Duan (In press), Jiang (2016). The annual leak rate of refrigerants was derived from the report of UNEP (2011). And the grid emissions factors of refrigerants and southern electricity was exported from Xue (2017) and China Life Cycle Database (CLCD) (See in Table 1).

Table 1. Grid emissions factors of refrigerants and southern electricity

<table>
<thead>
<tr>
<th>Materials</th>
<th>Emissions factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern electricity (kg CO2-eq/kwh)</td>
<td>0.78</td>
</tr>
<tr>
<td>HCFC-22 (kg CO2-eq/kg)</td>
<td>1080</td>
</tr>
<tr>
<td>HFC-410A (kg CO2-eq/kg)</td>
<td>2088</td>
</tr>
<tr>
<td>HFC-32 (kg CO2-eq/kg)</td>
<td>675</td>
</tr>
<tr>
<td>R600a (kg CO2-eq/kg)</td>
<td>20</td>
</tr>
</tbody>
</table>

3. Results and discussion

3.1 Electricity consumption and associated impacts

The carbon emissions from energy consumption of HACs in Shenzhen are shown in Figure 2. The total carbon emissions from energy consumption show an increasing trend, which has grown nearly 67% from 1876 kt CO2-eq in 2005 to 3124 kt CO2-eq in 2016. By contrast, as shown in Figure 2, the carbon emissions per unit GDP from the energy consumption have been decreasing significantly during the last decade. In 2016, it has dropped in half compared with eleven years ago. These results indicate that the energy-saving efforts on the energy consumption of HACs in Shenzhen are effective. However, due to the massive carbon emissions, related measures still needed to be in place.
In addition, HACs take a great proportion of household electricity consumption and carbon emissions (IPCC, 2014; Gou, 2017; Wu, 2017). In our calculation, by the end of 2016, the electricity consumption from HACs comprised of nearly 30% of the total residential electricity consumption in Shenzhen. This proportion is much higher than studies about other mega cities such as Shanghai (19.24%) by Zang (2013) and Beijing (13.33%) by Huang (2010) because of the hot climate in Shenzhen. Therefore, the HACs sector is still the crucial part of the energy-saving in residential buildings in Shenzhen.

3.2 Refrigerants impact

In China, four kinds of refrigerants are used in air conditioners, i.e. HCFC-22, HFC-410A, HFC-32 and R600a. HCFC-22, as a transitional alternative refrigerant, can cause ozone layer depletion by its content of chlorine. Therefore, this kind of refrigerant has been gradually substituted by those refrigerants that have zero ozone depression potential like HFC-410A, HFC-32 and R600a (Xue, 2017). For more detailed results, those four refrigerants and their substitution process were included in this study. The carbon emissions from refrigerant leak of Shenzhen’s HACs in the usage phase are specified Fig. 4. The carbon emissions have increased rapidly from 482 kt CO₂-eq in 2005 to 930 kt CO₂-eq 2011, then started to decrease since 2011 by the usage of lower global warming impact refrigerants. In addition, the carbon emissions from HCFC-22 and HFC-410A take almost the entirely part due to their higher global warming impacts, and the effect of R600a can be negligible. It also indicates that the substitution process of refrigerants has significant impacts on emission reduction.
3.3 Environmental implications

As presented in Figure 5, the carbon emissions from HACs in Shenzhen has been mainly arising from 2005 to 2016. Because of the adding quantity of HACs and residential living area, the carbon emissions from the usage stage of HACs in Shenzhen had increased at a sharp rate during 2005 to 2011. Then it begins to decrease a little bit after the usage of lower global warming impact refrigerants in 2011. And by 2016, this number peaks up to 3,831 kt CO$_2$-eq, 62% more than that of eleven years ago. On the one hand, most of the carbon emissions derive from the electricity consumption of HACs in the using stage, which arrives to 80% in 2016. In addition, the carbon emissions of this part have been ever-increasing. Therefore, to decrease the electricity consumption HACs, measures should be taken by the government and residents, such as stating subsidy of replacing energy-saving air-conditioners, increasing one degree of the working temperature of air conditioners and so on. On the other hand, the refrigerant leak should not be ignored as it accounts for nearly 20% of the carbon emissions from HACs during the usage phase. Therefore, the government should keep increasing the using of lower global warming impact refrigerants like HFC-32 and R600a, and decreasing the annual leak rate of refrigerants by setting the guideline to the air conditioner manufacturers.

![Figure 4. Carbon emissions from refrigerants leak of HACs during the using phase in Shenzhen](image)

![Figure 5. Carbon emissions from HACs in Shenzhen due to electricity consumption and refrigerants leak](image)
4. Constraints and limitations

This study quantified the carbon emissions of HACs during the usage stage in Shenzhen to offer basic data for emission reduction. However, due to the lack of sufficient data, the study did not take into account of dynamic changes in the annual electricity consumption from the usage stage of residential air conditioners in per unit area and the annual leak rate of refrigerants. In addition, this study did not specify the types of HACs, which is due to the limitations associated with on-site surveys. In addition, uncertainties have been not highlighted for the results expression.

5. Conclusion

This study estimated the carbon emissions of HACs in the usage stage from electricity consumption effect and refrigerant leak effect in Shenzhen. The results show that the carbon emissions from HACs in Shenzhen have increased more than 63% since 2005. Around 80% of the carbon emissions derive from the energy consumption effect. In addition, the electricity consumption from HACs sector takes for nearly 30% of the total residential electricity consumption in Shenzhen. Meanwhile, the carbon emissions from refrigerants leak effect should be paid attention because results show that the substitution process of refrigerants can effectively reduce the emissions. Overall, our analysis could offer a baseline for reducing the carbon emission from HACs sector in cities and beyond.

Acknowledgement

This study was supported by the Shenzhen Science and Technology Plan (no. JCYJ 20150525092941042 and JCYJ 20160520173631894), Natural Science Foundation of Guangdong Province (2017A030313438), NSFC 51478267 and the Young Faculty Promotion Plan of Guangdong Province (YQ2015139) for funding and support.

References


Transition Towards Solar-Powered Buildings?
-Understanding the Debates on Building Integrated Photovoltaics in Singapore Using Q Methodology

Cao, Y.1, Chang, R.D.2*, Lu, Y.J.3 and Shabunko, V.4

Abstract: The combustion of non-renewable energy sources contributes greatly to global warming and many other severe environmental problems, which provoked the worldwide consensus on the importance of sustainable development. In the building sector, the generation of electricity by harvesting solar energy using building integrated photovoltaics (BIPV) is an attractive approach of utilizing renewable energy, especially for those highly urbanized regions such as metropolises. Singapore is such a metropolitan city where the deployment of BIPV could potentially play a significant role in the nation’s renewable energy development. In order to understand the various stakeholders’ debates on BIPV in Singapore, this study employed Q methodology to analyze the different perspectives on BIPV in the local building industry. The results show that there are three main perspectives on BIPV in the industry, namely “support and manage”, “proactively promote” and “wait and see”. This study suggests that there are significant differences in the stakeholders’ perspectives on BIPV, which must be taken into consideration in the policy making and strategic planning of BIPV.

Keywords: Solar power; Building integrated photovoltaics; Innovation policy; Q methodology;

1 Cao, Y. Department of Building, National University of Singapore, Singapore. E-mail: caoyuan@u.nus.edu
2 * Chang, R.D., Corresponding author, Department of Building, National University of Singapore, Singapore. E-mail: bdgcr@nus.edu.sg
3 Lu, Y.J. Department of Building, National University of Singapore, Singapore. E-mail: luy@nus.edu.sg
4 Shabunko, V. Solar Energy Research Institute of Singapore E-mail: veronika.shabunko@nus.edu.sg
1 Introduction

The rapid development of the global economy is accompanied by the escalating consumption of fossil fuel and the resulting excess greenhouse gas (GHG) emissions, which triggered the issue of climate change and global warming. According to the International Energy Agency, the CO\textsubscript{2} emissions from fuel combustion has reached 32381 Mt in 2016, which had doubled over the last four decades, and the growing trend will continue in the future [1]. As a response to this issue, the conception of sustainable development started to gain popularity and gradually becomes a worldwide consensus, and the utilization of renewable energy is recognized as an important approach for sustainable development. For the application of renewable energy in buildings (REIB), solar energy is one of the most promising and reliable energy sources in most of the countries due to its inexhaustibility and zero pollution. The harness of solar energy by using photovoltaic (PV) technologies is commonly adopted around the world, in the form of rack-mounted photovoltaics. Besides, in urbanized regions, the integration of PV into building façade, also known as building-integrated photovoltaic (BIPV), can be suitable.

Over the last few decades, the BIPV market has started to bloom owing to the continuous decreasing of the PV prices and extensive researches carried out globally. However, there are still numerous barriers in the application of BIPV. Firstly, although the price of PV panels has dropped over the years, the total installation cost of BIPV system is still considered expensive, as the system consists of many other components to function properly. Moreover, the uncertain financial payback period further hindered the stakeholders’ willingness toward the adoption of BIPV systems. For example, without any government support or subsidies, the payback period of BIPV system is estimated to be 15-30 years [2]. Furthermore, the BIPV application is considered as a rather new trend in buildings and are still developing, and some technical issues are need to be addressed in the module efficiency [3], design and installation [4] as well as maintenance [5]. Last but not least, the successful adoption of BIPV requires the close collaboration and knowledge-sharing among multiple stakeholders. However, the current stakeholders’ awareness and confidence level of BIPV technologies are low due to the aforementioned financial and technical problems.

In view of the numerous barriers existed in the utilization of BIPV systems, some researchers had proposed their recommended resolutions. For instance, in term of the financial barriers to BIPV adoption, Azadian & Radzi (2013) disclosed that the government has the duty to launch more supportive policies and provide more financial aids to encourage further R&D activities to lower the cost of BIPV and shorten the financial payback period [3]. However, most of the past researchers of BIPV deployment focused on one specific barrier instead of investigating and making recommendations by considering all the barriers. Moreover, as discussed earlier, the strong collaboration and knowledge-sharing among different expertise is the cornerstone of the successful implementation of BIPV technology, but the current involvement is rather pessimistic [6]. This suggests that the best solution to involve everyone is to cater and address the different demands and interests among various stakeholders. Therefore, the aim of this study is to provide a holistic and systemic approach to assess and address different BIPV stakeholders’ perspectives in the context of Singapore by applying the Q methodology, thereby support future policy-making process.
2 Literature Review

2.1 Innovation Policy Mix for Sustainability Transition

With the global consensus of constructing a sustainable future, many countries are promoting the transitions to sustainability. Sustainable transition is commonly defined as ‘…long-term, multidimensional, and fundamental transformation processed through which established socio-technical systems shift to more sustainable alternatives’ [7]. Over the last two decades, a great number of scholars had studied in this area and proposed various approaches to promote sustainability transition. One of the most frequently utilized approaches in the studies of sustainability transition is the multi-level perspective (MLP) framework, which is a powerful tool for policymakers to direct transitions in three distinct levels: niches, regimes, and landscape. Niches are the ‘protective space’ where the innovation movements occur and where time-limited shelter is provided to protect the novelties from the dominant selection rules of the existing market. Regimes represent the prevailing regulations and routines of the existing system, which were established by various lock-in mechanisms. Landscape refers to the broader context outside the level of niches and regimes and has the capability to influence the other two levels. According to MLP, sustainability transitions take place as a result of the interplay of all three levels, that is, landscape factors create pressure and weaken regimes while more importantly, niches accumulate impetus to evolve and eventually break into the mainstream of the existing system. Therefore, niche plays an essential role in the MLP framework as it serves as the ‘seeds’ for successful sustainability transitions.

However, in order to take over the incumbent position of the existing regime, innovative niches need to overcome various barriers. For instance, most innovations are relatively crude with many uncertainties and usually come with a higher price compared to those widely adopted technologies, which could easily lead to negative perceptions of potential users. Therefore, without purposive protection and promotion, the development of innovative niches could be easily hindered or even fail entirely at the infant stage. Innovation policy mix, defined as the series of actions launched by the government or public organizations to affect the innovations procedures with the example of subsidies, incentives, and targets, are widely used to serve as the main protection measure for innovations. However, the selection of particular policy instrument to launch is vital for the successful implementation of innovation, as improper and flawed instruments would affect the process negatively.

2.2 Building Integrated Photovoltaics in Singapore

In Singapore, natural gas constituted around 95% of the total electricity generation, and the building sector accounted for more than one-third of the national electricity bill [8]. As the exceptionally heavy reliance on imported fossil fuel as a major energy source could lead to severe environmental problems and potential energy crisis, the Singapore government pledges to achieve CO₂ emission reduction by seeking alternative energy solutions from renewable and clean energy sources such as hydro and solar. With its tropical geographical advantage, Singapore receives high annual solar radiation with low seasonal fluctuation, granting solar PV an ideal and feasible option for energy generation.

Solar Photovoltaic (PV) is the technology that directly converts energy from sunlight into
electricity through the utilization of solar panels. With the advantage of pollution-free and renewable, solar energy is capable of fulfilling the continuous energy demand while keeping the adverse environmental impacts to a minimum. As estimated by the Sustainable Energy Association of Singapore [9], Singapore has adequate space to install 6 GWp of Solar PV and hence generate approximately 17% of national electricity demand [9]. However, the deployment of solar PV technologies in Singapore only started to flourish since 2008. Up to the first quarter of 2017, the total installed capacity of grid-connected solar PV systems around the island-state is 129.8 MWp, with more than 95% installation on non-residential buildings. However, with the constraints of land scarcity and high population density, the amount of vacant space to implement solar energy in Singapore is extremely limited, which makes the deployment of large-scale solar farms to harness solar energy impractical. Therefore, integrating PV into building façade elements by replacing the conventional material serves as a favorable alternative option, as it allows solar harvesting in densely populated regions while ensuring building functionality. Nonetheless, despite all the benefits it brings, BIPV technology has remained a niche technology in Singapore, with only few demonstration projects that have BIPV systems incorporated into building design.

3 Research Methodology

The research method used in this study is Q Methodology, a scientific model that combines both qualitative and quantitative approaches to study human subjectivities in a systemic and structured manner [10]. The uniqueness of this method is to explore the trends within and across individuals rather than across individual attributes, such as gender, age, and class. Q methodology was employed in studies that specially target on the policies related to the planning and implementation of renewable energy sources such as wind and biomass[11].

As proposed by Brown (1980) and Watts and Stenner (2012), Q methodology involves six consecutive stages. The first stage is the collection of Q population or also known as ‘concourse’: the extensive collection of written or spoken statements that reflect the diversity of a specific issue, which, in this study, is the innovation policy mix for BIPV. In the second stage, the collected concourses are filtered to a workable amount, thereby generating Q samples. The ideal size of Q sample ranges from 40 to 60 sentiments. In this study, 44 statements have been screened and eventually finalized through the process of literature review and interviews of local BIPV experts. Table 1 shows 10 out of the 44 statements for illustrative purpose.

The third stage involves the identification and recruitment of respondents from concerned stakeholder groups, referred as the ‘P-set’. In the fourth stage, the respondents (P-set) were instructed to rank orders of all statements in the Q sample from “strongly agree” to “strongly disagree” and at the same time to form a “forced” quasi-normal distribution (Figure 1). Results collected from Q-sorting stage then would be examined through factor analysis and interpreted in the fifth and sixth stage.

It is important to note that, different from the traditional factor analysis which normally relies on data in the form of Likert scale without prescribed distribution, Q methodology predetermines the number of statements in each category of Likert scale, and conducts dimension reduction on the respondents rather than the variables. These are the key differences between Q methodology and traditional factor analysis in terms of the calculation method.
Table 1. Examples of Q sample statements

<table>
<thead>
<tr>
<th>Statements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. BIPV is the best form to utilize solar energy in Singapore because Singapore has limited land resources for large-scale solar farm.</td>
</tr>
<tr>
<td>2. Singapore government should establish a comprehensive R&amp;D funding scheme or subsidies on BIPV for the industry.</td>
</tr>
<tr>
<td>3. Buildings with BIPV systems have a potentially large market value as they can generate electricity by themselves which reduces operational cost in the long run.</td>
</tr>
<tr>
<td>4. Singapore government should establish an information platform of BIPV, e.g. providing reference guidelines for the best available technology of BIPV for the industry.</td>
</tr>
<tr>
<td>5. Projects with BIPV systems face great difficulties in obtaining governmental approvals (e.g. from different agencies).</td>
</tr>
<tr>
<td>6. As an influential player in the development of public housing, HDB should take a more proactive attitude to promote BIPV.</td>
</tr>
<tr>
<td>7. Singapore government needs to conduct detailed potential analysis of BIPV to know how much solar power could be harvested.</td>
</tr>
<tr>
<td>8. In the long run, Singapore should gradually reduce the dependence on natural gas because someday natural gas will run out in the world.</td>
</tr>
<tr>
<td>9. Singapore should establish stronger energy efficiency policies for the industry e.g. zero energy buildings, so that BIPV will become a serious option for industries.</td>
</tr>
<tr>
<td>10. Allow key players of BIPV to participate more in the decision-making process of energy policy and to interact more with the government.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Moderately Disagree</th>
<th>Slightly Disagree</th>
<th>Neutral</th>
<th>Slightly Agree</th>
<th>Moderately Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 1. Quasi-normal distribution

4 Results and Discussion

4.1 Factor Analysis

In this study, 9 local BIPV experts and authority’s delegates participated in the Q-sort exercises, representing 5 groups of stakeholders ranging from the board of statutory, building
developers, architects and engineers, facility managers as well as BIPV manufacturers. Then, factor analysis was conducted on PQMethod, version 2.35, which is a statistical program that specially designed for Q methodology. The generated factors were then used to interpret the shared opinions among stakeholders.

For starters, a principal component factor analysis was carried out, and a total of eight unrotated factors were extracted by PQMethod, as shown in Table 2, whereas only three of the factors with an eigenvalue greater than one were filtered for later analysis and discussion.

Table 2. Unrotated Factor Matrix

<table>
<thead>
<tr>
<th>Factors</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>-0.2611</td>
</tr>
<tr>
<td>2</td>
<td>0.5620</td>
</tr>
<tr>
<td>3</td>
<td>0.4147</td>
</tr>
<tr>
<td>4</td>
<td>0.5753</td>
</tr>
<tr>
<td>5</td>
<td>0.4823</td>
</tr>
<tr>
<td>6</td>
<td>0.5101</td>
</tr>
<tr>
<td>7</td>
<td>0.4317</td>
</tr>
<tr>
<td>8</td>
<td>0.7951</td>
</tr>
<tr>
<td>9</td>
<td>0.7934</td>
</tr>
</tbody>
</table>

| Eigenvalues | 2.8280 | 1.3851 | 1.2391 | 0.9074 | 0.7889 | 0.7295 | 0.5151 | 0.3337 |
| % expl.Var. | 31     | 15     | 14     | 10     | 9     | 8     | 6     | 4     |

Subsequently, the three factors were rotated by using “varimax rotation” to maximize the amount of explained variance and to avoid human judgmental errors. As shown in Table 3, the three factors together accounted for 60 percent of the overall variances. Each factor represents one shared perspective of stakeholder towards BIPV and the asterisk indicates the factor group that each participant belongs to.

Table 3. Rotated Factor Matrix with Asterisk (*) indicating defining factor

<table>
<thead>
<tr>
<th>Factors</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>-0.0473</td>
</tr>
<tr>
<td>2</td>
<td>0.2824</td>
</tr>
<tr>
<td>3</td>
<td>-0.1271</td>
</tr>
<tr>
<td>4</td>
<td>-0.0010</td>
</tr>
<tr>
<td>5</td>
<td>0.4777 *</td>
</tr>
<tr>
<td>6</td>
<td>0.1479</td>
</tr>
<tr>
<td>7</td>
<td>0.8557 *</td>
</tr>
<tr>
<td>8</td>
<td>0.7742 *</td>
</tr>
<tr>
<td>9</td>
<td>0.5541 *</td>
</tr>
</tbody>
</table>

| % expl.Var. | 22     | 17     | 21     |
4.2 Perspectives 1: “Support and Manage”

As shown in Table 3, the perspective 1 consists of 4 participants, which in total could explain 22 percent of the overall variance. This perspective highly emphasizes on the importance and the needs of research and development for BIPV technologies by recognizing that ‘R&D capability of BIPV in Singapore is weaker compared to other developed countries’ and agreeing that ‘Singapore government should establish a comprehensive R&D funding scheme or subsidies on BIPV’. Also, perspective 1 stakeholders reveal that due to the technology unreadiness, large-scale mandatory installation of BIPV on residences should be avoided.

4.3 Perspectives 2: “Proactively Promote”

Perspective 2 consists of 2 participants, which accounts for 17 percent of the cumulative variance. In this group, an optimistic view of the current development and prospect of BIPV is shown. They believe that installation of BIPV panels should be mandatory as ‘BIPV is the best form to harvest solar energy in Singapore and use the façade area for acceleration of BIPV because Singapore has limited land resources for large-scale solar farm. Furthermore, it strongly recommended that Singapore should gradually reduce, or even cut off, the dependency on natural gas, and instead, make a transition to implementation of BIPV application for energy generation in the future.

4.4 Perspectives 3: “Wait and See”

In terms of perspective “Wait and See”, 3 participants fell into the same category and explained 21 percent of the overall variance. They shared a conservative perspective about the deployment of BIPV in Singapore. They believed that natural gas will continue to be the mainstream in Singapore in the near future and it is not practical to phase it out. On the other hand, they did point out that the future of BIPV is still promising if more R&D efforts could be made on BIPV technology since the current energy conversion rate and price of BIPV is not attractive.

4.5 Consensus Statements

Although three distinct perspectives were found in the study, some statements showed consistency among the 3 perspective groups. For example, all three perspectives concurred that the first step before promoting BIPV in Singapore is to conduct detailed potential analysis on how much solar energy could be harvest in order to understand market capacity better. Then the key players in the building industry, especially the public sectors, could step in to drive the market. For example, recent approach has been taken towards positive-energy low-rise, zero-energy medium-rise and super low-energy high rise buildings by Singapore Building and Construction Authority (BCA) that will drive integration of photovoltaics into the building facades [12].

5. Conclusions

This study sought to develop a holistic and systemic approach to assess and address different BIPV stakeholders’ perspectives in the context of Singapore. By introducing the Q methodology, the various key stakeholders’ opinion and viewpoints were collected and analysed quantitatively. Based on the results, three groups of perspectives were derived, and consensus understandings were identified, which could provide a reference for policymaking processes relating to BIPV. In the future, the pool of participants could be enlarged and more in-depth factor
analyses could be attempted in order to generate more accurate and comprehensive results for interpretation purpose.

6. Acknowledgements

This study is supported by the project “Holistic life-cycle cost analysis and real-world test-bedding for Building Integrating Photovoltaics (BIPV) facades”, funded by Ministry of National Development – Sino-Singapore Tianjin Eco-City Administrative Committee Green Building – Related Research and Development Programme.

References

Evaluation of Green Production in Building Materials Enterprises


Abstract: With the development of global economy, the problem of resource shortages, energy crisis, environmental pollution and other issues have become increasingly prominent. Building materials industry is one of the industries with high energy consumption and pollution. It is necessary to implement green production among building materials industries in order to develop recycling economy and achieve energy conservation. This paper puts forward the green production evaluation index of building materials enterprises including 4 first-level indexes and 11 two-level indexes. Then a new method based on the whiten weight function and AHP is proposed to evaluate the green production in building materials enterprises. Finally, the evaluation model is used to evaluate the green production of the environmental protection project of Three Gorges Reservoir area in Chongqing Conch Cement Company. The evaluation results are in accordance with the environmental monitoring results of Chongqing environmental monitoring center. Then some policy suggestions are put forward.

Keywords: Building materials enterprises; Evaluation index system; Gray cluster analysis; AHP

1*Chen, Y.
Corresponding author, School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China
E-mail: 14787807784@163.com

2 Zhou, Y.J.
School of Construction Management & Real Estate, Chongqing University, China

3 Wei, X.X.
School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China

3 Shen, L.Y.
School of Construction Management & Real Estate, Chongqing University, China
International Research Centre for Sustainable Built Environment, Chongqing University, China
1*Guo, Z.H
Corresponding author, Department of Chongqing University, China
E-mail:20160313012@cqu.edu.cn

2 Long, Z.J
School of Chongqing University, China

3 Shen, L.Y
School of Chongqing University, China
1. Introduction

With the development of economic globalization and the Reform and Opening, China has becoming the world's second largest economy. The total value of China’s GDP increases from 367.87 billion yuan in 1978 to 68902.2 billion yuan in 2015. The mode of economic growth with high energy consumption has also made it’s environmental pollution increasingly serious. The energy consumption of the building materials industry in 2014 was 370 million tons of standard coal, accounting for 9% of the country’s total energy consumption [1]. The annual resource consumption of building materials industry is still huge, in which mineral resources consumption in the building materials industry exceeds 7 billion tons. According to statistics, in 2012, 3.5 billion tons of new water is consumed in steel production, accounting for 3% of the national industrial new water consumption [2]. The coal based energy structure is another reason that leads building materials industry to one of the industries with serious environmental pollution. According to statistics, in 2014 the building materials industry discharges 2.79 million tons of smoke (powder) dust, 2.01 million tons of sulfur dioxide, nitrogen oxides 2.69 million tons, accounting for 16%, 10% and 13% of the total emissions of pollutants respectively in the country [3].

Building materials industry is the key industry in saving energy, reducing emission, developing circular economy and improving the environment.

Green production is an enterprise value based on environmental protection during its production process, which lies in taking the green production technology, equipment and environmental protection measures actively to make full use of resources and energy to reduce the emission of pollutants. Green production is a sustainable mode of production that takes resource utilization and environmental impact into account, and achieves the highest efficiency and the least environmental impact of the products in the whole life cycle, which is generally divided into four stages as green inputs, green craft, green output, green recycling processing.

Green production refers to the enterprise minimize its production activities’ damage on environment to the greatest extent. Rolf Fiire (1996) [4] established environmental impact assessment index system from three aspects as the raw materials and energy input, product output and pollutants, and put forward the environmental performance index calculated by using data envelopment analysis to show the features of the enterprise environment. L.F.Li and S.S Zhang (2003) [5] established the index system of environmental impact assessment from four aspects: raw material input, production process, product and environment. K.Hu (2006) [6] built the environmental impact assessment of beer enterprises evaluation index system from the resource consumption, energy consumption, waste discharge, waste recycling four aspects, the index value and green production standard value comparison to obtain the enterprise Green production evaluation rating. M. Margallol (2014) [7] studied the environmental evaluation of power plant production with a waste power plant in Spain as its example, and constructed the evaluation index system from five aspects: waste consumption, energy consumption, water consumption and air burden and land burden. Based on the analysis above and relevant literature, the author found that domestic and foreign enterprises have many different angles on the green production evaluation and environmental impact assessment of enterprises. It is necessary to establish a set of evaluation index system and evaluation model of green production of building materials enterprises with universal applicability.
2. Methodology

2.1 Establishment of index system

2.1.1 Establishment principle of index system

The following principles should be taken into account in the design of the system of evaluation of the green behavior of building materials enterprises: (1) scientific principle (2) principle of completeness (3) principle of hierarchy (4) principle of independence (5) principle of comparability Principle of sex

2.1.2 Identifying the assessing indicators

In this study, the research object is the green production of building materials enterprises. In the previous introduction, the green production includes four parts: green input, green process, green output, green recycling. The impact of Green technology on the environment is manifested through the green output which includes two aspects of resource energy consumption and various outputs. And green recycling treatment, including pollutant treatment and waste recovery, is based on the fact that the process of enterprise reproduction is carried out directly in the sewage outfall and waste emissions, the effect of the generation and treatment of contaminants and wastes is reflected in the emission of waste (waste water, waste gas, waste residue). And thus the four parts of green production can be adjusted to obtain the evaluation system of the four first-level indicators, namely Green inputs, green output, green emissions, green recycling. And then according to the meaning of the primary indicators and reference to domestic and foreign relevant evaluation index literature, the author decomposes the four first-level indicators into secondary indicators which can directly reflect the impact of production activities on the natural ecological environment, obtaining the evaluation of the evaluation system.

<table>
<thead>
<tr>
<th>Tab. 1 Green Production Evaluation Index System</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 1 indicators</strong></td>
</tr>
<tr>
<td><strong>Green input B1</strong></td>
</tr>
<tr>
<td>Recycling rate of raw material waste B11</td>
</tr>
<tr>
<td>Energy cleanliness B12</td>
</tr>
<tr>
<td>Purchasing localization rate B13</td>
</tr>
<tr>
<td><strong>Green emissions B2</strong></td>
</tr>
<tr>
<td>Unit building materials waste water discharge B21</td>
</tr>
<tr>
<td>Unit building materials exhaust emissions B22</td>
</tr>
<tr>
<td>Unit building materials solid waste emissions B23</td>
</tr>
<tr>
<td><strong>Level 2 indicators</strong></td>
</tr>
<tr>
<td>Total amount of solid waste contained in raw materials/Total raw material</td>
</tr>
<tr>
<td>Total converted energy standard for clean energy/Energy standard conversion total value</td>
</tr>
<tr>
<td>Local Purchased Resources/Total resource purchases</td>
</tr>
<tr>
<td>Total consumption of water resources/Annual total output</td>
</tr>
<tr>
<td>Total exhaust gas emissions per year/Total building materials output</td>
</tr>
<tr>
<td>Total amount of waste residue emission/Total building materials output</td>
</tr>
<tr>
<td><strong>Calculation formula</strong></td>
</tr>
<tr>
<td>B.Z.Bai(2001)[8], X.P.Liu(2009)[9], D.Hu(2015)[10]</td>
</tr>
<tr>
<td>L.L.Li(2012)[12]</td>
</tr>
<tr>
<td>Daryl Ritz and Janet Ranganathan (1998)[13], Burgos Jimenez (2001)[12], L.L.Li(2003)[13]</td>
</tr>
<tr>
<td><strong>references</strong></td>
</tr>
</tbody>
</table>
Green output B3

- Energy consumption per unit of building materials B24
- Unit building materials consumption B31
- Water consumption per unit building material B32
- Solid waste recovery rate B41
- Recycling rate of industrial water B42

Green recycling B4

- The total amount of energy consumption / Annual total output
- Total consumption of material resources / Annual total output
- Total water consumption / Annual total output
- The total amount of solid waste recovered / The total amount of solid waste generated years
- Total amount of wastewater recycling / Total amount of waste water

Daryl Ritz and Janet Ranganathan (1998)
Z.H. Wei (2000)
L.L. Li (2003)
Z.H. Wei (2000)
J. Hu (2009)

2.2 A Weight-deciding model based on AHP

2.2.1. Analytic Hierarchy Process

Analytic Hierarchy Process (AHP) is a multi-objective decision-making method. The method is to decompose the evaluation object, quantify the qualitative factor, form the index system with the hierarchical structure. Then some experts are invited to use the two-way comparison method to determine the relative importance of the evaluation index belonging to the same level index in the same dominance relation. Finally the matrix consistency test is carried out and the weight of each evaluation index is reached if the test is passed.

2.2.2 Determining the synthetic weights

(1) Identifying the assessing indicators

According to the evaluation target of green production of building materials enterprises, the hierarchical structure of evaluation index is constructed from four stages of green investment, green output, green emission and green recycling.

(2) Computing the vector of criteria weights

Use 1 to 9 integer and its reciprocal to the value of the degree of difference between the indicators assigned to the scale of the meaning of the table.

<table>
<thead>
<tr>
<th>Scaling</th>
<th>meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Comparison of index I and index J, Equally important</td>
</tr>
<tr>
<td>3</td>
<td>Comparison of index I and index J, Indicator I is moderate importance than indicator J</td>
</tr>
<tr>
<td>5</td>
<td>Comparison of index I and index J, Indicator I is strong importance than indicator J</td>
</tr>
<tr>
<td>7</td>
<td>Comparison of index I and index J, Indicator I is demonstrated importance than indicator J</td>
</tr>
<tr>
<td>9</td>
<td>Comparison of index I and index J, Indicator I is extreme importance than indicator J</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>2, 4, 6, 8 represent the median of 1-3, 3-5, 5-7, 7-9 respectively</td>
</tr>
</tbody>
</table>

If the important ratio between the index I and the index J is $a_{ij}$, then the importance of the index J and the index I The reciprocal ratio is $a_{ji} = 1/a_{ij}$

In this study, a simple method of improvement is used in the design of the questionnaire, and 15 experts in the green evaluation were invited to carry out the questionnaire. According to the questionnaire results written by the experts and the rules, all the information in the various improvements in the questionnaire is transformed into the corresponding judgment matrix.
Computing the matrix of option scores

Calculate the weight of the indicator based on the expert judgment matrix obtained by the conversion. In this paper, we use the power method to calculate the weights, and use the Super Decisions (SD) software to calculate the weights of the indexes at all levels.

Using the arithmetic mean method to synthesize the judgment weight of the expert group. Assume that for a set of indicators, K experts construct judgment matrix, The calculated weights are sorted by vector

\[ W = (w_1, w_2, \ldots, w_3)^T \]

(1)

Then the group of indicators of the expert group to determine the comprehensive weight is

\[ W^* = \frac{1}{k} \sum_{i=1}^{k} w_i, (i = 1, 2, \ldots, k) \]

(2)

Due to the complexity of the objective problem and the diversity of the subjective judgment of experts, inconsistency of expert judgement is frequently occurred. And therefore requires a consistency test. To determine the consistency of the judgment matrix, we need to calculate the maximum eigenvalue and consistency index CI of the judgment matrix A

\[ C.I = (\lambda_{max} - n) / (n - 1) \]

(3)

The ratio of the consistency index CI and the randomness consistency index RI, that is, CR = CI / RI for the matrix consistency of the judge, when CR <0.1, with a satisfactory consistency on the contrary, it is inconsistent; using SD software to calculate the score of 15 experts to determine the weights of the first and two levels of indicators as follows:

| Tab. 3. Building materials enterprise green production evaluation index weight system |
|--------------------------------------|--------|-----------------|--------|
| **Level 1 indicators**               | **weight** | **Level 2 indicators** | **weight** |
| Recycling rate of raw material waste B11 | 0.08   | Energy cleanliness B12 | 0.094  |
| Green input B1                       | 0.235  | Purchasing localization rate B13 | 0.061  |
|                                     |        | Unit building materials wastewater discharge B21 | 0.059  |
| Green emissions B2                   | 0.168  | Unit building materials exhaust emissions B22 | 0.056  |
|                                     |        | Unit building materials solid waste emissions B23 | 0.053  |
|                                     |        | Energy consumption per unit of building materials B24 | 0.085  |
| Green output B3                      | 0.262  | Unit building materials consumption B31 | 0.099  |
|                                     |        | Water consumption per unit building material B32 | 0.078  |
| Green recycling B4                   | 0.335  | Solid waste recovery rate B41 | 0.173  |
|                                     |        | Recycling rate of industrial water B42 | 0.162  |

2.3 Grey evaluation model based on whiten weight function and AHP

2.3.1 Determination of evaluation grey class
For the M evaluation indexes, the range of the evaluation indexes \([a_i, b_j], (j = 1, 2, ..., m)\), is determined according to the evaluation requirements, and the range of the evaluation indexes is divided into S grades. That is, to obtain the gray value of the evaluation index S. According to the relevant national and industry standards, statistical data and literature, the supposed or current scope of the range of such evaluation indicators can be identified. Building materials enterprises green production evaluation index is divided into five categories in this paper.

2.3.2 Establishment of triangle whiten weight function

Firstly, the triangular whiten weight function which corresponds to class 1 and s are changed to whiten weight function of lower measure \(f_j^{1} [-, -, \lambda_j^1, \lambda_j^2]\) and upper measure \(f_j^{s} [\lambda_j^{s-1}, \lambda_j, -, -]\).

Fig.1 Schematic diagram of endpoint mixed whiten weight function

After dividing the grey classes, \(\lambda_j^1, \lambda_j^s\) the turning points of grey 1 and grey S are determined respectively, and \(\lambda_j^2, \lambda_j^3, ..., \lambda_j^{s-1}\) the geometric central point of grey K \((k \in \{2, 3, ..., s - 1, s\})\) is determined. For the gray class 1, the lower limit measure \(f_j^{1} [-, -, \lambda_j^1, \lambda_j^2]\) of the evaluation index is constructed. Let X be an observation of evaluation index j, when \(x \in [a_i, b_j].\) According to the formula (4) to calculate the evaluation index j on the gray class 1 membership \(f_j^{1}(x).\)

\[
f_j^{1}(x) = \begin{cases} 
0, & x \notin [a_i^1, \lambda_j^2] \\
1, & x \in [a_i^1, \lambda_j^2] \\
\frac{\lambda_j^2 - x}{\lambda_j^2 - \lambda_j^1}, & x \in [\lambda_j^1, \lambda_j^2] 
\end{cases}
\]

(4)

For the gray class S, the upper limit measure \(f_j^{s} [\lambda_j^{s-1}, \lambda_j, -, -]\) of the evaluation index is constructed. Let X be an observation of evaluation index j, when \(x \in [\lambda_j^{s-1}, \lambda_j^{s+1}].\) According to the formula to calculate the evaluation index j on the gray class S membership \(f_j^{s}(x).\) For the grey class \(K(k \in \{2, 3, ..., s - 1, s\})\), the triangular whiten weight function of the evaluation index is
constructed. In the Cartesian coordinate axis, connect the point \( (\lambda_j^{k-1}, 1) \) and the center point of the grey k-1 \( (\lambda_j^{k-1}, 0) \) at the same time. Then obtain the triangular white weight function of index J about grey K. Let \( f_j^k \) be an observation of evaluation index j, when \( K=2,3,\cdots,s-1 \). According to the formula (5) to calculate the evaluation index j on the gray k \((k \in \{2,3,\cdots,s-1, s\})\) membership \( f_j^k(x) \).

\[
f_j^k(x) = \begin{cases} 
0, & x \not\in [\lambda_j^{k-1}, \lambda_j^{k+1}] \\
\frac{x - \lambda_j^{k-1}}{\lambda_j^k - \lambda_j^{k-1}}, & x \in [\lambda_j^{k-1}, \lambda_j^k] \\
\frac{\lambda_j^{k+1} - x}{\lambda_j^{k+1} - \lambda_j^k}, & x \in [\lambda_j^k, \lambda_j^{k+1}]
\end{cases}
\] (5)

2.3.3 Determining the weight of each evaluation index

According to the previous AHP model to determine the weight of the evaluation index.

2.3.4 Calculation of comprehensive evaluation

The actual value of the 11 indexes of the object to be evaluated is substituted into the corresponding whitening weight function, and the membership value of each index on 5 grey categories can be calculated respectively \( f_j^k(x) \), \( j = 1, 2, \ldots, 12 \) \((k = 1, 2, \ldots, 5)\). Combined with the comprehensive weights of the 11 evaluation indexes, the comprehensive clustering coefficients of the 5 grey categories are calculated according to the formula (6).

\[
\sigma^k = \sum_{j=1}^{12} f_j^k(x_j)w_j
\] (6)

the total ranking weight \( W_j \) of J is the evaluation index

Finally, according to the formula to determine the evaluation object belongs to the gray class \( k^* \).

\[
a^{k^*} = \max \left\{ \delta^k \right\} \quad (1 \leq K \geq 5)
\] (7)

3 Application and analysis

Chongqing Conch Cement Plant is a regional branch of AnHui Conch Cement Company. According to the data collected, the relevant evaluation data of A project are calculated and analyzed: the annual production of cement clinker is 1.782 million tons, the annual output of 2.376 million tons of cement is produced; the consumption of raw materials is 2.0499 million tons, of which 384,600 tons of domestic waste is all of which are from Chongqing. The energy consumption is mainly 1840,400 tons of bituminous coal and 227.92 million kw • h of electricity, of which 74.84 million kw • h comes from the remaining heat power generation system of the project itself. The bituminous coal comes from JiangXi Province and the transportation distance is more than 500km. Production of water consumption of 462,000 tons, all to achieve the recycling, no waste water discharge; with an annual output of 1333.4 tons of other pollutants; The production of solid waste generated by all is converted to raw materials or transaction processing, achieving zero emissions of industrial solid waste.

3.1 Calculation of comprehensive weight
The numerical results of each evaluation index are shown in the table.

### Tab.4 The calculation results of each index value

<table>
<thead>
<tr>
<th>Index</th>
<th>Index value</th>
<th>Calculation formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling rate of raw material waste B11</td>
<td>18.36%</td>
<td>38.46/209.49</td>
</tr>
<tr>
<td>Energy cleanliness B12</td>
<td>33.6%</td>
<td>7484×0.1229/(22796.2×0.1229+18.04×1.0995)</td>
</tr>
<tr>
<td>Purchasing localization rate B13</td>
<td>92.01%</td>
<td>209.49/(209.49+18.04)</td>
</tr>
<tr>
<td>Unit building materials waste water discharge B21</td>
<td>95.27%</td>
<td>(22796.2×0.1229+18.04×1000×1.0995)/237.6</td>
</tr>
<tr>
<td>Unit building materials exhaust emissions B22</td>
<td>0.88%</td>
<td>209.49/237.6</td>
</tr>
<tr>
<td>Unit building materials solid waste emissions B23</td>
<td>0.19%</td>
<td>46.24/237.6</td>
</tr>
<tr>
<td>Energy consumption per unit of building materials B24</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>Unit building materials consumption B31</td>
<td>0.56%</td>
<td>1333.4×1000/237.6×10000</td>
</tr>
<tr>
<td>Water consumption per unit building material B32</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>Solid waste recovery rate B41</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Recycling rate of industrial water B42</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

### 3.2 Clustering algorithm based on the whiten weight function

Then put the gray membership degree and the index weight of each index in the table into the formula to obtain the comprehensive clustering coefficient of the five objects.

### Tab.5 The membership degree of the 5 grey classes corresponding to each index

<table>
<thead>
<tr>
<th>Index</th>
<th>Gray class1</th>
<th>Gray class2</th>
<th>Gray class3</th>
<th>Gray class4</th>
<th>Gray class5</th>
<th>Index weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.93</td>
<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td>C2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.094</td>
</tr>
<tr>
<td>C3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.061</td>
</tr>
<tr>
<td>C4</td>
<td>0</td>
<td>0.04</td>
<td>0.96</td>
<td>0</td>
<td>0</td>
<td>0.059</td>
</tr>
<tr>
<td>C5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0.056</td>
</tr>
<tr>
<td>C6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.26</td>
<td>0.74</td>
<td>0.053</td>
</tr>
<tr>
<td>C7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.085</td>
</tr>
<tr>
<td>C8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.13</td>
<td>0.87</td>
<td>0.099</td>
</tr>
<tr>
<td>C9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.078</td>
</tr>
<tr>
<td>C10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.173</td>
</tr>
<tr>
<td>C11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.162</td>
</tr>
</tbody>
</table>

### Tab.6 The clustering coefficient of the evaluation object corresponding to 5 grey classes

<table>
<thead>
<tr>
<th>Gray class</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>The maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synthetic</td>
<td>0.0024</td>
<td>0.0566</td>
<td>0.1571</td>
<td>0.7839</td>
<td>0.7839</td>
<td></td>
</tr>
</tbody>
</table>

According to the data of the table, the maximum value of the comprehensive clustering coefficient is 0.7839, which belongs to the fifth gray class, so that it can be judged that the evaluation object A belongs to the fifth grade.

### 3.3 Evaluation results and discussion

According to building production enterprise green production evaluation system, A project belongs to the fifth level that has high green production enterprises and advanced level in the industry. According to the result measured by the Environmental Monitoring Center of Chongqing Municipality, there are few pollutants in the project, and the project production has little effect on the local air, surface water and soil. The evaluation results coincide with this monitoring
conclusion, and the acquisition of each index is relatively easy, so this study also has applicability. At the same time, it can be seen from the hierarchical membership of each index, the project still need to be improved in three aspects as raw material utilization waste rate, unit cement material consumption and energy consumption.

4 Conclusion

In this paper a new method is proposed to evaluate the green production of building materials enterprises based on the whiten weight function and AHP, and an evaluation index system is put forward including 4 first-level indexes and 11 two-level indexes. And the correctness and practicability of the evaluation model are verified by the example of Three Gorges Reservoir area in Chongqing Conch Cement Company. The research on green production evaluation system of building materials enterprises enriches the theoretical research on green production evaluation and has practical significance. Through the evaluation of model on green production of building materials enterprises and dividing green production grade level, we can drive out or improve the enterprises with excessive production energy consumption and excessive pollution, promote the entire building materials industry to implement green production to save energy and reduce emission.

Acknowledges

This research work is supported by the National Planning Office of Philosophy and Social Science Foundation of China under Grant Nos. “15AZD025” and “15BJY038”.

References

economy  [D]. Tianjin University of Technology, 2009.
Theme Based Comparison of International Green Neighbourhood Assessment Systems

Karimipour, H¹, Tam, V. W. Y²*, Le, K.³

Abstract
Neighbourhood is widely recognized as a fundamental building block of a city, and a good starting point to create a truly sustainable community. Green neighbourhood is also broadly defined as being moderately dense, mixed-use, designed at a human scale, active and public transportation oriented and literally “green”. A green neighbourhood assessment system is a tool that evaluates sustainability performance of a given neighbourhood against a set of criteria. This paper evaluates 20 main international green neighbourhood assessment systems in according to their sustainability coverage and features. Sustainability aspects used in this paper include transportation, infrastructure, ecology, resources, energy, community, location, economy and building. The results of this study show that community, resources and ecology are the three major sustainability aspects that applied in 18, 17 and 16 out of 20 assessment systems respectively. However, after assessing the sustainability aspects by their weightings in the assessment systems, the differences among them are reduced and their rate of importance in all the assessment systems became closer. Ecology, energy, transportation, resources and economy receive the highest weightings after affecting by their weightings and incredibly community dropped to the very low importance of weightings. Future research can be conducted on the implementation of several green neighbourhood assessment systems on actual projects and compare their capability in measuring the rate of greening.

Keywords: Green neighbourhood; assessment systems; sustainability.

¹ Karimipour, H.
Western Sydney University, School of Computing, Engineering and Mathematics, Locked Bag 1797, Penrith, NSW 2751, Australia.

² Tam, V. W. Y.
Western Sydney University, School of Computing, Engineering and Mathematics, Locked Bag 1797, Penrith, NSW 2751, Australia.
College of Civil Engineering, Shenzhen University, China
*Corresponding author, Tel: 61-02-4736-0105; Fax: 61-02-4736-0833;
Email: vivianwytam@gmail.com

³ Western Sydney University, School of Computing, Engineering and Mathematics, Locked Bag 1797, Penrith, NSW 2751, Australia.
1. Introduction

Environmental issues are undoubtedly the challenge of the 21st century. Climate change and rising energy prices bring the need to seriously reconsider the way cities should be designed [1]. In fact, cities now find themselves at the very centre of the “Green revolution” as one of the main components for achieving sustainability [2, 3]. As a result, several urban initiatives are being put forward to make cities greener, healthier and eco-friendlier than before. One of these is the concept of green neighbourhood, which is probably the very first attempt to connect urban sustainability principles with micro-level community planning.

Along with this new concept of green neighbourhood, a need for assessing the city neighbourhood and regions according to their rate of greening has become an issue for consideration [4]. Recent literature has discussed the importance of assessing sustainable development at the communities and neighbourhood scale [5, 6].

The important point is that a framework is required to evaluate the objectives and strategies of sustainable community development. This need has resulted in the emergence and spread of certification systems. A green neighbourhood assessment system is a tool that evaluates sustainability performance of a given neighbourhood against a set of criteria [7]. According to the classification by Sharifi and Murayama [7] there are two types of neighbourhood sustainability assessment frameworks: the decision making tools embedded into neighbourhood scale planning (e.g. HQE2R, Ecocity, EcoDistricts, SPeAR, One Planet(Communities) Living, EcoDistricts Performance and Assessment Toolkit), and the systems created from existing third-party building assessment systems. (e.g. LEED (ND), BREEAM (Communities), CASBEE (For Urban Development), QSAS, Green Star (Communities), Green Mark for Districts, and Green Neighbourhood Index [8]. The full terminologies of the 20 green neighbourhood assessment systems are shown in Table 1.

Therefore, the aim of this review is:
- An in-depth review of both groups of Green Neighbourhood systems including: decision making tools and the third-party assessment systems.
- Preparing a complete list of all the green neighbourhood assessment system around the world
- Compare all the green neighbourhood assessment system in the world based on their sustainability coverage and their special features along with their regions and their emergence time.

This study can provide insight for urban planners and stakeholders of sustainable urban development for their further sustainable urban development.

2. Research methodologies

Numerous methodological approaches have been taken to assess sustainability. All these approaches use indicators as tools for generating usable and relevant information from the increasingly expanding volume of data that they acquire from a wide array of sources [9]. A plethora of research exists that focuses on the principles and indicators of sustainable urban and neighbourhood development [10].

Green neighbourhood’s assessment systems are compared based on sustainability framework which is reflected in their indicators and main topics. This type of comparison is useful for those who are interested in the concept of sustainable cities and its specifications or for comparing the systems based on the sustainable development approaches.
A set of viewpoints for comparison are defined based on the existing literature [7, 11-13] to synthesise currently available data in existing studies and supplement with new findings. Then the selected neighbourhood sustainability assessment frameworks are evaluated according to the defined viewpoints. The steps of the evaluation methodology and the connections between the phases are presented in Figure 1.

Figure 1: The five simplified steps of the novel analysis of the international green neighbourhood assessment systems

2.1. Theme based comparison (sustainability coverage)

The frameworks of each system tend to be organised in different ways making analysis of scope difficult, indeed Haapio and Viitaniemi [13] noted that the complexity of framework and their different structures may provide them impossible for comparison. For instance, LEED (ND) has 5 themes, while Green Star (Communities) has 6 themes and SPeAR has 23. Likewise, criteria within themes are described and grouped differently [14].

Therefore, for the theme based comparison and on the basis of the categories mentioned above, the relation of the systems main topics to the different aspects of sustainability becomes evident. For this purpose, a pairwise comparison is conducted among these 9 aspects of sustainability framework.

Weighted comparison is also conducted to show not only the number of each sustainability aspect into the green neighbourhood assessment systems, but also their weightings as an indicator for their importance. The scoring methods which is used for weight based comparison is straightforward as shown in Error! Reference source not found.

\[
Weighted\ Theme\% = \frac{\sum \text{Weight of theme in any system which have it}}{\sum \text{All the weights in all systems}} \times 100
\]

Equation 1: The formula for theme based comparison
This theme-based comparison would help the industry and governmental bodies in the green
neighbourhood sector when they intend to adapt themselves with one of the sustainability systems
around the world. In particular, they can have a quick look at the different global green
neighbourhood systems around the world, their main criteria, fees, assessment period, countries and
period of validity and then select the best match based on their specific case.

3. Results and discussions
3.1. Theme based comparison

The results of the comparison are summarised in Figure 2. It should be mentioned that because
of the plenty of systems to be comprised it could not mention the main topics of each assessment
system individually and otherwise we summarized them according to the 9 sustainability topics.

The results of this comparison show that some assessment systems considered additional
sustainability aspects compared to other systems. Although this result could previously have
been predicted, whereas some of these systems are designed for only temporary or specific use
such as green infrastructure project which is only prepared for the green infrastructure project
botanic gardens of South Australia covers only 4 sustainability aspects; however, GSAS as a
system expects to be applicable for all green neighbourhood systems around the Qatar or even
Middle East regions, covers 7 sustainability aspects.

Another major different among systems, is not only the number of sustainability aspects they
considered, but also the weighting they allocated to each of their main topics or sustainability
aspects. With this viewpoint, some of the systems may consider some aspects more important than
the others which show their priorities. The results of this weighting comparison are shown in
Figure 4. It can be suggested that the differences among sustainability aspects in Figure 3 are faded
after affecting by their weightings. It is shown that economy, resources, transportation, energy and
ecology acquire the highest importance. Economy alternatively, moves to the highest importance of
sustainability aspects after affecting by its weighting. It means that the average of systems collects
its higher weighting of importance.

4. Conclusion

This paper compared 20 international green neighbourhood assessment systems. It was
found that:
- Community, resources and ecology are the top three sustainability aspects that applied in
  18, 17 and 16 systems out of 20.
- These three aspects earning almost the same importance in the systems around the world.
- With a review to these three selected sustainability aspects, it can be extracted that they
  are arranged so can cover the three pillars of sustainability. Community goes back to
  society, resources can indirectly go back to economy and ecology refers to environment.
- However, after affecting the sustainability themes by their weighting in each system, the
differences among the aspects were removed and they became closer to each other. At this
new set, ecology, energy, transportation, resources and economy received the highest rate
and incredibly community dropped to the lower rate of importance.
- In this new set of significance, the environment pillar of sustainable development can
easily be highlighted.
<table>
<thead>
<tr>
<th>Row</th>
<th>Abbreviation</th>
<th>Full terminology</th>
<th>First version year</th>
<th>Last version year</th>
<th>Number of indices</th>
<th>Country</th>
<th>Institution</th>
<th>Verification fee (USD)</th>
<th>Assessment period (month)</th>
<th>Number of certificate/project</th>
<th>Link to the website</th>
<th>Period of validity of certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>STAR (community rating system)</td>
<td>Sustainability Tool for Assessing and Rating communities</td>
<td>2012</td>
<td>2015</td>
<td>48</td>
<td>United States</td>
<td>Star Communities non-profit organization</td>
<td>1500-7500</td>
<td>2</td>
<td>50</td>
<td><a href="http://www.starcommunities.org/rating-system/">http://www.starcommunities.org/rating-system/</a></td>
<td>3 years</td>
</tr>
<tr>
<td>Row</td>
<td>Abbreviation</td>
<td>Full terminology</td>
<td>First version year</td>
<td>Last version year</td>
<td>Number of indices</td>
<td>Country</td>
<td>Institution</td>
<td>Verification fee (USD)</td>
<td>Assessment period (month)</td>
<td>Number of certificate/project</td>
<td>Link to the website</td>
<td>Period of validity of certification</td>
</tr>
<tr>
<td>-----</td>
<td>--------------</td>
<td>-----------------</td>
<td>--------------------</td>
<td>-------------------</td>
<td>------------------</td>
<td>---------</td>
<td>-------------</td>
<td>------------------------</td>
<td>--------------------------</td>
<td>----------------------------</td>
<td>----------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>10</td>
<td>Green Townships (IGBC)</td>
<td>Indian Green Building Council</td>
<td>2010</td>
<td>2015</td>
<td>26</td>
<td>India</td>
<td>Indian Green Building Council</td>
<td>1450-3450</td>
<td>-</td>
<td>-</td>
<td><a href="https://igbc.in/igbc/">https://igbc.in/igbc/</a></td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>QSAS/ GSAS</td>
<td>Qatar/Global Sustainability Assessment System</td>
<td>2010</td>
<td>2015</td>
<td>39</td>
<td>Qatar</td>
<td>Gulf Organization for Research and Development</td>
<td>700-1400 reg fee+ $0.05/m2+ $550 Appeal fee</td>
<td>-</td>
<td>-</td>
<td><a href="http://www.gord.qa/gord-trust">http://www.gord.qa/gord-trust</a></td>
<td>1 year</td>
</tr>
<tr>
<td>14</td>
<td>EcoDistricts (Performance and Assessment Toolkit)</td>
<td>-</td>
<td>2011</td>
<td>2016</td>
<td>95</td>
<td>United States</td>
<td>Portland Sustainability Institute</td>
<td>-</td>
<td>12</td>
<td>16</td>
<td><a href="https://ecodistricts.org/">https://ecodistricts.org/</a></td>
<td>Progress Report every 2 years</td>
</tr>
<tr>
<td>15</td>
<td>Green Infrastructure (project)</td>
<td>-</td>
<td>2012</td>
<td>2014</td>
<td>35</td>
<td>Australia</td>
<td>Department of Environment, Water and Natural Resources</td>
<td>-</td>
<td>-</td>
<td>1 project</td>
<td><a href="http://gievidencebase.botanicgardens.sa.gov.au/">http://gievidencebase.botanicgardens.sa.gov.au/</a></td>
<td>-</td>
</tr>
<tr>
<td>16</td>
<td>EcoCity</td>
<td>-</td>
<td>2005</td>
<td>2012</td>
<td>41</td>
<td>Europe</td>
<td>European Commission, DG Research</td>
<td>-</td>
<td>-</td>
<td>3 communities</td>
<td><a href="http://www.ecocity-project.eu/">http://www.ecocity-project.eu/</a></td>
<td>-</td>
</tr>
<tr>
<td>17</td>
<td>HQE2R</td>
<td>High Quality Environment and Economy in Regeneration</td>
<td>2004</td>
<td>2004</td>
<td>51</td>
<td>Europe</td>
<td>European Commission (France)</td>
<td>-</td>
<td>-</td>
<td>The Project took about 40 months</td>
<td><a href="http://www.suden.org/en/european-projects/the-hqe2r-project/">http://www.suden.org/en/european-projects/the-hqe2r-project/</a></td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>EarthCraft Communities</td>
<td>-</td>
<td>2005</td>
<td>2014</td>
<td>74</td>
<td>United States</td>
<td>EarthCraft, Greater Atlanta Home Builders Association, Southface</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td><a href="http://www.earthcraft.org/builders/programs/earthcraft-communities/">http://www.earthcraft.org/builders/programs/earthcraft-communities/</a></td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>SPEAR</td>
<td>Sustainable Project Appraisal Routine</td>
<td>2000</td>
<td>2012</td>
<td>15</td>
<td>United Kingdom</td>
<td>ARUP</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td><a href="http://www.arup.com/">http://www.arup.com/</a></td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 2: The sustainability coverage of 20 main green neighbourhood systems around the world

<table>
<thead>
<tr>
<th>Building</th>
<th>Economy</th>
<th>Location</th>
<th>Community</th>
<th>Energy</th>
<th>Resources</th>
<th>Ecology</th>
<th>Infrastructure</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEED</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DGNB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASBEE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BREEAM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Star</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Envirodevelopment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>One Planet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BCA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IGBC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GSAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighbourhood Sustainability Framework</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EcoDistricts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Infrastructure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EcoCity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HQE2R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EarthCraft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GCAP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPeAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3: Sustainability aspects of the green neighbourhood assessment systems
Figure 4: The weighted counts of the sustainability aspects for the green neighbourhood assessment systems

5. Acknowledgement

The authors wish to acknowledge the financial support from the Australian Research Council (ARC) Discovery Project under grant number DP150101015.

6. References

BIM- and IoT-based Framework for Building Energy Consumption and Indoor Human Comfort Management

Chen, W.W.¹, Chen, K.Y.², Cheng, J.C.P. ³*

Abstract: Energy consumption for buildings has grown significantly, which attracts increasing attention in the architecture, engineering, construction and operation (AECO) industry. Building information modeling (BIM) and Internet of Things (IoT) technologies have currently been used in the AECO industry to reduce energy consumption and to enhance human comfort in buildings. However, BIM models only show the results of energy simulation in the design stage, and do not provide real-world energy consumption data in the operations and maintenance (O&M) period. Meanwhile, information from IoT sensor network is often displayed in 2D graphs or excel files, making it difficult for end-users to clearly understand the energy consumption performance and level of human comfort. To improve visualization of building energy analysis and human comfort management, this study applies IoT technology to gather data from sensor networks and to visualize them in BIM models through API. Two plug-ins of BIM models were developed to dynamically adjust HVAC system and lighting system based on the actual level of human comfort, which is convenient for facility management staff to control energy consumption as well as viewing the 3D BIM model. The framework facilitates the balance of the status of building energy consumption and indoor human comfort.

Keywords: Building information modeling; Energy consumption performance; Human comfort; Internet of things

¹ Chen, W.W.
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong

² CHEN, K.Y.
Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong

³* Cheng, J.C.P.
Corresponding author, Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong
E-mail: cejcheng@ust.hk
1 Introduction

According to De Boeck et al. [1], the global energy consumption reached 11 billion tons of carbon emission in 2012. In developing countries, the energy consumption from buildings has grown from 24% of the total energy consumption to 40% [2]. As a result, there is a global trend for promoting green buildings in the architecture, engineering, construction and operation (AECO) industry. In addition to implementing specifications for standardizing green buildings, people can also use building information modeling (BIM) technology to perform energy analysis during the design stage of a building life cycle. For example, energy analysis software like Ecotect, Autodesk Vasari, and Bentley AECOsim Energy Simulator use BIM for predicting energy consumption of buildings at the design stage. However, with regards to energy efficiency, once the buildings are in the operations and maintenance (O&M) period, they experience unexpected impact factors, including complex usage of the electrical equipment or space, uncertain occupancy behavior, and human comfort.

Not only is energy efficiency an important part for facility management (FM) in the O&M period, but also indoor human comfort is an essential part for occupants in a building. For example, Horr et al. [3] studied the relationship between building operations and the productivity of occupants, and concluded that the better indoor environment it is, the higher productivity the occupants have. Green building standards, such as the Leadership in Energy and Environmental Design (LEED) standard [4], indicate that the indoor environment quality (IEQ) or indoor human comfort is a key factor to evaluate sustainability of a building. Besides, the international WELL building institute promotes the WELL building standard [5], which is a leading tool for advancing health and well-being in buildings globally to improve health and human experience through design. Therefore, FM staff currently faces the problem to keep a building energy-efficient as well as to provide a comfort environment for occupants in the O&M period.

To solve this problem, Internet of Things (IoT) and BIM technologies can be applied to collect and visualize the environmental data. Firstly, BIM is a shared digital representation of physical and functional characteristics of a facility founded on open standards for interoperability [6]. BIM can be used to predict the energy performance by creating models of existing buildings, proposing alternatives, analyzing and modeling improvements [7]. In addition, IEQ is usually calculated based on environmental data, which can be gathered from a variety of sensors, such as temperature sensor and humidity sensor. IoT has object-oriented functionality, and each object or device can be interconnected to form a network through the use of Information and Communications Technology concepts and wireless transmission technology [8]. The installation of monitoring systems and sensing devices can help to manage lighting and air conditioning systems in buildings and control energy consumption.

Therefore, based on the above research literature, this study proposes a framework to automatically adjust energy consumption of a building as well as considering the level of human comfort based on BIM and IoT technologies. The framework can collect the required sensor data, environmental impact factors, and energy consumption data of individual items of mechanical and electrical equipment, and visualize the energy efficiency data and environmental information in BIM models. This study helps building occupants and FM staff to better understand comfort status of the indoor environment that they live in, and can serve as a reference for adjusting the usage of HVAC and lighting equipment.

2 The Proposed Framework

The objective of this study is to provide a better human comfort environment while minimize energy consumption. Based on BIM and IoT technologies, a prototype framework is proposed to achieve human comfort analysis and energy consumption monitoring. The key points in developing the content of prototype system involve a number of processes to read data from sensors and connect to digital data control (DDC) controller board. Therefore, the proposed framework includes processes for collecting indoor environmental data and monitoring operation condition of equipment to find balanced solutions. The framework allows users to directly interact with their building and improve human comfort, as shown in Figure 1.

This framework contains three layers – (1) physical layer, (2) information layer, and (3) application layer. The physical layer consists of the physical building, IoT sensor network, and occupants. It provides the accurate information from the physical world. In the information layer, the geometry information from physical building will be used for BIM models, while environmental
data (such as temperature, humidity and CO₂ data) and occupant sensor data are gathered from the IoT sensor network. The third kind of information, the suggestions of occupants, is obtained from questionnaire. In the integration model stage, sensor data is integrated in BIM model through API and finally stored in a SQL database. In the application layer, the various sensor data are visualized in a 3D BIM model, and data statistics of sensor information are also illustrated in 4D BIM model for facility condition monitoring. In the analysis part, one plug-in is developed for energy consumption data visualization, while another one is developed for automatically calculating the level of human comfort and timely showing the result in BIM model. In the process, sensor data are constantly obtained and the level of human comfort is calculated according to the updated sensor data. The process is a real-time feedback cycle for managing energy consumption and human comfort.

Figure 1. The proposed framework of BIM- and IoT-based energy consumption and human comfort management

3 Design and Implementation of the Proposed Framework

3.1 Indoor human comfort index

The indoor environmental conditions that potentially influence human comfort in the building environment are (1) thermal comfort, (2) indoor air quality (IAQ), (3) visual effect, and (4) acoustic aspects, etc. [9-12].

Thermal comfort, ranked by building occupants, is of greater importance compared with visual and acoustic comfort and good air quality [12]. In this context, standards such as ASHRAE Standard 55[13] and ISO Standard 7730 [14] are used to obtain appropriate thermal conditions in the buildings. ASHREA standard 55 defines the thermal comfort as a state of mind which expresses satisfaction with the thermal environment. Main factors are air temperature (°C), relative humidity (%), mean radiant temperature (°C), air velocity (m/s), metabolic rates (met), and clothing insulation (clo). In modern city life, IAQ has a significant impact on human health and comfort. IAQ includes several parameters, namely, room temperature, relative humidity, air movement, Carbon Dioxide (CO₂), Carbon Monoxide (CO), Respirable Suspended Particulates (PM₁₀), Nitrogen Dioxide (NO₂), Ozone (O₃), etc.

Visual comfort is defined as “a subjective condition of visual well-being induced by the visual environment”[15]. Although the definition implies that there is a psychological dimension of comfort, a number of physical properties of the visual environment are defined and used to evaluate its quality in an objective way. Visual conditions are characterized by such parameters as luminance distribution, illuminance and its uniformity, glare, color of light, color rendering, flicker rate and amount of daylight [15]. In this study, the most common function of light sensor is to control indoor brightness as need. We can make it darker in daytime for energy saving and lighter in night for better sight. Navai and Veitch [16] defined acoustic comfort as “a state of contentment with acoustic conditions”. However, the term acoustic comfort is not commonly used and providing a good
acoustic environment is mainly associated with preventing the occurrence of discomfort (annoyance). The acoustic environment is influenced by such physical room properties as sound insulation, absorption and reverberation time [17]. The sound sensor is able to measure noise levels in decibels (dB) at frequencies around 3-6 kHz where the human ear is most sensitive.

According to the above literature review and some studies of occupants’ satisfaction [3,9,12], indoor temperature, relative humanity, air velocity, CO concentration, CO₂ concentration, lighting control, sound level are essential to evaluate the level of human comfort. Therefore, the human comfort indices and criteria to be studied in this paper are concluded in Table 1.

Table 1. The calculation index and criteria of human comfort management [18]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
<th>Unit of measure</th>
<th>Excellent</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor temperature</td>
<td>From sensors</td>
<td>°C</td>
<td>20 to &lt; 25.5</td>
<td>&lt;25.5</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>%</td>
<td>40 to &lt; 70</td>
<td>&lt;70</td>
<td></td>
</tr>
<tr>
<td>Air velocity</td>
<td>m/s</td>
<td>&lt; 0.2</td>
<td>&lt;0.3</td>
<td></td>
</tr>
<tr>
<td>CO concentration</td>
<td>ppmv</td>
<td>&lt;1.7</td>
<td>&lt;8.7</td>
<td></td>
</tr>
<tr>
<td>CO₂ concentration</td>
<td>ppmv</td>
<td>&lt;800</td>
<td>&lt;1000</td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>Xi</td>
<td>&lt;500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound level</td>
<td>dB</td>
<td>&lt;50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupancy</td>
<td>number of people</td>
<td>/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space area</td>
<td>From BIM models</td>
<td>m³/</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2 IoT sensor network for data collection

According to the human comfort indices in Table 1, the corresponding sensors are used to detect the value of each parameter. This section aims to provide insights about smart control and optimized building energy management by detailed data acquisition and modeling.

The BACnet (Building Automation and Control Networks) protocol, a data communication protocol between pieces of equipment, is used to get sensor-derived operation data from IoT sensor network in real time [19]. In order to gather the sensor data from the indoor building environment and critical equipment, the sensor network was established. The prototype of sensor network is shown in Figure 2. After data acquisition, the signal was decoded in DDC controller to get these condition parameters and external environmental parameters. The types of operations information collected from the sensor and DDC controller system include operation logics, facilities conditions, and live data streams from deployed sensors, set points and control parameters, alarms and events, and trend logs. In this study, we focus on set-point data and sensor-derived performance data to indicate the status of equipment and facilities and analyze the level of human comfort of each room in a building. There are six object types for modeling various types of sensor-derived operation data such as temperature, humidity, and ON/OFF status: Analog Input (AI), Analog Output (AO), Analog Value (AV), Binary Input (BI), Binary Output (BO), and Binary Value (BV), as shown in Figure 2. By checking set points and sensor-driven performance data to see if the equipment responds accordingly, they can make correct decisions of what should be done to fix the problem.
This combination of performance data with geometry model could enhance readability and comprehensibility of information, especially for FM staff who do not have any background knowledge of the particular piece of equipment.

3.3 Integration of building information modeling and IoT sensor network

A crucial concept of the BIM process is to provide interoperability between two or more platforms for exchanging information and facilitating collaboration between stakeholders [20]. One of the various applications of BIM is to monitor energy consumption. However, BIM models cannot evaluate indoor human comfort or IEQ directly. Therefore, the integration of BIM and IoT sensor network is indispensable to achieve the objective.

The challenge of combining BIM and IoT is integrating sensors into BIM models to show sensor data and analysis results. The key is correctly mapping built-in Revit parameters and the relative IFC objects. Each sensor modelled in Revit belongs to the IfcDistributionControlElement class. To specify the behavior of the object, IfcExportType and IfcExportAs parameters have been set. IfcExportType, a parameter that defines the predefined type of the IFC entity, has been set to IfcSensorType, which models the common information shared within types of sensors as the representations of shape or the composition of elements. For example, IfcSensorType.TemperatureSensor is an IFC entity of type IfcDistributionControlElement with the IfcExportType property set to IfcSensorType, and the IfcExportAs property set to TemperatureSensor in IFC4 edition. In this way, sensor related information can be stored in the BIM model. An updating of these sensor values, using data collected on the field, allows visualizing and analyzing them in suitable plug-in with embodied algorithm.

In addition, because the current standard of BIM (i.e., IFC2x4) does not include all the required properties and relationships related to the O&M phase. Examples of such properties are: operational statuses (e.g., broken or inactive), downtime information, and failure classes. Therefore, the data schema of sensor is created for data representation, as shown in Figure 3. It presents the basic information of sensor, such as name, location, GlobalID, description and No. of sensors, which will be represented in BIM model.

3.4 Energy consumption

The energy analysis process is performed to monitor the efficiency of the building behavior in dealing with energy usage rates and carbon emissions. The value of energy consumption due to different factors such as lighting, air conditioning, hot water and other factors. Simulation was carried out on the building by changing the internal systems to improve the energy usage and decrease the carbon emission. L. Pérez-Lombard et al. [21] indicates that the 70%–85% energy consumption in office building by end user is from HVAC and lighting. Therefore, this paper only considered the energy consumption of HVAC system and lighting system in buildings.

Some researcher have studied on the calculation methods of building energy consumption [22,23]. M. Kavgic et al. [22] studied the bottom up approaches for energy consumption, including approaches based on baselines, statistical models and hybrid models. Swan and Ugursal [23] studied a review of the bottom up and top down modeling techniques of energy consumption. The statistical approach is suitable for this paper, and the HVAC system is monitored to get the operation condition for energy analysis.
4 Illustrative Example

In order to verify the feasibility of the framework, the new sport center of the Hong Kong University of Science and Technology is selected as the illustrative example, and the BIM model of new sport center was created using Autodesk Revit. The IoT sensor network was established to collect sensor data. In this example, four indices (temperature, humidity, CO and CO2) were selected to calculate the level of human comfort in IAQ aspect, and the corresponding evaluation criteria are shown in Figure 4 according to the human comfort standard in Hong Kong [18]. In addition, HVAC system is monitored using IoT sensor network to control the energy consumption and operation status. In total, there are 4 types of sensors to monitor human comfort, including sensors of (1) indoor temperature, (2) relative humidity, (3) CO, (4) CO2, and 3 types of sensors for energy consumption analysis, namely, sensors of (1) temperature, (2) pressure and (3) flowrate.

![Figure 4. Selected criteria for evaluating human comfort in buildings](image)

BIM model and sensor data are the inputs in the information layer, as shown in Figure 1. The next step is integrating BIM model and sensor data for data visualization and analysis. In this example, two plug-ins were developed for data visualization and analysis of energy consumption and human comfort.

One plug-in was developed using Autodesk Revit API to show the real time sensor data in BIM model through BACnet and monitoring the energy consumption, as shown in Figure 5. In the application process of the proposed framework (Figure 1), BACnet protocol was applied to connect the sensor network and BIM models, so that sensor data, Analog data (AI, AO and AV) and Binary

![Figure 5. The condition monitoring and operation status of HVAC system](image)
data (BO, BI and BV) can be gathered and displayed. In addition, the proposed sensor data schema was used to represent the sensor and to correctly map sensor parameters into the relative IFC sensor types in BIM model. Therefore, this plug-in has four functions: 1) obtain sensor data (temperature, pressure, and flow rate of HAVC system) and visualize them in the user interface. The real-time data, average value, maximum value, minimum value, historical value can also be retrieved. 2) Control the operation status of HVAC system, such as turn on or turn off. 3) Monitor the condition of HVAC system and visualizing the data trend to find the abnormal signal. Once any abnormal event happens, the FM staff can fix the problem immediately. 4) Provide the information of operating period of each HVAC system for the energy consumption analysis.

The other plug-in was designed to automatically analyze and control the indoor environment condition according to the level of human comfort, as shown in Figure 6. The FM staff can select one room tag in BIM models to active the plug-in. The real-time value of each aspect in IAQ is shown in the user interface, and the result of IAQ is automatically calculated and displayed, which is user-friendly for FM staff to control the indoor environment condition.

The combination of these two plug-ins can promote integration management of human comfort and energy consumption. It is convenient for FM staff to dynamically control HVAC system to improve human comfort. The illustrative example indicates the proposed framework is feasible and useful.

Figure 6. User interface of indoor human comfort management in BIM model

5 Conclusions

There is an increasing interest in real-time monitoring of environmental data to reduce energy consumption and to provide comfortable building environment. The research proposed a framework for operating buildings to control the energy consumption and improve the level of indoor human comfort based on BIM and IoT technologies. In this proposed framework, facility managers can track the operations status of HVAC system and lighting system, and record the data of temperature, humidity, and IAQ through the real-time information from sensors. The sensor data, the energy consumption trend, and the level of human comfort can be visualized in 4D BIM model. In addition, the application of BIM- and IoT- based framework provides a communication between occupants and indoor environment. In the future, the energy consumption data will be used to predict the future energy efficiency, while human comfort data will be analyzed as the benchmark, which provides the operation suggestions for facility managers.

Acknowledgement

The authors would like to thank for the partial support in this research that was provided by the Innovation and Technology Fund (ITP/047/15LP).
References


Absenteeism due to Manual Handling Job Demands in Australian Construction Industry

Rahman, A.1*, Ekambaram, P.2, Kulkarni, A.

Abstract: Missing work as of absenteeism caused by musculoskeletal disorder related illness from manual handling have been focused for a long time in many different academic disciplines. This study presented relationships between lifting/ lowering related manual handling job demand and absenteeism for musculoskeletal disorder. A quantitative study was undertaken. This study has been conducted on 107 bricklayers working in construction industries. Information related to their job demand and absenteeism for musculoskeletal problem/ disorder from lifting/ lowering related manual handling task measured with structured questionnaire using the self-report/ psychophysical approach. The relationship between the predictor and predicting variables is strong (R = .719, p<.001). Lifting/ lowering related manual handling job demand has significant influences on musculoskeletal disorder related absenteeism (F = 27.521, p<.05). According to the observed Relationship, lifting/ lowering related manual handling task demand can be design/ redesign to reduce absenteeism in the workplace.

Keywords: Absenteeism, Lifting/ Lowering, Bricklayers, Construction.

1* Rahman, A. Corresponding author, School of Engineering, Faculty of Science, Engineering & Technology, Swinburne University of Technology, Australia E-mail: azizurrahman@swin.edu.au

2 Ekambaram, P. School of Engineering, Faculty of Science, Engineering & Technology, Swinburne University of Technology, Australia E-mail: pekambaram@swin.edu.au

3 Kulkarni, A. School of Engineering, Faculty of Science, Engineering & Technology, Swinburne University of Technology, Australia E-mail: ambarishkulkarni@swin.edu.au
1 Introduction

Absenteeism is a major problem in industries globally in term of productivity in the workplace. Construction workers are major group seeking absenteeism. Construction trade workers, bricklayers include supervisor bricklayer, bricklayer, and apprentice bricklayer [1]. According to Work cover Queensland (2016) some of the tasks of bricklayers are (i) manually loading and unloading bricks and blocks on pallets (the brick, stone and building blocks vary in size and weight; typical concrete blocks is used include 140mm X 400mm X 200mm weighing 11kg each and 200mm X 400mm X 200mm weighing 13-15kg each) (ii) cement and mortar mixes are handled in 20kg quantities/bags between ground and chest height (iii) laying bricks individually by hand in the mortar, laying approximately 150 blocks per day (therefore can manually handle up to 2-3 tones of blocks) [2]. Bricklayer’s absenteeism claims were for musculoskeletal & connective tissue related which accounted for just 13% of all absenteeism claims in this industry. Pains, sprains and strains are the common forms of MH related MSD [3, 4]. These claims arise out of repetitive movements over time [5]. Between 34% and 66% of time, bricklayers perform lifting of objects up to 15kg between ground and chest height. 5% to 33% of time Bricklayer lift object weigh up to 25kg between ground and waist height [2]. Awkward work posture and lifting bricks weighing 5kg to 24kg at 100 times per hour is a risk factor for back problems/ disorder in this occupation [6], which leads to them to take sick leave from the workplace.

This study explored relationships between bricklayers lifting/ lowering related manual handling job demand and absenteeism.

2 Materials and Methods

2.1 Data collection procedure

In line with the National Statement on Ethical Conduct in Human Research in Australia, this research been approved by Swinburne’s Human Research Ethics Committee (approval number SHR Project 2015/138). A structured questionnaire survey was conducted for data collection. Respondents attended questionnaire based on their perception. The method has been used in this research is well established as self-evaluation of manual handling tasks [7]. This method has also been using in online questionnaire survey for example, Borg scale have been used as methods in research for recent few years [8-11]. The target respondents were workers engaged in lifting and lowering related MH tasks in their daily works. Informed consent was noted by the survey participation. This paper presents only bricklayer’s absenteeism from lifting/ lowering related MH works in the construction industry.

2.2 Data summary

After cleaning the data set, the total number of valid responses from Australia based bricklayers occupation were 107. Table 1 shows the age and experience details of the participants in this cross sectional research. Participants are full of different age (years) groups (i.e. less than 40, 40 to 59, 60 and above), experienced in this area of work (years) (i.e. Less than or equal to 10, 11 to 20, More than 20, and gender (i.e. male, female). To confirm the variation of result between the groups of respondents some hypotheses were checked and found that all null hypotheses are rejected that means there is no differences of distribution of absenteeism between groups.
Table 1. Summary of participants

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-category</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age (years)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less than 40</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>40 to 59</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>60 and above</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Experience (years)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less than or equal to 10</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>11 to 20</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>More than 20</td>
<td>20</td>
</tr>
</tbody>
</table>

2.3 Predictor variables

2.3.1 Loads and frequency of lifting/ lowering

Handling loads is risk factors for musculoskeletal problems/disorders [12, 13]. Handling varying size of the loads has relationship with musculoskeletal disorder related absenteeism, e.g. 5 kg, 10 kg once a day at least, and 20 kg [14-16]. Under optimal condition 20 to 23 kg is the maximum weight a person can carry [17-19]. International standard has mentioned safe lifting weight, which is 15 kg for both young and elderly people. Code of Practice for manual handling has advised to keep the weight within 16-20 kg or below this range. To categories weight, different ranges of load have been mentioned in the literature: (i) 0–2 kg, 2–10 kg, >10 kg [20] (ii) 1–5 kg, 6–15 kg, 16–45 kg, >45 kg [21] (iii) <10 kg, 10–20 kg, >20 kg [22]. Light and heavy loads have been defined differently in the literature [23]. Hence, it is uncertain which level of physical strength is required to keep the level of exposure minimal during lifting/ lowering tasks [24-26]. A study has found that frequent lifting is a risk for MSDs [13, 27]. According to the international standard, lifting frequency is a risk factor for WMSDs of the back, shoulder, wrist, neck, and knee [28]. The standard recommended that the maximum lifting frequency is 15 lifts per minutes for 7 kg weight lifting. Respondents were asked to mention their physical discomfort from the load and frequency of lifting/ lowering tasks.

2.3.2 Absenteeism

There are many different way to ask respondents about absenteeism such as, one relies on the respondent estimating how many hours he/she worked over a four-week period [29, 30], other asked score in terms of hours lost per month [30, 31]. In this research, respondents were asked to mention level of impact from musculoskeletal disorder related absenteeism on performance of manual handing tasks.

3 Results and discussions

Physical discomfort from <5 kg of lifting/ lowering tasks (standardized β = .095): This value (in table 2) indicates that as physical discomfort from less than 5 kg of lifting/ lowering tasks increase by one standard deviation (.810), musculoskeletal disorder related absenteeism increase by .095standard deviations. The standard deviation for musculoskeletal disorder related absenteeism is .929 and so this constitutes a change of .088(.929 x .095). Therefore, for every .810 kg more weight in lifting/ lowering task can increase .088 (in a scale from 1 to 5) musculoskeletal
disorder related impact of absenteeism, when other predictor variables remained constant.

Physical discomfort from 6 to 10 kg of lifting/ lowering tasks (standardized $\beta = .596$): This value (in table 2) indicates that as physical discomfort from 6 to 10 kg of lifting/ lowering tasks increase by one standard deviation (.814), musculoskeletal disorder related absenteeism increase by .596 standard deviations. The standard deviation for musculoskeletal disorder related absenteeism is .929 and so this constitutes a change of .55 (.929 x .596). Therefore, for every .814 kg more weight in lifting/ lowering task can increase .55 (in a scale from 1 to 5) musculoskeletal disorder related impact of absenteeism, when other predictor variables remained constant.

Physical discomfort from 11 to 15 kg of lifting/ lowering tasks (standardized $\beta = .228$): This value (in table 2) indicates that as physical discomfort from less than 11 to 15 kg of lifting/ lowering tasks increase by one standard deviation (.799), musculoskeletal disorder related absenteeism increase by .228 standard deviations. The standard deviation for musculoskeletal disorder related absenteeism is .929 and so this constitutes a change of .21 (.929 x .228). Therefore, for every .799 kg more weight in lifting/ lowering task can increase .21 (in a scale from 1 to 5) musculoskeletal disorder related impact on absenteeism, when other predictor variables remained constant.

Physical discomfort from 16 to 20 kg of lifting/ lowering tasks (standardized $\beta = .049$): This value (in table 2) indicates that as physical discomfort from 16 to 20 kg of lifting/ lowering tasks increase by one standard deviation (.993), musculoskeletal disorder related absenteeism increase by .049 standard deviations. The standard deviation for musculoskeletal disorder related absenteeism is .929 and so this constitutes a change of .05 (.929 x .049). Therefore, for every .993 kg more weight in lifting/ lowering task can increase .05 (in a scale from 1 to 5) musculoskeletal disorder related impact on absenteeism, when other predictor variables remained constant.

Table 2. Coefficient of the variables

<table>
<thead>
<tr>
<th></th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
<th>95.0% Confidence Interval for B</th>
<th>Correlations</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td></td>
<td></td>
<td>Lower Bound</td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>(Constant)</td>
<td>.107</td>
<td>.915</td>
<td>- .574</td>
<td>.640</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.095</td>
<td>- .773</td>
<td>.441</td>
<td>- .389</td>
<td>.171</td>
<td>.544</td>
</tr>
<tr>
<td>2</td>
<td>.596</td>
<td>5.283</td>
<td>.000</td>
<td>.425</td>
<td>.936</td>
<td>.697</td>
</tr>
<tr>
<td>3</td>
<td>.228</td>
<td>1.992</td>
<td>.049</td>
<td>.001</td>
<td>.530</td>
<td>.560</td>
</tr>
<tr>
<td>4</td>
<td>.049</td>
<td>.497</td>
<td>.620</td>
<td>- .145</td>
<td>.242</td>
<td>.516</td>
</tr>
</tbody>
</table>

1 for physical discomfort from <5 kg of lifting/ lowering tasks, 2 for physical discomfort from 6 to 10 kg of lifting/ lowering tasks, 3 for physical discomfort from 11 to 15 kg of lifting/ lowering tasks, 4 for physical discomfort from 16 to 20 kg of lifting/ lowering tasks

Table 3 shows ANOVA test. The test result meaning that predictor variables have significant relationship with predicting variables and have significant ability to predict absenteeism from lifting/ lowering related manual handling tasks.
Table 3. ANOVA test

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>47.295</td>
<td>4</td>
<td>11.824</td>
<td>27.251</td>
<td>.000</td>
</tr>
<tr>
<td>Residual</td>
<td>44.256</td>
<td>102</td>
<td>.434</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>91.551</td>
<td>106</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In Table 4, the R (.719) value shows simple relationship between predictor and predicting variables, the relationship is strong.

Table 4. Correlational Model fitting summary

<table>
<thead>
<tr>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>Change Statistics</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>.719*</td>
<td>.517</td>
<td>.498</td>
<td>.659</td>
<td>R Square Change</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>F Change</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>df1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>df2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sig. F Change</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Durbin-Watson</td>
<td></td>
</tr>
</tbody>
</table>

R-square value indicates that 51.7% of the variability of absenteeism from lifting/ lowering related manual handling task can be explained by the physical discomfort from weight lifting from lifting/ lowering related manual handling task. Absenteeism is predicted by four predicting variables in this model the F change in table 4 represents the difference made by adding predictor variables to the model. In table 4, Durbin-Watson statistics has indicates that the assumption certainly been met, that is predicting of absenteeism for musculoskeletal disorder from lifting/ lowering task can be done by the load of the task.

4 conclusions

It has been found that lifting/ lowering related manual handling tasks load variables are strongly related to musculoskeletal disorder related absenteeism. In this study only task load been included, work posture, work environment can be considered as predictor variables. As predictor variables, physical ability can also be considered in further study. The proposed multiple regression model and relationship between bricklayers job demand and affect absenteeism systematically integrates developing useful decision support frameworks/ systems e.g. workload arrangements in MH tasks.

This relationship model can also serve occupational health and safety practitioners to design the lifting/ lowering related manual handling work for rehabilitation and return to the work programme. Moreover, manipulation in the lifting/ lowering related manual handling work demand by the industrial engineers might take palace using this model considering the interrelationships of the model components. Not only do the business managers can use it to take their decision with respect to lifting/ lowering related manual handling work restrictions but supervisors will also take it to plan work load in activities.
References


China’s AEC Industry and BIM Adoption Challenges: Understanding the Influence of Positive and Negative Mindsets

Qi, C.A.1*, Liu, L.2 and Jupp, J.3

Abstract: For the past decade, the challenges to the effective and efficient utilization of building information modelling (BIM) processes, technologies and standards across the architectural engineering construction (AEC) industry have been well-documented, with most still remaining significant and pertinent today. The lack of understanding of the role of industry culture and mind-sets within existing studies of the barriers to BIM adoption is a deficiency in furthering an understanding of successful applications of BIM. This research study examines the issues related to the main implementation challenges of BIM within the Chinese AEC industry, with a particular focus on industry perceptions. The methodology for this paper utilizes an online survey and statistical analysis. The results show that China’s adoption of BIM is foremost affected by two areas; the first being the attitudes of key stakeholders and secondly the related obstacles of project development. The result of this simple study aims to contribute towards extending academic and industry discussions surrounding the influence that industry culture and mind-sets have on BIM adoption.

Keywords: BIM Adoption; China; AEC industry; Barriers; Mindsets.

1 Introduction

BIM has been applied in developed countries for decades, and it has brought a variety of benefits to the AEC industry[4]. Compared to developed countries, China’s AEC industry’s levels of BIM adoption are comparatively low across all sectors of industry, and the uptake of more advanced forms of BIM and model uses in China is also arguably relatively slower[5].

The purpose of this article is to bring further clarity to the interdependent process-based obstacles to BIM adoption. Based on a literature review and an online survey, the findings of the research show that the Chinese AEC industry shares common obstacles as identified in studies of other countries. The paper focuses on the results from the online survey of 140 valid responses from Chinese industry professionals; highlighting industry perception and mindset as a key factor, which is responsible for hindering the application of BIM on both private and public projects. On the basis of the survey analysis, obstacles linked to this factor are identified as being related during BIM

---

1* Qi, C.A.
Corresponding author, School of Civil Engineering, The University of Sydney, Australia
E-mail: chqi7701@uni.sydney.edu.au

2 Liu, L.
School of Civil Engineering, The University of Sydney, Australia

3 Jupp, J.
School of the Built Environment, The University of Technology Sydney, Australia
implementation stages.

The structure of this paper is as follows: Section 2 presents a literature review. It describes the development status of BIM in China. In Section 3, the research methodology is presented together with the details of the survey questions and data collected process (using a Construct Measurement approach[10]). Section 4 describes the data analysis process (using SPSS software), including the use of reliability factor analysis, bivariate analysis, correlations analysis, and linear regression analysis. This section presents a discussion of our analysis, where the main challenges to BIM implementation for the Chinese AEC industry are summarized. Section 5 concludes the paper and discusses the limitations of the research study.

2 Background

The implications of BIM adoption across multidisciplinary project teams are vast. Where BIM is mandated contractually, all disciplines can be affected – whether directly engaged in its use or indirectly due to model-based collaboration or object-based workflows[3]. As in other countries, the adoption of BIM in China has implications not only for its impact existing work practices and the development of new digital and social network exchanges but also for the skills demand created.

2.1 China’s AEC Industry in Context

In May 2011, China’s Ministry of Housing issued policy document titled the “2011 ~ 2015 Construction of Information Technology Development Program.” The document signaled an official ‘push ahead’ with regard to the use of BIM[15]. In January 2012, the Ministry of Housing announced commenced the development of the Chinese BIM standard. This Standard contains a unified approach building information model, including model delivery, management and storage plans, building classification schemas[5]. In July 2017 the “unified standards for the application of building information modelling was officially released[16]. With increasing government leadership, AEC enterprises have steadily increased the use of BIM, especially large and medium-sized projects. Whilst large to medium-sized design firms can be seen to have developed some good levels of BIM expertise with dedicated BIM teams, construction contractors are seemingly less mature, having started out on the adoption journey slightly later. However, many large construction enterprises have increased their levels of BIM maturity and capability reporting some successful implementation cases[7]. As is the case in most countries, the use of BIM to deliver as-built information models and digital assets for the operation and maintenance phase is still in the exploratory stage[6]. At the same time, a small number of Chinese universities have to developed BIM related courses to promote the implementation of BIM in China. For example: Tsinghua University, Tongji University, and Shanghai Jiao Tong University have all developed programs[16].

2.2 Related Research

In 2012, Pan & Zhao[11] conducted a survey to identify the main barriers of BIM in China’s AEC industry. Four factors determined to be significant included: 1) legal issues, 2) cost issues, 3) perception issues, and 4) skills shortages. In 2016, Cao at el.[1] classified BIM implementation motivations into four categories: 1) image motives, 2) reactive motives, 3) project-based economic motives, and 4) cross-project economic motives[11]. The results of stratified regression show that the growth of economic motives does not necessarily require a better social image. But that the
motivation of AEC stakeholders to implement BIM is related to the organization’s ownership type and project characteristics\cite{11}. In 2017, Sun et al.\cite{12} conducted a review of related literature and identified a range of factors were seen to limit the application of BIM in industry. The most frequently cited issues were management related (64%), technology (62%), personnel (62%), legal (46%), and cost related (33%)\cite{12}. 

Whilst it is beyond the scope of the paper to provide an extensive review of related literature on BIM adoption in China. What these studies show is that the barriers to BIM include most if not all of the same barriers identified in developed countries (i.e., legal, cost, skills shortage, organizational, technical, and personnel issues). However, their analyses lack descriptions of the logical relationships between the questions. Whilst Cao et al.\cite{11} provides a critical analysis of existing literature there is no raw data captured nor statistics analysis undertaken. Further, these and other related studies do not have a logical relationship between factors relating to stakeholder perception and the effects of non-analytical factors. Therefore, this article focuses on AEC stakeholder perception and the relationship between positive and negative mind-sets and associated factors on impact of BIM implementation in China.

3 Research Design

3.1 Data Collection

The Survey is divided into three main parts. Basic information survey, Investigation of influencing factors of BIM and perception survey of BIM application in China. The survey started with basic information survey. In this section, the following topics were included to measure the gender, age, educational background, and work experience and work nature of the respondents. The remaining questions of this first section were then used to gauge the extent of BIM adoption and the development obstacles which are set for ordinal questions.

According to the literature review, the specific questions set for measuring the factors focused on five areas, and a five-point Likert scale was used to assess\cite{13}. Thus the second section of the survey was designed to address the following challenges related to: (i) Legal issues, (ii) Cost issues, (iii) Skills shortages (iv) Market & Organisational Issues, and (v) Technical issues. Questions related to the ranked importance of factors identified on the application of BIM in China based on the scoring: 1, 2, 3, 4, 5, which correspond to ‘Not Important’, ‘Important’, ‘Neutral’, ‘Important’, and ‘Very Important’, respectively. The third and final part of the survey related to stakeholder perceptions, which included a range of negative and positive issues. These perception or mind-set questions focused on attitudes toward the application and promotion of BIM in China’s AEC industry, and were ranked from 1 to 5 points; with ranking corresponding to 1= ‘Strongly Disagree’, 2 = ‘Disagree’, 3 = ‘Neutral’, 4 = ‘Agree’ and 5 = ‘Strong Agree’. The survey questions are shown in Table 1 section 4.1.

The online survey was created in Wenjuan.com (https://www.wenjuan.com), a Chinese online survey service provider. The survey was implemented in Chinese and the questions and responses translated into English. The approach provided a research solution that was low cost, easy to deploy efficient investigation cycle, comprehensive coverage, and flexibility\cite{14}. Potential respondents were identified through personal networks. The survey was open for one month and was completed a total of 594 times. Of these replies a total of 140 valid questionnaire responses where all questions were answered were utilized in the research analysis. This resulted in an overall response rate of 23%.
The main characteristics of the respondent demographics include the following.

- Live or work in China's major provinces and municipalities.
- Obtained a degree at either the undergraduate 57.14% or master's level 28.57%,
- 2.86% of the total number of respondents were doctoral candidates.
- Distributed across different types of private AEC companies and government departments.
  - Design companies accounted for the largest proportion of total, at approximately 38%.
  - Number of consultants accounted for 23%.
  - Construction firms accounted for 25%.
- Percentage of government departments’ clients and construction project owners were relatively small, at approximately 7%.

The details of these characteristics are illustrated in The Figures 1(a) and 1(b) below. The representation from across geographical, educational backgrounds, and stakeholder roles of respondents conform to the research design.

![Educational Status and Nature of Your Company](image)

**3.2 Construct Measurement and Validation**

In the design of the survey the reliability of the Likert scale to as assessed before completing the range to be used. To validate the reliability of the findings, factor analysis and alpha analysis were used. Data that did not satisfy the reliability requirement was omitted. All items contained in the Component Matrix (see Table 1) calculated to be greater than 0.7, and alpha values greater than or equal to 0.8 are included\[6\]. The results show that only a small number of samples could not be included, resulting in a high reliability of the dataset.

**4 Data Analysis and Findings**

As we can see above, the 140 responses were collected. Construct validity was checked using Cronbach's Alpha method. The analysis process is further explained in this Section.

**4.1 Establishing the SPSS Data Model and Pre-Processing Stage**

The questionnaire survey data from the Census website was download, in Excel format, and imported directly into the SPSS software. The creation and editing of the data files were then able to be used in a spreadsheet-like method. The Data Editor, Viewer and Variable Viewer were used to check and demonstrate actual data values or defined value labels. Regarding Variable view, it provides variable definition details such as defined variable, value labels, data type, measurement level and user-defined missing values\[9\]. The Pearson correlation coefficients, the Rho and Kendall levels of Spearman and Tau-b, and their significance levels were obtained using SPSS. A correlation
measure of a variable or rank. Before calculating the correlation coefficients, the data is filtered to find evidence of outliers (outliers can lead to misleading results) and linear relationships. Pearson correlation coefficient has a linear relationship.

Table 1 Value of Component Matrix and Alpha.

<table>
<thead>
<tr>
<th>ITEMS</th>
<th>Component Matrix</th>
<th>Reliability Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legal Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government efforts to implement BIM is not enough.</td>
<td>0.817</td>
<td>Alpha 0.903</td>
</tr>
<tr>
<td>Government development of large public projects did not mandate the use of BIM.</td>
<td>0.748</td>
<td></td>
</tr>
<tr>
<td>China's lack of uniform laws and regulations to regulate the use of BIM.</td>
<td>0.842</td>
<td></td>
</tr>
<tr>
<td>Nationwide lack of unified laws and regulations, regulate the use of BIM.</td>
<td>0.828</td>
<td></td>
</tr>
<tr>
<td>BIM talent title system is missing.</td>
<td>0.696</td>
<td></td>
</tr>
<tr>
<td>Lack of BIM related software development standards and protection of laws and regulations.</td>
<td>0.803</td>
<td></td>
</tr>
<tr>
<td>No BIM project execution mechanism or intellectual property protection law or related laws.</td>
<td>0.837</td>
<td></td>
</tr>
<tr>
<td><strong>Cost Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIM investment cost is big, but the short-term cost is low.</td>
<td>0.672</td>
<td>Alpha 0.805</td>
</tr>
<tr>
<td>BIM application personnel need long-term training, high cost.</td>
<td>0.818</td>
<td></td>
</tr>
<tr>
<td>Configuration hardware (purchase, upgrade, maintenance) cost is great.</td>
<td>0.877</td>
<td></td>
</tr>
<tr>
<td>Promotion of small, accepted may be small, face operational risks.</td>
<td>0.803</td>
<td></td>
</tr>
<tr>
<td><strong>Skills Shortage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel ideological tradition, the transformation of thinking difficult.</td>
<td>0.827</td>
<td>Alpha 0.885</td>
</tr>
<tr>
<td>The lack of related personnel training in Colleges and Universities.</td>
<td>0.773</td>
<td></td>
</tr>
<tr>
<td>Designers to establish a fixed two thinking, it is difficult to change.</td>
<td>0.850</td>
<td></td>
</tr>
<tr>
<td>Personnel at all stages of construction cannot reach full information exchange.</td>
<td>0.784</td>
<td></td>
</tr>
<tr>
<td>The traditional construction industry personnel status quo, after using BIM, work pressure.</td>
<td>0.762</td>
<td></td>
</tr>
<tr>
<td>Lack of power, so BIM has a strong resistance to the Perception?</td>
<td>0.784</td>
<td></td>
</tr>
<tr>
<td><strong>Market &amp; Organizational Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decrease development of large projects.</td>
<td>0.736</td>
<td>Alpha 0.836</td>
</tr>
<tr>
<td>Lack of customer demand.</td>
<td>0.747</td>
<td></td>
</tr>
<tr>
<td>The management mode of the enterprise is difficult to change.</td>
<td>0.789</td>
<td></td>
</tr>
<tr>
<td>Companies cannot professional and technical personnel and BIM technical personnel.</td>
<td>0.779</td>
<td></td>
</tr>
<tr>
<td>From the owners, design to the construction of the model of information sharing is too low.</td>
<td>0.754</td>
<td></td>
</tr>
<tr>
<td><strong>Technical Issues</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operability and ease of operation of BIM software.</td>
<td>0.846</td>
<td>Alpha 0.868</td>
</tr>
<tr>
<td>The software developed by China is poor in interactivity and lack of connection ports.</td>
<td>0.836</td>
<td></td>
</tr>
<tr>
<td>Industry attaches importance to development of BIM software, but modest results.</td>
<td>0.819</td>
<td></td>
</tr>
<tr>
<td>BIM requires high spec hardware requirements; requirements cannot be reached.</td>
<td>0.756</td>
<td></td>
</tr>
<tr>
<td><strong>Negative Perception</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If all AEC companies to start using BIM technology, would feel significant pressure.</td>
<td>0.911</td>
<td>Alpha 0.868</td>
</tr>
<tr>
<td>Feeling under significant pressure when not working in 2D and to try to use 3D BIM.</td>
<td>0.877</td>
<td></td>
</tr>
<tr>
<td>Level of avoidance in using BIM despite acknowledged benefits.</td>
<td>0.886</td>
<td></td>
</tr>
<tr>
<td><strong>Positive Perception</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once I start applying for BIM technology and work, I'm unlikely to give up using BIM.</td>
<td>0.847</td>
<td>Alpha 0.797</td>
</tr>
<tr>
<td>Aware of BIM technology and believe that will contribute to advancement of BIM.</td>
<td>0.796</td>
<td></td>
</tr>
<tr>
<td>If stuck in application of BIM, will attempt to learn about BIM technology to problem solve.</td>
<td>0.895</td>
<td></td>
</tr>
<tr>
<td><strong>BIM Adoption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding of the degree of BIM.</td>
<td>0.810</td>
<td>Alpha 0.836</td>
</tr>
<tr>
<td>Level of application of your company or unit BIM.</td>
<td>0.877</td>
<td></td>
</tr>
</tbody>
</table>
You are working in the application of the degree of BIM. 0.924

Development Obstacles
High levels of perceived development difficulty in application of BIM. - -

The two variables may be well correlated, but if there are not linear association metric, it may not a statistic suitable when assessing the correlation of Pearson Correlation\(^2\). The analysis results are summarized in the Table 2. An asterisk is used to identify the correlation coefficient with a level of significance of 0.05, and two stars are used to determine the correlation coefficient with a significance level of 0.01. The relationships between all variables are significant.

### Table 2 Value of Correlation

<table>
<thead>
<tr>
<th>Correlations</th>
<th>Legal</th>
<th>Cost</th>
<th>Skills Shortage</th>
<th>Market/Organizational</th>
<th>Technical</th>
<th>Negative Perception</th>
<th>Positive Perception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal issues</td>
<td>Pearson Correlation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>Pearson Correlation</td>
<td>.494**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skills shortage</td>
<td>Pearson Correlation</td>
<td>.602**</td>
<td>.533**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market &amp; Organizational</td>
<td>Pearson Correlation</td>
<td>.627**</td>
<td>.619**</td>
<td>.781**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical</td>
<td>Pearson Correlation</td>
<td>.539**</td>
<td>.600**</td>
<td>.588**</td>
<td>.697**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Negative Perception</td>
<td>Pearson Correlation</td>
<td>.287**</td>
<td>.399**</td>
<td>.443**</td>
<td>.375**</td>
<td>.514**</td>
<td>1</td>
</tr>
<tr>
<td>Positive Perception</td>
<td>Pearson Correlation</td>
<td>.577**</td>
<td>.307**</td>
<td>.493**</td>
<td>.471**</td>
<td>.271**</td>
<td>.241**</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

### 4.2 Findings

In the pre-process of data, and according to the relationship between all factors under consideration by the study, it was identified that the coefficients of the linear equations containing one or more independent variables were statistically significant, which was estimated using linear regression analysis\(^2\). Linear regression analysis best predicts the value of the dependent variable; thus the relationship between the independent and dependent variables were analyzed and those dependent variables that were found to be as significant were utilized in the survey analysis.

It was found that the barriers to BIM adoption in China show a linear relationship between factors related to Negative and Positive Perception and Development Obstacles. It was also found that a linear relationship existed between Development Obstacles and Cost. In addition, Perception and Cost factors were affected by other factors surveyed including legal and market and organizational issues. Further, Cost was also utilized as a dependent variable. A summary of the survey findings are shown in Tables 3 and 4.

### Table 3 Linear Regression

<table>
<thead>
<tr>
<th>Dependent Variable: BIM adoption</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
<th>Adjusted R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>2.388</td>
<td>.308</td>
<td></td>
<td></td>
<td>0.465</td>
</tr>
<tr>
<td>Development obstacles</td>
<td>.448</td>
<td>.047</td>
<td>.587</td>
<td>9.461</td>
<td>.000</td>
</tr>
<tr>
<td>Negative Perception</td>
<td>.168</td>
<td>.052</td>
<td>.208</td>
<td>3.260</td>
<td>.001</td>
</tr>
<tr>
<td>Positive Perception</td>
<td>-.327</td>
<td>.064</td>
<td>-.330</td>
<td>-</td>
<td>.5153</td>
</tr>
</tbody>
</table>

0.465
a. Dependent Variable: BIM Adoption

Table 4 Linear Regression

<table>
<thead>
<tr>
<th>Dependent Variable: Development obstacles</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
<th>Sig.</th>
<th>Adjusted R Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>4.500</td>
<td>0.447</td>
<td>-10.066</td>
<td>.000</td>
<td>0.042</td>
</tr>
<tr>
<td>Cost</td>
<td>-0.287</td>
<td>0.118</td>
<td>-2.446</td>
<td>.016</td>
<td></td>
</tr>
</tbody>
</table>

6 Discussion & Concluding Remarks

The aim of this paper was to add to the discussion of the challenges to BIM adoption and implementation in the Chinese AEC industry. To achieve this goal, a literature review and an online questionnaire survey were used. The results of the literature review provide evidence of the types of BIM adoption challenges in China which have been previously identified. Using an online survey, 140 valid responses were collected and analyzed using factor, alpha, bivariate correlations and linear regression analysis. According to the results of the alpha and linear regression analysis, the findings and relationships between the barriers of BIM adoption can be illustrated in Figure 2. The relationship between the variables and the implementation challenges of BIM in the Chinese AEC industry focus on Development Obstacles and Attitudes / Mindsets to BIM Adoption.

Thus, based on the analysis provided in Tables 3 and 4, together with the main relationships shown in Figure 2, illustrate that BIM Adoption is positively linearly related to ‘Positive Perception’, and that BIM Adoption is negatively linear related with ‘Negative Perception’ and ‘Development Obstacles’ (where the $\beta$ is a coefficient greater than zero smaller than one). Among them, Positive Perception and Negative Perception belong to the Attitude / Mindset that underpins BIM implementation efforts. In other words, BIM implementation levels are first and foremost affected by the three domains of Positive Perception, Negative Perception, and Development Obstacles. Based on the above analysis, it can be seen that Development Obstacles is mainly affected by Cost.

The questionnaire responses represent an appropriate cross-section of Chinese AEC stakeholders, which can help inform rich descriptions. However further research is necessary. To this end, our
preliminary study is informing future research, which is looking at the effects of industry culture and mindsets on BIM implementation, and in particular on the industry’s established set of attitudes and assessing levels of flexible thinking, “can-do” attitudes, and a genuine desire to improve efficiency and effectiveness on AEC services and products in China.

References


A Review of Underused Urban Land Redevelopment in China

Lin, J.\(^1\)*, Ye, Z.J.\(^2\)

**Abstract:** To deepen the reform of land management system and to realize high-quality new urbanization, land use is changing from "developing the incremental" to "revitalizing the stock" gradually in China. Accordingly, underused urban land redevelopment is one of the most important methods to realize the intensive use of urban land. This paper, tries to review the latest progress of underused urban land redevelopment in China through systemic examination, meanwhile, to compare and analyze the policy differences between typical areas including Guangzhou, Shenzhen, Ningbo, Nanjing and Chengdu.

**Keywords:** Underused urban land; Land use; Redevelopment; China.

\(^1\)* Lin, J.
Corresponding author, College of Urban & Environmental Sciences, Peking University, China
E-mail: jlin@urban.pku.edu.cn

\(^2\) Ye, Z.J.
College of Urban & Environmental Sciences, Peking University, China
1 Introduction

Activating the urban stock land and improving the land use efficiency are the basic requirements to develop the land resource management in China. At present, it’s still easy to find unreasonable or inefficient urban land use in China. In another word, the extensive use of land resources in China has not fundamentally changed. For example, Guangdong Province has recorded nearly 313.44 million mu of underused urban land until the end of 2016, accounting for about 10% of the total area of the constructing land in Guangdong; Zhejiang Province has recorded approximately 115 million mu of underused urban land. During the “Twelfth Five-year Plan” period, China developed 3925 million mu of newly-increased constructive land, therefore, to reverse the extensive land use, it decided to cut down 669 million mu of newly-increased constructive land during the “Thirteen Five-year Plan” period.

Currently, China is in a period of comprehensive reform, and underused urban land redevelopment is practically needed[1]. For the advance of the new urbanization and the construction of ecological civilization, China has to abandon the extensive way of development, and to realize the intensive land use[2]. To improve the intensive use of land resources, Decision of the CPC Central Committee on Some Major Issues proposed to improve the land utilization ratio. Similarly, Opinions of the CPC Central Committee and the State Council on Accelerating the Ecological Civilization Construction clearly pointed out persisting in the most stringent intensive land use system and improving urban land use efficiency. Recommendations for the 13th Five-Year Plan for Economic and Social Development further emphasized the relevant requirements and made it clear to promote the redevelopment of underused urban land.

Underused urban land redevelopment is a relatively new research area with Chinese characteristics. However, there are some researchers have studied it from some perspectives. For example, Zhang[3] compared changing modes of governance of urban redevelopment in Beijing, Guangzhou and Shenzhen; Tang[4] introduced the "three old" transformation effects and policy changes, compared the institutional designs and policies between Shenzhen and Foshan; Wu[5] suggested that Chinese megalopolis governors should learn the experience from the cites global cities and create more proper urban regeneration mechanism; Pan[6] reviewed literatures on China’s urban village in four aspects containing definition, developing mechanism, value judgment, renewal measures and so on.

While, until now, little research focus on both all-round and latest progress of underused urban land redevelopment in China. Based on these aspects, this paper, tries to clarify the present situation of underused urban land redevelopment in China through systemic examination. Furthermore, to provide experience for future research and work, the paper compares and analyzes policy differences between typical areas, including Guangzhou, Shenzhen, Ningbo, Nanjing and Chengdu, which all have achieved remarkable results in underused urban land redevelopment.

The review consists of five sections. Section 1 provides the overview and theoretical basis for underused urban land redevelopment in China. Section 2 describes the three-stage process and effectiveness of this work. Section 3 presents the experience of five typical areas from several aspects. Section 4 discusses the findings, and finally, Section 5 presents the conclusion of the paper.

2 Work Review Analysis
2.1 Development processes

Underused urban land redevelopment in China has gone through 10 years which can be separated into three stages.

2.1.1 Before February 2013: Guangdong-first-exploration stage

Foshan, a city in Guangdong Province, issued Decision to Accelerate the Renovation of Old Town Old Plant Old Village and Three Relevant Guidelines in June 2007, and first proposed "three old" transformation (another name of "underused urban land redevelopment") clearly in China. In December 2008, the Ministry of Land and Resources and the government of Guangdong Province launched a joint effort to establish Guangdong into the intensive land use demonstration area, and "three old" transformation became one of the important tasks and policy innovation in this project. Some Opinions on Promoting the "Three Old" Transformation to Promote the Conservation of Intensive Land Use was introduced by the government of Guangdong Province, standing for the formal establishment of "three old" transformation policy system in August 2009.

2.1.2 From February 2013 to November 2016: provincial-pilot-exploration stage

In February 2013, the Ministry of Land and Resources, in conjunction with the experience of the pilot cities in Guangdong Province, handed out Pilot Guidance on the Development of Underused Urban Land Redevelopment, and assigned 10 provinces including Inner Mongolia, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Jiangxi, Hubei, Sichuan and Shanxi to carry out underused urban land redevelopment.

2.1.3 After November 2016: nationwide-promotion stage

November 2016, learning from the experience of the early pilot, especially combining with the new urbanization and the ecological civilization construction background, the Ministry of Land and Resources issued Guidance on Further Development of Underused Urban Land Redevelopment (trial). Then, underused urban land redevelopment stepped into nationwide-promotion stage.

2.2 Effectiveness summary

According to the statistics published by departments and bureaus of Land and Resources nationwide, underused urban land redevelopment has achieved some success over the past decade. For example, Guangdong Province, implemented 9306 "three old" transformation projects up to April 2017, with an area of 57.01 million mu, of which the completion of the transformation project is 5420 with an area of 31.51 million mu. Guangdong Province invested 1104.434 billion yuan, accounting for 6% of the same period fixed-asset investment of the entire province. Undoubtedly, Guangdong Province has achieved considerable benefits in economy, society, ecology and culture. Zhejiang Province, has completed 6430 underused urban land redevelopment projects from 2014 to 2016, with an area of 23.9 million mu. During this period, the average floor area ratio of profit-oriented land, investment intensity, per acre output and tax have increased. For instance, the average floor area of industrial warehouse space has increased from 0.8 to 1.7; the investment intensity has increased from 1 million yuan per mu to 2.53 million yuan per mu; per acre output has increased from 840,000 yuan to 2.72 million yuan; the per acre tax has increased from 12 million to 41 million.

3 Comparative Analysis of Typical Areas

3.1 Cognition of Connotation
As shown in Table 1, underused urban land redevelopment in Guangzhou, initially known as the "three old" transformation, renamed as "urban renewal" (another name of underused urban land redevelopment) in 2015; it has been called "urban renewal" in Shenzhen since 2009; Ningbo, Nanjing and Chengdu name it "underused urban land redevelopment" as the Ministry of Land and Resources does.

On conceptual connotation, definitions are similar but they are focused on disparate points. Guangzhou, on the one hand, stresses that "three old" transformation, shantytowns transformation and transformation of old and dangerous houses should be considered into the work of urban renewal; on the other hand, Guangzhou suggests some flexible types of redevelopment, including remediation, improvement, rebuild, activation, promotion, etc. Shenzhen focuses on the three types of urban renewal, which are comprehensive renovation, functional readjustment and demolition-reconstruction. Ningbo also has listed a variety of underused situation.

Considering different categories, some areas like Guangzhou, the capital city of Guangdong Province, in accordance with "three old" transformation of Guangdong Province, divide underused urban land into old town, old plant and old village; Ningbo further divides it into old factory-and-mine, old town, old village and other-type. Some areas carry out divisions in accordance with the land use classification, for example, Shenzhen has divided underused urban land into old-industrial land, old-commercial land, old-residential land, urban village and old-building land. Similarly, Nanjing has divided underused urban land into underused-industrial land, underused-commercial land, old-city land, old-village land and other-underused land.

Table 1. Connotation of underused urban land readjustment in typical areas

<table>
<thead>
<tr>
<th>Area</th>
<th>Name</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangzhou</td>
<td>&quot;three old&quot; transformation → urban renewal</td>
<td>old town, old plant, old village</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>urban renewal</td>
<td>old-industrial land, old-commercial land, old-residential land, urban village, old-building land</td>
</tr>
<tr>
<td>Ningbo</td>
<td>underused urban land readjustment</td>
<td>old factory-and-mine, old town, old village, other-type</td>
</tr>
<tr>
<td>Nanjing</td>
<td>underused urban land readjustment</td>
<td>underused-industrial land, underused-commercial land, old-city land, old-village land, other-underused land</td>
</tr>
<tr>
<td>Chengdu</td>
<td>underused urban land readjustment</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Preparation of planning

As shown in Figure 1, special plan, annual plan and project plan are carried out in some typical areas. Additionally, to provide the basis for annual plan, Guangzhou innovatively proposes delimiting the urban renewal district and making the planning scheme of the urban renewal district, according to the urban renewal overall planning and urban development strategy. Shenzhen, delimits and plans for key renewal units based on the urban renewal "Thirteen Five-year" Plan.
3.3 Mode of redevelopment

3.3.1 Guangzhou: multi-type and multi-level mode
Guangzhou sets different ways to redevelop old town, old plant and old village respectively. It takes the comprehensive-transformation mode, mainly containing reconstruction of urban renewal projects that have great impact on urban core-functional-areas, in order to improve the city’s functions, enhance the industrial structure and improve the urban landscape. Micro-transformation mode, mainly including remediation and protection, is taken in built-up area in Guangzhou, where it has little effect on the overall pattern of the city, but has contradictions between the status of land use and the surrounding development, low land use efficiency or poor living environment.

3.3.2 Shenzhen: comprehensive renovation & functional readjustment & demolition-reconstruction mode
In Shenzhen, according to the characteristics of projects, the mode of underused urban land is divided into comprehensive renovation, functional readjustment and demolition-reconstruction. The comprehensive renovation project mainly includes improving the fire-fighting facilities, infrastructure and public service facilities, improving the street facade, environmental remediation, existing building energy conservation, etc. But this type of redevelopment does not transform the main structure and the use of building function. The functional readjustment project changes some or all of the building use function, but does not change the owner of land use right and the use period. It retains the original structure of the building. Provided that the owner of land use right is the same as the owner of the building, structure or attachments on the ground, it may be demolished and reconstructed by the right owner.

3.3.3 Ningbo: nine-detailed mode
Ningbo, combines with the actual situation around and explores nine modes of underused urban land, including "shifting from labor-intensive industry to tertiary industry" optimization mode, "transformation and upgrading" platform mode, "reconstruction of urban village" development mode, "underground space " expansion mode, etc. Take one of these modes as an example, the "shifting from labor-intensive industry to tertiary industry" optimization mode is using the original underused-industrial land to develop commercial services and other new formats through the temporary change of land use.

3.3.4 Nanjing: underused-industrial land redevelopment as core mode
The underused urban land redevelopment in Nanjing is carried out with the underused-industrial land redevelopment as the main mode, and the underused-industrial land is defined as six kinds in
accordance with different location and situation. For instance, Jiangning District, located in Nanjing, exists 122 plots of underused-industrial land, with the whole area of 338.95 hectares, accounting for 61.72% of the entire area of underused urban land in Nanjing.

### 3.3.5 Chengdu: old-city reconstruction as core mode

The main effort of underused urban land redevelopment in Chengdu is to reconstruct the old city. Chengdu has implemented a series of old-city reconstruction projects, such as the transformation of the East Main Street, shantytowns transformation, North City transformation, etc. Up to the end of 2016, Chengdu has implemented 39 North City projects and revitalized 2322 acres of the stock land.

### 3.4 Organization and leadership

Guangzhou, Shenzhen, Ningbo and some other places have set up leading groups of underused urban land redevelopment, and have clearly defined the functions at all levels and departments of the leading group. Particularly, Guangzhou and Shenzhen have set up administrative agencies which are named as Urban Renewal Bureau. On the one hand, some governments decentralize the management authority to improve administrative efficiency, such as the government of Guangzhou released 11 administrative authorities to district governments, in order to strengthen the leading role of district governments; similarly, Shenzhen has changed the two-level approval system into one-level approval. On the other hand, governments explore innovative and effective management modes, like Changsha has set up a set of management mechanism in development zone.

### 3.5 Supervision and management

Guangzhou has developed a regulatory system, including financial supervision, basic databases and information system, regular assessment system, exit mechanism, etc. In addition, Guangzhou is also working on monitoring of construction waste and staff working. Shenzhen takes supervision of the standard implementation of qualifications, the establishment of information reporting system, building demolition, the clean-up of redevelopment plan, performance appraisal and some other aspects. Other areas mainly focus on strengthening the target assessment and full-dynamic supervision.

### 4 Discussion

#### 4.1 Connotation need to be unified

Underused urban land is the construction land with low efficiency, low quality, unsafety or unreasonable use. The concept of underused urban land redevelopment is still unclear. The definition and understanding of connotation are relatively different as well. Obviously, the certain object has not been pointed out extremely clear in China. However, it is important to clarify the connotation of underused urban land redevelopment, since it is significant to set specific targets and areas of exploration and innovation, especially during the reform and innovation stage. Without the explicit definition of the specific object or range, it will be hard to reflect effects of the innovative policy.

#### 4.2 Coordination need to be strengthened

In the first place, underused urban land redevelopment needs to be well-planned at first and then to operate. Currently, only Guangdong, Zhejiang and Chongqing have developed the special planning.
while most of other areas have not been prepared. More importantly, on the one hand, redevelopment areas are generally fragmented, and time arrangements are usually casual. On the other hand, it is prone to concern the quantity but ignore the quality in the process of redevelopment. Moreover, the distribution of benefits is a common problem in the process of redevelopment. Especially when the existing land property rights need to be expropriated and registered, some intractable issues might arise, such as how to properly handle the financial funds.

4.3 Incentives need to be refined

Although the existing policies have provided relevant guidance, including encouraging the original owner of state-owned land to redevelopment, guiding the collective construction land in urban to redevelopment, encouraging upgrading industrial transformation and optimizing land use structure, strengthening the construction of public facilities and people's livelihood project, etc., there are still a lot of details are indistinct. Therefore, local governments don’t dare to implement these innovative policies, which is a common problem nationwide.

5 Conclusion

Considering unreasonable and inefficient use of urban construction land, China is gradually changing from "developing the incremental" to "revitalizing the stock". In the last few years, the fundamental purpose of underused urban land redevelopment in China is to promote the transformation of economic development mode, to optimize the layout of urban and rural structure, to deepen the reform of land management system and to realize high-quality new urbanization. Overall, underused urban land redevelopment in China still has a long way to go, though it has achieved some success. It still needs to unify the cognition, to strengthen the coordination and to refine the incentives in the future. In fact, it is difficult to set a unified model in China, and currently there are wide variations in the specifics, with different types and approaches taken. Guangzhou, Shenzhen, Ningbo, Nanjing and Chengdu have their own characteristics of policy innovation. Especially, these typical cities have provided good examples for other areas in China.

References

An Investigation into the Water Infrastructure PPP Failures in Europe: A Case Study Approach

Tariq, Salman* and Zhang, Xueqing.

Abstract: Private participation in the European water sector has existed for decades, however following the UK’s private finance initiative (PFI) success in the 90s, water PPPs gained popularity. The outcome, however, could only be rated as diverse since not all the projects were successful in meeting the expected targets, and in fact quite a few failed. Motivated by these failures, this paper investigates the potential failure reasons for water PPPs in this region, using a case study approach. Seven failed projects from two major players in the European water sector i.e. France and Germany, were selected and thoroughly analyzed. Several potential failure reasons were revealed: a lack of formal project assessment prior to privatization, excessive profit by the private sector, lack of transparency, soaring tariffs, poor technical performance of the private sector, corruption, and high interest debt. Analysis of these case studies also unveiled that, more than one failure reasons frequently led to a water PPP downfall.

Keywords: Water PPPs; Failed PPPs; Europe; Public-private partnerships.

* Tariq, Salman.
Corresponding author, Department of Civil and Environmental Engineering, Hong Kong University of Science and Technology, Hong Kong
E-mail: stariq@connect.ust.hk

2 Zhang, Xueqing.
Department of Civil and Environmental Engineering, Hong Kong University of Science and Technology, Hong Kong
1 Introduction

Water services have been traditionally managed and operated by public authorities, who usually retained ownership of the system as well. However, in the pursuit of overcoming the public sectors’ fiscal deficits, introduction of effective management approaches and catering to the infrastructure needs of rising population, private sector participation was promoted in a number of countries[1]. During the 1990s, there was a significant increase in private sector participation in the water sector in the form of total privatization and public-private partnerships (PPPs), and by the end of 2000, at least 93 countries attempted privatization to deliver their water services[2]. However, due to the fact that PPPs enable governments to invite private participation for finance and development without losing the regulatory control over the services, PPPs became a popular option[1]. Unlike total privatization, which involves selling of public held assets to private owners, PPPs exercise different contractual forms ranging from short term management contracts to long term concession contracts[3].

Following the UK’s private finance initiative (PFI) in the 1990s, PPPs have been introduced in areas where water privatization had not been attempted, such as Scotland and Northern Ireland. Other European Union (EU) countries also began experimenting with PPPs following the signing of Maastricht treaty which put a limit on government finance[4]. By the mid-2000s, most of the EU countries had implemented PPPs, some opting for a trial basis and others more extensively, for instance, in France, by 2004, PPPs accounted for 75% of the water services delivered through private operators[4]. Governments had huge expectations from the water PPPs in terms of efficiency gains, improvement in customer services and cost reductions; projects such as Dwr Cymru Welsh Water (DCWW), UK delivered such promises[5]. However, many projects, on the other hand, failed to meet such expectations, suffered difficulties, and proved to be failures resulting in the loss of resources and consumers trust. In order to identify the reasons behind these failed water PPPs, this article discusses detailed case studies of seven projects in Europe and analyzes the possible reasons that caused the failures in this region. The article is divided into methodology, analysis of the failure reasons and conclusions.

2 Methodology

The first step was the selection of case studies from Europe. For such purpose, documents citing failed water PPPs were explored through the internet by using the search term ‘failed water PPPs in Europe’. Hundred of research papers, reports and online articles on websites containing information on various failed water PPP projects in Europe were found using this approach. These documents were thoroughly examined and piece by piece information such as contract type, various actions of public and private sector etc., was extracted from these sources. Both negative and positive events that occurred during the course of the projects were assembled and arranged in a timeline sequence i.e. events were placed according to their order of occurrence. This arrangement helped in defining the interrelationship between the events thereby depicting the whole failure story. Projects with incomplete stories were rejected i.e. insufficient information was available to deduce any conclusion about how the project failed. Ultimately, seven projects, 5 from France and 2 from Germany, with complete details were selected for further analysis. Only negative events or failure reasons were
considered. Table 1 lists the sample case studies and the type of failures.

Table 1. Failed water PPPs and the type of failures

<table>
<thead>
<tr>
<th>No.</th>
<th>Project Title</th>
<th>Country</th>
<th>Type of Failure</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Bordeaux Water Supply and Sewerage Systems</td>
<td>France</td>
<td>Contract Termination Planned</td>
<td>1991-</td>
</tr>
</tbody>
</table>

3 Analysis of failure cases

The main failure reason found in each case study is listed in table 2.

Table 2. Main failure reasons in Europe

<table>
<thead>
<tr>
<th>No.</th>
<th>Projects</th>
<th>Main failure reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Paris Water Supply and Billing Services, France</td>
<td>Lack of formal project assessment prior to privatization, Excessive profit by the private sector</td>
</tr>
<tr>
<td>2.</td>
<td>Grenoble Water Supply and Sewerage Systems, France</td>
<td>Excessive profit by the private sector, Corruption</td>
</tr>
<tr>
<td>3.</td>
<td>Castres Water Services, France</td>
<td>Lack of transparency, Soaring tariffs</td>
</tr>
<tr>
<td>4.</td>
<td>Varages Water Supply and Wastewater Services, France</td>
<td>Poor technical performance of the private sector</td>
</tr>
<tr>
<td>5.</td>
<td>Bordeaux Water Supply and Sewerage Systems, France</td>
<td>Soaring tariffs, Excessive profit by the private sector</td>
</tr>
<tr>
<td>6.</td>
<td>Potsdam Water Supply and Wastewater Services, Germany</td>
<td>High interest debt</td>
</tr>
<tr>
<td>7.</td>
<td>Berlin Water Works, Germany</td>
<td>Lack of transparency</td>
</tr>
</tbody>
</table>

3.1 Lack of formal project assessment prior to privatization

This failure reason was found in one project in Paris, France. Veolia and Suez were awarded a 25-year concession contract in 1984 to manage Paris water supply systems and billing services. The city council did not undertake any formal assessment prior to privatization. The city subsequently began to lose valuable technical information of the system and had to rely more and more on the private sector for state of network. Suspicions of illegal profit and lack of knowledge of the existing
system made the newly elected Paris Socialist Mayor assert in 2008 that the city wanted to regain complete control over the system. Hence, the contract was not renewed on expiry\[^6\].

### 3.2 Excessive profit

Excessive profit by the private sector than that agreed in the contract was witnessed in three French water PPPs, namely Grenoble Water Supply and Sewerage Systems, Paris Water Supply and Billing Services, and Bordeaux Water Supply and Sewerage Systems. In the Grenoble Water Supply and Sewerage Systems, the private sector was blamed for earning high excessive profit due to dubious accounting practices, overcharging by manipulating the tariff index, and increasing tariffs that were not justified by the level of investment made. The private operator made false claims and their accounts lacked transparency. The Chambre Régionale des Comptes (CRC) criticized the private operator for creating fictitious costs\[^7\][^8][^9][^10]. CRC, six years after the initial contract signing, estimated that the illegal practices and manipulation of the contract clauses by the private sector cost citizens more than FF 1 billion over the project lifespan. Ultimately, the contract was terminated in 2001 on account of corruption, lack of transparency and excessive pricing\[^7\][^8][^9][^10].

In Paris Water Supply and Billing systems, there was speculation of high illegal profit; annual reports of Veolia and Suez stated 6 to 7% profit but sources argued that both earned around 15%. Equally important, over 25 years the tariff increased massively by 265% despite inflation rising only by 70.5%, which also pointed towards high illegal profit. This illegal profit later became one of the reasons behind contract non-renewal\[^6\]. Similarly, in Bordeaux Water Supply and Sewerage Systems, audits and inspections, after court rulings, found many examples of deviousness used in the private operators’ accounts to gain high illegal profit\[^11\].

### 3.3 Lack of transparency

Castres’ water privatization took place, in 1991, to Lyonnaise des Eaux through a 30 year concession contract\[^12\]. Customer bills soared by 60% just one year into the concession contract. This led three citizens to investigate the contract thoroughly and found that company, Lyonnaise des Eaux, was entitled to increase the water rate by 5% per year. In addition to this, customers were also re-paying the ‘entrance fee’ which company paid to access the water system\[^13\]. Citizens filed a case in court which ruled in the favor of citizens. The contract price was considered as way too high. The contract itself was declared illegal; as per a legal requirement, a contract could only be signed after consulting the town council but the former Mayor signed it without any consultation\[^13\].

In Berlin Water Works, Germany, ‘lack of transparency’ and ‘guaranteed high return rate to the private sector through secret contracts’ were the failure reasons which resulted in rapid tariff increases. Consequently, in 2006, the Berliner Water Table (BWT) was created, by citizens, and a popular referendum was launched, in 2007, for disclosure of the secret contracts. In 2011, 666,235 citizens, at the end of the referendum, voted for the popular proposition ‘Berliners want their water back’. Thus, the Senate looked at different options for remunicipalisation; ultimately deciding to buy the RWE (a private operator) shares for €618million in 2012, and Veolia’s (another private operator) shares for €590million in 2013\[^11\][^14].

### 3.4 Soaring tariffs

Tariff hiking is a common problem associated with water privatization, and was observed in three
sample projects. In Bordeaux Water Supply and Sewerage Systems, France, high tariffs, other than
the private sector’s dubious accounting practices, was the failure reason. Consumer campaigns
condemned the high tariff and financial practices of the private sector and resulted in a
remunicipalisation decision by the city council. The contract will be terminated on January 01, 2019,
and city will be required to pay between €50 and €70 million to the private operator, in penalties for
early termination\(^\text{[10],[11],[15]}\). In Castres Water Services, France, tariffs increased significantly right
from the beginning of the privatization\(^\text{[13]}\) and in Paris the tariff increase was not justified by the
level of inflation\(^\text{[6]}\).

3.5 Poor technical performance of the private sector

The town council of Varages in France awarded the water supply and waste water lease contract to
SEERC in 1990. New EU water quality standards were adopted but the water quality deteriorated
because too much chlorine was put in the water. The headquarters were 50 km away and customer
service was so poor that in case of any complaint only one technician covered several villages\(^\text{[16]}\).
Therefore, due to public and political demand for remunicipalisation, the contract was not renewed
with SEERC at the end of the contract in 2002\(^\text{[16]}\).

3.6 Corruption

The Grenoble Water Supply and Sewerage Systems lease contract in France was a corruption based
deal in which the private operator was awarded many privileges such as exclusive rights for all
subsequent contracts. The Mayor was accused of being bribed by executives of Lyonnaise des Eaux
(the private operator) to fund his electoral campaigns. The court sentenced the convicted Mayor and
executives to prison. The court ruled that the corrupt deal had damaged customers\(^\text{[8],[9]}\).

3.7 High interest debt

High interest taken by the private sector became the basis of a water PPP failure in Potsdam,
Germany. In Postdam Water Supply and Wastewater PPP, Germany, the city council was not
satisfied with the financing mechanism of Eurawasser, which used a high interest debt for the
investment. Eurawasser used this expensive loan of DM 167 million to buy shares, and in return
gave the bank a guarantee to cover DM 400 million, over a span of 20 years, from the revenue. The
city council considered it an unfair deal since users had to bear the repayment. Due to this,
Eurawasser projected a high future tariff increase of more than 100 percent. Further, Eurawasser
wanted to record their operating cost as an investment because investments had to be paid by the
city, which was unacceptable to the city. The city bought back the shares and paid €12.8 million in
compensation\(^\text{[11],[17],[18]}\).

4 Conclusions

This paper used the case study approach and discusses case studies of 7 failed water PPPs from two
European countries namely, France and Germany, in an attempt to explore potential failure reasons
in Europe.

The main failure reasons found from the five sample cases from France were high tariffs, lack of
transparency, and excessive profit by the private sector. Two projects were affected by soaring tariffs,
one by lack of transparency, and three by excessive profit. Grenoble Water Supply and Sewerage
Systems, France, was a corruption based contract and the private sector was given unnecessary privileges which they manipulated to gain excessive profit, much more than stated in the contract. On the other hand, no formal assessment of the existing system prior to privatization had been made in Paris Water Supply and Billing Services, France, so the city lacked reliable information about the system, which negatively affected the project.

In Germany, a guaranteed high return rate to the private sector resulted in a high tariff increase in the Berlin Water Works. Subsequently, the high tariff, and lack of users’ participation during the contract process led to a referendum by the citizens to remunicipalise. In contrast, the high interest debt by the private sector and conflicts between the two parties on accounting issues were the failure reasons that occurred in Potsdam Water Supply and Wastewater Services.

The findings of this research are beneficial for both the public and private sector in comprehending the negative actions on their parts and other social issues which interrelate with each other to cause water PPP failures. The failure reasons discussed in this study can act as a guidance for the stakeholders and researchers in establishing preventive measures.

**Acknowledgement**

This study is financially supported by the National Natural Science Foundation of China (Project Number: 71472052).

**References**


Study of Global Waste Quantification Models


Abstract: Throughout the world, construction and demolition (C&D) waste is a very critical issue. It has caused worst situation globally especially in developing countries’ construction industry. Increasing amount of waste generation has led to need of certain model or mechanics which can quantify construction and demolition waste amount. Quantification of waste generation will assist in develop proper mechanics for controlling this generation. This paper presents a review of various models developed during last decades to quantify C&D waste. Intensive study of these models indicated that the waste quantification depends of various numerical and empirical attributes. These attributes vary from location to location. Effective and accurate quantification depends on the quality of data collection which can help to estimate annual amount of waste generation so that proper arrangements can be made for managing it. It could be beneficial and helpful in establishing national construction and demolition waste reduction plan to minimize waste at construction place.

Keywords: C&D waste; Construction activities; Waste calculation; quantification

1 Background

For more than last two decades, construction and demolition waste generation issue have drawn an in-depth interest from academicians. The result of this interest reveals a range of published research articles in different journals. This achievement manifestly shows an increasing challenge associated with construction and demolition waste problem. Nevertheless, it gives the idea that the establishments and the high percentage of experienced professional stakeholders show less interest towards these challenges. In continuation to it, current literature review covers wide-range of C&D waste management systems and models[1-5].

Reviewing the development of previous researchers is an important aspect for the inclination in any area if study. Identification and determining the produced amount of waste is basic step towards its managing[6-7]. Song et. al.[8] stated that C&D waste is documented as dangerous to environment as construction works are key consumers of natural, artificial resources, material and energy. Natural and artificial construction materials and its major
components utilize 50-60% of the total construction value and around 10% of the total material is wasted\(^9\). A study of 2006 conducted by Hong Kong government’s environmental protection department stated that 38% of solid waste materials originated from the construction industry\(^10\). C&D and renovation activities produce notable levels of solid waste that puts severe burden on waste management solutions\(^11,12\). Lu and Yaun (2011) developed a measurement method for C&D waste material to increase the efficiency for controlling waste and also evaluate their benefits with other regions of the world \(^13\). Whereas Gheewala & Kofoworola (2009) stated that assessment of national and local C&D waste in Thailand is usually done on nearby sites but precise estimation can be made by developing waste generation quantification models\(^14\).

Estimation of annual waste generation will help authorities to forecast life of landfill areas and evaluate the feasibility of construction and demolition waste recycle program\(^15,16\). These construction departments are playing a role of policy makers which can lead to development of new regulations, guidelines and principles. Further the motivations for stimulating and encouraging the use of better waste management techniques, low waste building practices, developing a recognized system from authorities for recording the quantitative data and use of valuable guidelines to minimize construction waste generation throughout the project\(^17,18\). Successful implementation is subjected to the fulfillment of above mentioned criteria.

The aim of this research paper is to present an in-depth review of developed waste quantification models from literature, applied in different countries. Whereas, these models provide suggestions for future research work in making more valuable, reliable and accurate waste generation quantification model. These available models must be introduced and implemented for calculating the construction and demolition waste generation at local and national level. The studied models focus on construction and demolition debris of buildings related to non-residential and residential works. Public works, infrastructure projects and sanitary projects’ waste generation was not measured because of unavailability of required information. These waste generation & assessments methods are not pertinent globally. Because, the quantity of C&D waste material produced at different location rely on weather conditions, nature of projects, rules and regulations, disasters and overall financial conditions of the surrounding areas\(^19,20\). Furthermore, a research study concludes that type and amount of construction and demolition waste generally depend upon the size of construction projects’ works and technology implemented during the execution\(^18\).

2 Methodologies of C&D waste generated models

Construction waste and demolition waste generation trends are mainly dependent upon nature and type of the project\(^21,22\). Solís-Guzmán (2009) studying activities during execution phase identified apparent demolished waste volume, wreckage and packing waste volume\(^11\). A research work conducted in USA resulted in proposing a precise technique associated with different building data from national statistics departments. This technique helps in determining estimated and distinct number of financial values with general empirical construction waste generation rate of presented data\(^28\). Several researchers have quantified waste amount generated from different studies worldwide as summarized in table 1 below.
Table 1. Waste Generated in construction projects

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country of study</th>
<th>Amount of waste generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>United Kingdom</td>
<td>44% of the total waste generated in the country is contributed from construction activities</td>
</tr>
<tr>
<td>24</td>
<td>Brazil</td>
<td>Waste generated from construction activities is up to 40% of the total waste</td>
</tr>
<tr>
<td>25</td>
<td>Hong Kong</td>
<td>Waste generated from construction projects is approximately 65%</td>
</tr>
<tr>
<td>26</td>
<td>China</td>
<td>40% to 50% of total landfills contains waste generated from construction works</td>
</tr>
<tr>
<td>27</td>
<td>India</td>
<td>C&amp;D debris contribute to 36% of the total solid waste generated</td>
</tr>
</tbody>
</table>

In quantifying construction waste generation, waste characterization is a critical stage and several research works have been conducted for classification of various forms of construction and demolition waste material\[8,14,19,22\]. Several methods for measuring the waste are existing for calculating the waste generated which have been put into practice in number of different countries as discussed in succeeding section.

2.1 Waste quantification Models developed in 1996 and 1998

Yost and Halstead (1996) and Franklin Associates (1998) developed model for quantifying construction waste based on type of waste generated. The authors used National Statistical Data and integrated it with samples gathered from various project sites selected randomly throughout the USA. Focus of Yost and Halstead’s work was on quantifying the waste of gypsum wall board in USA to evaluate the opportunity of wallboard recycling program\[28\]. On the other hand, Franklin Associates focused on calculating nationwide rate of waste generation. From these research works, it was concluded that waste generation could be expressed as product of total area (sq-ft) and average waste generation retrieved from observed waste measurement information (lb/sq-ft). Table 2 indicates the results of waste generated from residential projects\[19\].

Table 2. Residential Construction wreckage/debris

<table>
<thead>
<tr>
<th>Method to Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Start with total dollars of new construction, from Census Bureau.</td>
</tr>
<tr>
<td>2. Calculate sq ft of new construction from total dollars and $/sq ft construction cost.</td>
</tr>
<tr>
<td>3. From empirical waste assessment, estimate lb/sq ft of new construction.</td>
</tr>
<tr>
<td>4. Calculate total generation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. C-30. Residential construction (1996) — (Includes private new housing units and public housing and redevelopment)</td>
</tr>
<tr>
<td>2. Residential construction</td>
</tr>
<tr>
<td>Residential sq ft of new constr</td>
</tr>
<tr>
<td>Cost of new construction</td>
</tr>
<tr>
<td>Total sq ft of new constr – 181,795,000,000 / 58.89 / 1.03</td>
</tr>
<tr>
<td>(Includes 3% inflation factor)</td>
</tr>
<tr>
<td>3. See sampling waste assessment results:</td>
</tr>
<tr>
<td>Average generation –</td>
</tr>
</tbody>
</table>

Developed waste quantification model\[29,31\] can be simply described as:

\[
\text{Waste Produced in a Region} = [\text{Activity level of construction, demolition/renovation in a region}] \times [\text{Waste produced perceptivity}] 
\]

(3)
While quantifying waste material generated, information gathered from project sites showed that composition of waste consisted of several materials. Bergsdal et al. (2007) reported that in new construction projects of Norway, common type of waste material included timber and concrete/bricks which contributed up to 15% and 67% respectively of the total waste generated while demolition projects resulted in 85% of concrete from total waste\[31\]. By analyzing the gather data through Monte Carlo simulation, it was envisaged that wastage of timber will be increased with time and will reach to be doubled by 2018 whereas concrete/brick waste will be raised to four times. Similarly, it was realized that C&D debris composed of 56% concrete, 13% wood/timber, 11% drywall, and 7% asphalt roofing materials\[31\].

2.2 Waste quantification Model developed in 2002
Studying waste generation trend in Taiwan, Hsiao et al. (2002) developed a dynamic model for waste quantification\[29\]. Since, major type of waste generated in this small island country of Taiwan is concrete, hence major motivation for research work in waste quantification and management era in this model was to focus on increasing the awareness regarding renewal of resources through creating enhancing recycling of the materials. In Taiwan, national statistical bureau is authorized to issue permission of total floor areas of work with respect to C&D activities. Data for computing the statistic of waste generation of concrete was acquired from Architecture and Building Research Institute (ABRI). From statistical data, it was reported that approximate amount of concrete waste generation was 21.17%. Developed model is formulated as:

\[
WC = d_{cc} \times [\Sigma A_{ij} \times F_{ci}] \times P_{cc} \quad (1)
\]

\[
WD = d_{cd} \times [\Sigma A_{ij} \times F_{ci}] \quad (2)
\]

\(WC/D\) = generation of waste concrete from construction/demolition (tones); \(d_{cc/d}\) = specific gravity of C&D waste concrete; \(A_{ij}\) = total floor area on use permits built (m\(^2\)); \(F_{ci}\) = volume of waste per area (m\(^3\)/m\(^2\)) and \(P_{cc}\) = percentage of waste concrete in construction waste. This waste quantification model enumerates the local and national quantity of concrete waste output. It enlightens the major factors of construction and demolition waste from local and national regions’ C&D events. In implementing this model, the authors used MINITAB application package for forecasting future changes and estimating waste generation. Furthermore, economic benefits of concrete waste resources recovery plan were evaluated for various part of the country\[29\].

2.3 Waste quantification Model developed in 2004
Wang et. al.\[30\] developed a model for calculating the amount of waste generation. The model was equipped with the spread sheet application to facilitate the users with user friendly application. In supporting this developed system, economic assessment system was also developed to monitor C&D waste. The researchers collected data from renovation, demolition and construction activities of residential buildings in Massachusetts; USA to develop this model for quantifying various C&D debris materials. The developed model assisted in decision making to propose proper C&D waste management strategy. Authors tested the model by computing information received from the building projects under an organization R. S. Means to determine waste amount of drywall, wood, carpet and asphalt shingles. The output of is summarized in Table 3.
Table 3. Typical Factors used in the estimating system

<table>
<thead>
<tr>
<th>Conversion factors used in the estimator module</th>
<th>First Story Residential Building (1600ft²)</th>
<th>Two Story Residential Building (2000ft²)</th>
<th>Three Story Residential Building (2000ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood (ft³/ft²)</td>
<td>3.21</td>
<td>3.18</td>
<td>0634</td>
</tr>
<tr>
<td>Plywood (ft³/ft²)</td>
<td>3.27</td>
<td>3.01</td>
<td>N/A</td>
</tr>
<tr>
<td>Drywall (ft³/ft²)</td>
<td>3.29</td>
<td>5.57</td>
<td>1.52</td>
</tr>
<tr>
<td>Shingles (ft²/ft²)</td>
<td>2.49</td>
<td>1.25</td>
<td>N/A</td>
</tr>
<tr>
<td>Carpet (ft²/ft²)</td>
<td>0.8</td>
<td>0.8</td>
<td>0.6</td>
</tr>
</tbody>
</table>

R.S. Means specializes in publishing construction productivity and cost data. Cost-benefit analysis of different waste management settings was done through an analysis model based on spreadsheet system using Microsoft Excel and virtualized through visual basic user interface. It was utilized for calculation of revenue versus cost of four restricted materials.

The developed system by Wang et al. was capable to compute total weight of C&D wreckage for different materials in Massachusetts. The authors integrated the computed waste quantities of several numbers with GIS which show spatial distribution of C&D debris for individual regions and towns in Massachusetts. The model is very beneficial for regulating bodies of the countries to determine waste materials as well as uncovering obstacles which hinder recycling. Effective use of this model is also helpful in promoting of various waste management practices which can result in cost effective waste management plan.[30]

2.4 Waste quantification Model developed in 2009

Gheewala and Kofoworola[14] developed a quantification model to appraise the possibility of national C&D waste recycling plan. Due to absence of proper information, the author did not consider demolition, renovation, and infrastructure projects. The motivation behind encouraging the implementation of recycling was to control adverse effects of material of environment, reduce energy consumption in construction activities and also generate chances for job for the public. The developed model is described as:

\[ Q_x = A \times Gav \times Px \]  \hspace{1cm} (4)

\( Q_x \) = quantity in tons; \( A \) = area of activity in m², \( Gav \) = waste generation rate and \( Px \) = percentage of waste material

2.5 Waste quantification Model developed in 2011

In order to support EU directives of developing recycling society Llatas (2011)[31] proposed a new model to quantify waste generation. The target of EU directives to ensure that at least 70% of C&D waste (in terms of weight) should be recovered. The authors classified building components and waste types (including remains, soil, and packaging). During study of 200 building elements in a project it was reported that the rate of waste generation is 0.1388 m³/m² in Spain. Waste of packaging was generated at a rate of 0.0819 m³/m² while the same for soil generation was 0.2805 m³/m²[27].

2.6 Waste quantification Model developed in 2016

Through a research work in Indian construction industry, an optimization model for C&D waste was established by Ghosh et al., (2016)[32]. As reported, in India more than 30% of solid waste is not recycled. Major reasons behind that is the enforcement on waste management by the regulating authorities. In order to curtail the C&D waste, the author suggested a
mathematical model which is capable to compute wastage revenue of demolition and construction. The developed model is expressed as:

\[ X_{br} = \text{Quantity of brick in demolition waste}; \]
\[ X_{st} = \text{Quantity of steel in demolition waste}; \]
\[ X_{plm} = \text{Quantity of plastering material in demolition waste}; \]
\[ X_{lm} = \text{Quantity of lime in demolition waste}; \]
\[ X_{rcc} = \text{Quantity of RCC in demolition waste}; \]
\[ X_{me} = \text{Quantity of mixed earth}; \]
\[ Y_{nrc} = \text{Payable cost to truck driver for non-recyclable wastes}; \]
\[ Y_{re} = \text{Revenue from recyclable wastes}. \]

The purpose of this model was to motivate the practitioners in adopting recycling practices by realizing the monetary benefits. This would make realizing the need of improving level of accuracy in estimating the quantity of raw materials required and financial investment. This will not only benefit the stakeholders involved in the construction but also be beneficial for the environment.

3 Discussion

Quantification of waste is very important task in the field waste management. Several researchers have put their effort in devising methodologies and techniques for estimating the generation of waste at site. In this era, method proposed by Franklin Associates (1998) is deemed as the yardstick for computing amount construction and demolition waste[19]. The limitation of this model was that it was developed based on one national data only and universal applicability of the model was not checked. This approach was extended by Bergsdal et al. (2007) and Cochran et al. (2007) by incorporating iterative process to forecast various types of waste materials[15,33]. This benefited the experts in determining the expected waste generation. On the other hand, the model developed by Gheewala and Kofoworola’s (2009) was related to assessment of feasibility of waste recycling programs[14]. This model was ineffective as it did not include strong database. Also, this mode had limited applications as the developers did not consider the waste generated in demolition, renovation, and infrastructure projects. Development by Martinez-Lage’ et al. (2010) is believed having better and inclusive results[7] as it incorporates more practical considerations such as acquire waste of each work components, density of the material. The model anticipated by Llatas (2011) gives consistent and thorough mechanism for calculating waste generated from each single project, incorporate packaging, soil etc[32]. Yuan and Shen (2011) had pointed out that more advanced simulation and modelling techniques. Works of Yost and Halstead (1996), Hsiao et al. (2002), and Wang et al. (2004) are appropriate for reviewing possibility recycling programs[28-30]. Recent study by Ghosh et al. (2016) reported an innovative method in waste modelling and found revenue generation through the waste accumulated at the end of a project[33]. This model is proven the effective and useful for construction industry.

4 Conclusion and Recommendation

Construction waste generation has become global annoyance. Many efforts have been put to control it. One of the challenges faced in controlling waste especially on site waste is the quantification for different types of material. Quantification is very imperative in adopting the waste management system. Always, it is recommended that the waste material should be re-used at maximum level otherwise be recycled. But the rate of materials be re-used or recycled depend on the type of waste generated. Hence, several researchers have put efforts in developing models and
methods to quantify the amount of waste. This study has provided in depth view of various models and method proposed in quantifying the amount of waste generation of different materials. This review highlights the strength and limitations of the models which will be useful for selecting the appropriate method for quantifying waste depending on the type of project and level of data available.

References


Characterizing the Carbon Emission from Buildings’ Decoration Process: A LCA Study


**Abstract:** Most existing studies have placed focuses on buildings’ energy and their impacts during the operation stage. This paper is designed to focus on residential buildings’ decorative activities, to characterize the environmental impact (measured by carbon emissions) via LCA approach. Specifically, decoration-related activities data (such as materials use and energy consumption) has been collected by field investigation. The embodied carbon emissions factors of building materials, transport, and grid mix were drawn from commercial databases subjected to Chinese context. The result shows that the carbon emission from decorative activities of a residential building is 110 kg CO2 eq. per square meter. The wall decoration activity contributes most to total emissions (by 40%), followed by detailing (by 34%), and the decorative surface activities (by 26%). These results could help to better understand the environmental implications in the decoration sector, and provide a useful reference for sustainable decorative construction.

**Keywords:**
Decoration; LCA; carbon emission;

1 ZAHNG, T.N
Department of civil engineering, Shenzhen University, China
E-mail: 673195300@qq.com

2 DUAN, H.B.*
Corresponding author, Department of civil engineering, Shenzhen University, China
E-mail: 13828866@qq.com

3 Wei, H.Q.
Luohu District, Shenzhen Shennan Road 3027, China
E-mail: weihuiqiang@sz-ruhe.com

4 Zuo, J.
School of Architecture & Built Environment, The University of Adelaide, Australia
E-mail: jian.zuo@adelaide.edu.au

5 Yu, B.
Project manager, decoration company in Shenzhen, China
E-mail: 776541739@qq.com

6 Li, X.Y.
School of Resources and Environmental Engineering, Wuhan University of Science and Technology, China

7 Zillante, G.
School of Architecture & Built Environment, The University of Adelaide, Australia
E-mail: George.zillante@adelaide.edu.au
1 Introduction

Life cycle assessment (LCA) evaluates the environmental impacts of the product, industry and even the entire life cycle of the industrial chain. Coca-Cola Company used LCA method for the first time to analyze the product's packaging using REPA theory. Since then, this approach has been employed in various industries.

In the building sector, the LCA method has been frequently used to evaluate the environmental impact from the following aspects: (1) Analysis in building materials’ usage stage: Gaofeng et al. defined the boundary and the computing method of the building materials using the LCA theory. Ian-Frederic et al. examined the environmental impact of material on the building using the LCA method, combined the sensitivity analysis. (2) Analysis in service stage. The data of the impact will provide macro-scope model as a reference. Zhang et al. defined a scope about environment accounting of the life cycle of the building, and conducted a list analyzing the building from materialization, employment, demolish and recycling. The impacts of the different architectural design schemes in calculation of carbon emissions using the LCA model were summarized by Zhang. (3) Evaluation and prediction model: Huang et al. established the CO2 emissions model of residential building from the perspective of the LCA theory. Yuan et al. enhanced the capacity of I-O LCA models for calculating the product chain energy of different building types in China.

In the field of building decoration, LCA studies mainly involve the following aspects: (1) Materials use and comparison. Yu measured and analyzed nine kinds of decorative materials’ life cycle energy consumption and carbon emissions, and conducted suggestions to reduce energy consumption and reduce carbon emissions. Giuseppe et al. applied LCA on the ceramic and marble flooring for the environmental evaluation. (2) Assessment of environmental impact. Yan used LCA method to evaluate the environmental impact of the three different wood-based products when materialization. Xiong et al. analyzed and compared the use of these two kinds of plastic pipes' energy consumption, (3) Pollution and damage from decoration process. Li et al. quantified the health damage using life cycle inventory (LCI) and forecasted the damage of decoration project. Joke et al. mainly evaluated the air pollution caused by decorative materials. Xiong et al. applied LCA method to evaluate the energy consumption of two kinds of core pipes.

In short, the LCA method has been widely used in the construction stage and operation stage, however, compared to the decoration stage the study is largely overlooked. The LCA method is therefore employed to calculate the environmental impacts of decoration projects, which providing an effective reference for the study of green decorative activities and green building.

2 Life cycle assessment

2.1 Purpose and Scope

The building decorative stage will be completed until consigned to the users through the process of water, electricity, wall, floor, ceiling, kitchen and toilet work etc. It involves complex types of materials, which the typical LCA evaluation can be applied to. This paper mainly addresses the residential construction, and discusses a specific project. The research covers a new integrated
construction project, which means the customer only requires purchasing personalized furniture, and the decoration has been finished.

In the course of entire LCA process, combing materials’ use (quantity, e.g. kg) with materials embodied impacts from is used to calculate the materials impacts for various decorative stages.

As for the process of distance, assumptions are made to combine the local project supply situation; the years of use from the yearbook statistics; the recovery rate of products through the actual research in the acquisition. In the course of daily use, unless the intentional damage happen, like natural disasters such as earthquakes, the decoration maintenance costs too small to take into account. As shown in Fig 1:

Fig.1. Resource of carbon emission in each stage of decorative activity

2.2 Method and calculation

2.2.1 Embodied impact of decorative materials

Because of the complexity of decoration materials, including the fast upgrade rate and wide variety of building decoration market. In this paper, the material composed of multiple parts is split into sub-components and calculated. As for the decoration material that the database does not exist, the relevant data in literature will be collected as a reference index and adjusted according to the different conditions.
2.2.2 Transport impact of decorative materials

In general, residential renovation project is located close to the city, the average distance is determined. The formula of carbon emission in transportation process \[^{[18]}\]:

\[
C_{\text{trans}} = \sum_{i=1}^{n} I_{\text{trans}_i} \times W_{\text{trans}_i} \times D_{\text{trans}_i}
\]

In the formula, \(I_{\text{trans}}\) is unit carbon emission factor, \(W_{\text{trans}}\) is the weight of the goods transported, \(D_{\text{trans}}\) is the distance from the project and building material market. The calculated carbon emission is 171948.32 tons, and the carbon emission produced from transportation is 33.339 ton.

According to the results of field research, the common transport vehicles is the medium-sized diesel trucks, whose carrying capacity is 8 tons to 10 tons, their carbon emission factors are as follows:

<table>
<thead>
<tr>
<th>Vehicle carbon emission factor (unit: kg/t*km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>10t</td>
</tr>
</tbody>
</table>

Assumptions: this calculation method is not enough because of the vehicle cannot be fully loaded for the wide range of materials.

2.2.3 Energy use impact during various decorative processes

The process’s energy use impact involves environmental pollution, resource consumption and occupational health, the production of material and the installation of the furniture will generate harmful gas and dust especially in the surface decorative process. And the worker’s health will be influenced without proper protection which cannot be evaluated by CE.

2.3 Inventory

Decorative activities data were mainly collected from a residential decoration site located in Guangzhou, and a qualified decoration company was in charge of this project (see Table 2)

<table>
<thead>
<tr>
<th>Table 2. Data and sources in the various life cycle stage of building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage or source of carbon emission</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>Decoration product</td>
</tr>
<tr>
<td>Decorative process (Use of electricity and water)</td>
</tr>
<tr>
<td>Product transportation</td>
</tr>
<tr>
<td>Transportation to landfill</td>
</tr>
</tbody>
</table>

Note: Data from a standardized integrative decorative project located in Guangzhou (Fig 2) with 200 days construction duration and 40766.5 square meter construction area.
Fig.2. Site survey in decorative construction site

2.4 Materials type and quantity

As for the carbon emissions inventory, the quantity bill of the decoration project including the building decoration materials in Guangzhou is taken as an example (see table 3). Based on the Eblance and SimaPro database, the unit's square meters of data is aggregated when calculating carbon emissions.

Hypothesis in transport stage, the project is located 10 kilometers from the construction site, and 30 kilometers from the landfill. The decoration material is transformed by the normal Diesel truck. The average age of the residential furniture is 20 years [19], and the average age limit of a framework building is 60 years. At the same time, when analyze the lifecycle assessment, the wear and tear of decoration material can be ignored as the difference of individual needs is too uncertain to quantify.

In disuse stage, decoration material will be disused when the building is removed or the decoration material reaches its age limitation. And the average recycle rate is a reference indicator of the material consumption.

Table 3. Carbon Emission Factor of Main Material in the Decoration Process

<table>
<thead>
<tr>
<th>Material (main material)</th>
<th>Unit</th>
<th>Carbon Emission Factor (Kg CO2 eq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ceramic tile</td>
<td>kg</td>
<td>0.229</td>
</tr>
<tr>
<td>latex paint</td>
<td>kg</td>
<td>2.400</td>
</tr>
<tr>
<td>cement</td>
<td>kg</td>
<td>0.623</td>
</tr>
<tr>
<td>switch</td>
<td>kg</td>
<td>6.430</td>
</tr>
<tr>
<td>ceramic</td>
<td>kg</td>
<td>0.638</td>
</tr>
<tr>
<td>stainless steel</td>
<td>kg</td>
<td>89.200</td>
</tr>
<tr>
<td>wire alloy</td>
<td>kg</td>
<td>0.017</td>
</tr>
<tr>
<td>keel</td>
<td>kg</td>
<td>0.870</td>
</tr>
<tr>
<td>aluminum alloy</td>
<td>kg</td>
<td>4.620</td>
</tr>
<tr>
<td>black stone</td>
<td>kg</td>
<td>2.280</td>
</tr>
<tr>
<td>brick</td>
<td>kg</td>
<td>0.140</td>
</tr>
<tr>
<td>calcium silicate board</td>
<td>m²</td>
<td>0.143</td>
</tr>
<tr>
<td>plastic pipe</td>
<td>kg</td>
<td>0.079</td>
</tr>
<tr>
<td>industrial water</td>
<td>kg</td>
<td>0.00001</td>
</tr>
<tr>
<td>industrial electricity</td>
<td>kwh</td>
<td>0.86</td>
</tr>
</tbody>
</table>

Data sources: Eblance database.

In this study, limitations arise because of only one decoration project is involved, in further
study, more cases will be taken into consideration. Furthermore, the data has its uncertainty, due to the difference between each project and the workers’ skill.

3 Results and discussion

3.1 Materials use and their embodied impact

According to the decoration supplies and quantities data from project cite investigation. The carbon emission of the various decoration components per square meter is calculated from the project's data in Guangzhou decoration site.

The bill of quantity to calculate the per square meter amount of the total project cost is listed in Table 4.

Table 4. Decorative use and their impact for a specific project

<table>
<thead>
<tr>
<th>Materials</th>
<th>Per square meter consumption</th>
<th>Unit</th>
<th>Consumption overall (unit: t)</th>
<th>Carbon emission overall (unit: t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic tile</td>
<td>35.93</td>
<td>kg</td>
<td>10984.04</td>
<td>2515.35</td>
</tr>
<tr>
<td>Latex paint</td>
<td>5.25</td>
<td>kg</td>
<td>1605.18</td>
<td>3852.43</td>
</tr>
<tr>
<td>Cement</td>
<td>10.00</td>
<td>kg</td>
<td>3057.49</td>
<td>1904.81</td>
</tr>
<tr>
<td>Switch(plastic)</td>
<td>0.09</td>
<td>kg</td>
<td>27.81</td>
<td>178.83</td>
</tr>
<tr>
<td>Ceramic</td>
<td>0.85</td>
<td>kg</td>
<td>260.41</td>
<td>166.14</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>0.16</td>
<td>kg</td>
<td>49.11</td>
<td>4380.24</td>
</tr>
<tr>
<td>wire alloy</td>
<td>5.21</td>
<td>kg</td>
<td>1591.52</td>
<td>26.42</td>
</tr>
<tr>
<td>keel</td>
<td>0.05</td>
<td>kg</td>
<td>14.42</td>
<td>12.54</td>
</tr>
<tr>
<td>aluminum alloy</td>
<td>0.05</td>
<td>kg</td>
<td>14.06</td>
<td>64.98</td>
</tr>
<tr>
<td>black stone</td>
<td>1.88</td>
<td>kg</td>
<td>573.98</td>
<td>1308.67</td>
</tr>
<tr>
<td>brick</td>
<td>0.05</td>
<td>kg</td>
<td>15.78</td>
<td>2.21</td>
</tr>
<tr>
<td>calcium silicate board</td>
<td>0.20</td>
<td>m²</td>
<td>60.22</td>
<td>8.61</td>
</tr>
<tr>
<td>plastic pipe</td>
<td>1.53</td>
<td>kg</td>
<td>467.58</td>
<td>36.99</td>
</tr>
<tr>
<td>industrial water</td>
<td>0.21</td>
<td>kg</td>
<td>63.70</td>
<td>0.002</td>
</tr>
<tr>
<td>sum</td>
<td></td>
<td></td>
<td>18721.61</td>
<td>14478.29</td>
</tr>
</tbody>
</table>

Data sources: Site research and project list calculation

As shown in Table 4, the total amount of carbon emission is 14,478 ton, while the top consumption of material is ceramic tile, the largest part of carbon emissions is the use of stainless steel, indicating that the production of the steel produce huge amount of carbon emissions. The application process generated 5.21 kwh electricity per square meter, and has 20 tons CE in the whole process, which is not included in the material inventory.

10% -12% of the project estimate is lost, from the experience of the project manager. Provided that reasonable measures are taken to control the material loss of the decoration process, such as the worker operating technology’s promotion, material utilization rational planning. This can set aside nearly ten thousand tons of carbon emissions, which has remarkable energy-saving emission reduction effect.
3.2 Impact of decorative process

The overall decorative process is as follows: production and installation of the wire laying, air conditioning beam production, light steel keel, ceiling seal, ceilings calcium silicate board lights, toilet waterproof layer, bathroom backfill, toilet water supply, bathroom floor leveling, bathroom wall, ground waterproof layer treatment, bathroom brick wall, marble paving, toilet floor paving, bathroom shower paving, kitchen floor tiles etc. Through the division, the entire process needs simplifying to wall project, decorative surface project, detail project these three major projects. And calculating the carbon emission can compare the different stages of a decoration project.

According to the decoration supplies and quantities’ percentage data from cite investigation of this project. Decorative surface project occupies the largest proportion of carbon emission (61%), followed by Wall work (23%), while the detail project accounted for the least proportion of carbon emissions (16%). As shown in Fig3. It is worth noting that the distribution of engineering quantity doesn’t correspond with the carbon emission: wall project instead of surface project accounts for the largest proportion (40%), followed by the detail project (34%), and decorative surface project accounted for the smallest proportion (26%).

![Fig.3. (a) Distribution of project inventory (b) Distribution of CE](image)

4 Conclusions

This study is designed to quantify the carbon emission of a decorative project. The major findings are listed as below: (1) The total carbon emission of residential building during decorative activities is approximately 110 kg per square meter. The wall-related decorative processing is the biggest contributor, followed by the detail processing, and the decorative surface processing. (2) The environmental impact from buildings’ decorative activities could not be ignored. It is urgent to promote green decoration.

Acknowledgement:

This study was supported by the Shenzhen Science and Technology Plan (no. JCYJ 20150525092 941042 and JCYJ 20160520173631894), Natural Science Foundation of Guangdong Province (2017A030313438), NSFC 51478267, and the Young Faculty Promotion Plan of Guangdong Province (YQ2015139) for funding and support.

References:


Critical need for urban regeneration in Perth – a holistic view for sustainable strategy development

Dodd, S.C.¹* and Ramanayaka, C.D.D.²

Abstract: Despite a rapid population growth in Perth because of its reputation for being one of the most liveable cities in the world, the existing urban development strategies are widely criticised as ‘unsustainable’. Inadequate planning for dwelling types and poor utilisation of land resources trigger urban sprawl, increasing the urban footprint of the Perth Metropolitan region by more than 31% just between 2002 and 2008. Whereas high car dependency and increased green-house gas emissions are highlighted frequently as the repercussions of urban sprawl, the Western Australian government is blamed in literature for not establishing effective urban regeneration strategies due to the fear that the current liveability standards will be eventually compromised. We argue that this conventional belief is not necessarily true specifically when a sustainable city is perceived holistically including the environmental, social and economic dimensions as well as their interconnectedness. Further, our desk study shows that high-density, high-rise developments are futile even in environmental terms when socio-economic perspectives are neglected. Although infill housing and green construction are suggested by the Western Australian Planning Commission as viable urban regeneration strategies, evidence suggests that their realization is subjected to a large strategy-to-implementation gap when the context-dependent nature of urban sprawl is not well-understood. Therefore, this paper identifies the fastest and largest population growths in Greater Perth and provides a future research direction for establishing viable urban regeneration strategies while considering the well-being of both built and natural environments.

Keywords: Cities; Livability; Perth; Sustainability; Urban Regeneration; Urban Sprawl.

¹* Dodd, S.C.
Corresponding author, Department of Construction Management, Curtin University, Australia
E-mail: stephen.c.dodd@student.curtin.edu.au
1 Introduction

Persuading with this research was triggered by a continuously increasing pressure on the Built Environment in Australia, to effectively cope with urban sprawl. There is an emerging trend in the country for a collaborative approach for city planning among citizens, private companies, universities and public organizations and the City Ignite Summit 2017 is one of those initiatives to close the existing knowledge gap in the context of urban regeneration.

Both world and urban populations experience large growth. The total population in 2050 is estimated to be 9.3 billion, which is nearly a 24% increase since 2017 [1]. With more than 50% of the World’s population currently living within urban areas, [2] and an estimate of a 23% increase by 2050; there will be little to no space remaining in the metropolis to accommodate the increasing urban population and the provision of facilities, hence demanding land clearing at greater distances from the Central Business District (CBD). Perth, which is the focus of the current study, is one of the most rapidly growing urban regions to reflect these changes [3]. In estimate, Perth population will reach 3.5 million individuals by 2051 from 2.06 million in 2016 [4].

Perth is one of the most livable cities in the world. It is ranked at 07th place in The Economist’s Global Livability Ranking (EGLR) in 2016, and acknowledged for its ideal conditions (i.e. 100%) for three of the five measures used in the ranking: education, healthcare and infrastructures. However, Perth is widely known for its poor performance in terms of sustainability [3, 5]. This issue is reflected even in EGLR, placing Perth significantly lower than the remaining Australian state capitals for ‘culture and sustainability’.

The issue of increasing population is not the only threat to our natural environment. Perth has a historical preference for a low-density urban development [5]. If the current development trend is not intervened proactively, urban sprawl will cause an irreversible damage and it is emphasized that rectification should be done before 2031 [5]. Otherwise, the Western Australian Planning Commission (WAPC) estimates that increasing urban population will produce 328,000 new dwellings by 2050, each clearing an average of 214 m² of green-lands [6].

Whereas urban sprawl in Perth is subjected to a large research gap, it’s consequences should not be underestimated. By emphasizing on reduced waterfalls, rising temperatures and lack of wet winters, Professor Tim Flannery – a renowned environmentalist and Australian of the year-2007 – predicted that Western Australia could become the world’s first ghost metropolis of the 21st century [7]. This warning resembles the Systemic Ecological Collapse Model and the Drought Theory, which are developed to explain the collapse of the Great Mayan Civilization. However, the major repercussions of urban sprawl are not limited to environmental concerns, but present in terms of both economic and sociological perspectives [8]. Whereas they are discussed later in detail in this paper, the immediate focus here is to emphasize that the Western Australian Government is widely criticized, for not taking effective control measures against urban sprawl, and continuously encouraging a low-density development [3].

It is believed that public authorities are reluctant to interfere with the current development trend towards ‘high-density’ because of the political and cultural sensitivity of this issue [9]. While there is lack of scientific evidence to support this statement, a high-density development will not necessarily lead to sustainable cities even in environmental terms. Explaining this, it has been a widely-held belief by sustainability scholars that high density areas with multi-story
developments contribute to significantly less carbon emission on the per capita basis compared to low-density, low-rise developments [10]. However, there are counterarguments in literature where researchers validate the opposite [11]. Considering the two arguments, a conclusion could be made that sustainability cannot be simply measured by quantitative terminologies such as population density; there is an overarching effect from qualitative variables such as the type of region and consumption habits on sustainability of cities [10, 11]. Since the inattention by public authorities towards these qualitative factors, it is now identified that the development of infill housing against urban sprawl has become an utter failure in some Australian state capitals [3]. Thus, the issue of urban sprawl should be diagnosed more comprehensively in the context of Perth.

Thus, the current paper is based on a larger research that focuses on evaluating sustainable strategies, to form a more resilient capital city for Western Australia via establishing successful development methodologies to ensure both livability and sustainability. While the larger study is carried out in three different stages entitled problem identification, problem diagnosing and strategic conceiving, the scope of this paper is limited to the preliminary research carried out in the first stage. Following the introduction, we discuss the issue of urban sprawl in the Perth context in detail and then a potential for interference is identified. Findings are inconclusive at this stage, future study direction is provided for an academic debate. Future research questions developed for the greater study are 1 - “what design and construction methodologies will assist the Built Environment to achieve an optimum balance between economic and sociological sustainability in future infill housing in Perth”. 2 - “what strategies will best fit to minimise urban sprawl in each largest/fastest population growth area in the Perth metropolitan area”. 3 - “what strategies will assist Perth urban planning authorities to realise a lower total carbon footprint while accommodating the increasing metropolitan population”.

2 Urban sprawl: Perth perspectives

Though there is no universally accepted definition for urban sprawl, it represents a continuous, low-density, scattered, strip or leapfrog development, particularly in the urban and suburban areas surrounding major cities. It notably creates a limited-functioning community with heavy reliance on motor vehicle transportation and is unsustainable both in social and environmental terms, respectively.

Figure 1. Sprawl Pattern in Perth between 1925 and 2008 [6]

British occupation in Western Australia is an aspirational story, converting the previously known largely uninhabitable land by Dutch and French navigators into a cosmopolitan city. It has since been a historical preference by Perth residents towards the idea of a 'project home' and consequently, there are lengthy commutes to the CBD. With reluctance to use shared facilities such as parking and preference to own large backyards, conventional high density developments seem contradictory [3]. Greater Perth is a collection of the Perth Metropolitan Region, the City of
Mandurah and the Pinjarra Statistical region, and provides residence for 70% of the state population. Adding to this, the largest population declines in Western Australia between 2014 and 2015 were all recorded outside Greater Perth including: Goldfields, Pilbara, Newman, Leinster - Leonora and Meekatharra [12]. This is an indication that more and more people prefer to reside within Greater Perth and hence demand for resources is ever increasing. Thus, it requires an understanding of how this immigration impacts urban sprawl in Greater Perth (see Figure1).

Whereas the most rapid urban footprint increase is between 2002 and 2008 (>31%), it is evident that the population of the Greater Perth prefers living great distances away from CBD. Consequences include loss of natural habitats and increased greenhouse gas emission due to high car dependency. Considering low fuel prices and easy access to motor vehicles, it is unrealistic to assume that there will be an attitudinal shift in residents towards using public transport although the provision is reasonable in and around Perth [1]. However, new developments on the urban fringe have less frequent and inefficient public transport infrastructures and this could further increase residents’ car dependency. Therefore, an immediate intervention is a must.

As of 2015, the population density in Greater Perth is as low as 320 people/km$^2$ and the Statistical Areas Level 2 (SA2s) with the highest population densities were around its CBD and include: Tuart Hill-Joondanna (3,600 people/km$^2$), Scarborough (3,400 people/km$^2$), Innaloo-Doubeview (3,200 people/km$^2$) and North Perth (3,200 people/km$^2$). In comparison with the highest population densities of the Eastern State capitals [Sydney/Melbourne: >17000 people/km$^2$ and Brisbane (=7470 people/km$^2$)], these values are significantly lower [12].

Literature acknowledges the role of city administration bodies in terms of taking proactive and reactive measures to control urban sprawl [5]. Nevertheless, the outcome is not satisfactory and the issue of low density development is common for many Australian and North American cities and appears in literature in many terms including: poor utilization of land uses, inefficient suburban development around cities, poor special planning techniques and densities unsustainable for future outlook [5,7,8,9].

### 3 Need for sustainable urban development in Perth

Traditionally, a ‘sustainable city’ and a ‘liveable city’ are measured differently and considered as mutually exclusive. We believe that this is often because Built Environment researchers consider sustainability only in environmental terms. However, city planning should consider its multidimensional nature, including economic and sociological, and/or through integration of Government Departments.

**Environmental:** Urban land cover through the sprawl patterns of low-density developments surrounding cities, threatens biodiversity and the productivity of an eco-system; as habitats are destroyed at the detriment of the natural environment. Adding to that, long travel distances contribute to greenhouse gas emissions significantly and evidence suggests that low-density developments are almost four times more energy intensive than high-density growths [10]. Furthermore, there is a positive correlation between low-density developments and poor regulations, leading to significantly high energy consumption for household activities. High energy use in the Australian housing sector is a critical threat, which needs to be acted on immediately; as the sector is responsible for 10% and 13% of national energy usage and greenhouse gas emissions respectively in 2010 [13]. Though the aforementioned studies argue for
the necessity of high-density developments, evidence suggests that high-density developments in some cities have enhanced total energy consumption and total carbon emission. These two realities are governed by qualitative variables such as the nature and consumption patterns of residents and how a society is segregated in terms of income distribution [10, 11]. These qualitative indicators are unattended in the Perth context.

**Economic:** A lack of effective planning for construction/dwellings, future economic growth and poor utilization of land resources induces urban sprawl and influences the economic development of cities negatively [8]. Capital expenditures on new infrastructure developments on the fringe of Perth (including roads, cabling and sewer lines) account for a substantial portion of government budget allocations; the ongoing maintenance costs which are overwhelming for taxpayers. High car dependency contributes to traffic congestion, demanding much wider roads to encompass the vehicular traffic. In contrast, much lower land rates and rentals trigger Australians to live further away from cities. Though high affordability for private transportation further encourages such trends, we believe that it is unsustainable, in economic and social perspectives, to increase the cost of private transportation without planning and regulating high affordable city dwellings. Whereas non-affordability is the leading cause of failure for infill housing in the Sydney and Melbourne inner city limits, a potential for similar incidents should be minimized. While considering these challenges, a density of 3000 people/km² should be achieved in Perth by 2050 to enhance economic sustainability [6].

**Sociological:** Environmental factors negatively influence occupants’ mental and physical well-being in low-density urban developments [3]. Further, individuals in areas with a great sense of community have low levels of sociological distress, leading to enhanced social sustainability. Socially sustainable communities are eventually sound in economic perspectives. However, improper planning leads to enhanced poverty and crimes and hence the aforementioned benefits are eventually diminished. Lack of privacy, poor acoustic qualities and low ceilings are major issues in high density developments in Sydney and Melbourne, and hence they are well-known for residents as ‘chicken coops’ [9]. In summary, a holistic approach is in need to regenerate Perth into a high-dense and more livable (i.e. sustainable in economic, sociological and environmental perspectives) city.

### 4 Outlook into Perth regeneration and future studies

Literature seems to follow an optimistic approach in the validation of high-density developments for Perth and rejects most frequently highlighted economic, sociological and environmental consequences of high-density growths in literature as myths [14]. However, these studies are conceptual and hence, the results are inconclusive. Although foreigners may prefer to stay in CBD’s high-density apartments, Australians’ historical preference for project homes should not be neglected as a myth without a scientific validation. It is emphasised that technical solutions to urban planning and construction are not of much significance to residents whereas; social, cultural and political values are more important in the process of changing the behaviour of housing consumers in Australia [9]. However, the studies argue towards an attitudinal change in residents’ housing preferences investigates urban regeneration, predominantly from the perspectives of construction systems only; thus, it is of momentous significance to investigate city planning perspectives in terms of controlling urban sprawl.
As shown in Figure 2. (a) Australia’s average wages and salaries income for 2010-11 and growth rates for SA2 from 2005-06 to 2010-11 [12]; (b) Largest and fastest population growth in Western Australia (a), the highest wages and salaries income as well as income growth are in and around Australian capital CBDs whereas areas beyond the great metropolis represent the lowest income and growth. When compared the highest population growths (Figure 2. (a) Australia’s average wages and salaries income for 2010-11 and growth rates for SA2 from 2005-06 to 2010-11 [12]; (b) Largest and fastest population growth in Western Australia (b)) and declines (namely Goldfields, Pilbara, Newman, Leinster - Leonora and Meekatharra) in Western Australia, it indicates that they coincide with high and low income areas, respectively. Although inconclusive currently, this observation is an indication that the Australian metropolis will attract residents because of cities’ potential to upgrade their financial security. With high income, consumer patterns will change, leading to a high-energy consumption lifestyle. Consequently, Australia’s total carbon footprint will rise. Although promoting green buildings is in WAPC’s agenda for the future of the Perth metropolitan boundary, an action plan should be established to regulate an environmentally sound construction design methodology in a context whereas building construction and operational sustainability is minimally considered at the moment.

Figure 2. (a) Australia’s average wages and salaries income for 2010-11 and growth rates for SA2 from 2005-06 to 2010-11 [12]; (b) Largest and fastest population growth in Western Australia

As shown in Figure 2 (b) and Table 1, the largest and fastest population growth in Western Australia is in the outskirt of the Perth metropolis. This is a clear sign that urban sprawl is rising, including near the state and national forests. As mentioned before, the reason could be higher affordability and much lower land prices with compared to the inner city. Although the provision of 47% of future dwellings in Perth will be via infill developments by 2031 [6], Perth should learn from failures in Sydney and Melbourne and make infill housing construction affordable for residents to assist in minimising urban sprawl. With the potential that the population increase in the Perth metropolitan area is related to enhanced social well-being, the Built Environment will face an utter challenge to achieve a balance between affordability and social acceptability in future infill housing.

Due to income, cultural and historical diversities of the fastest and largest population growths of Western Australia, infill housing will not be ideal for all the regions. For example, urban sprawl in North Coogee could be minimized better by encouraging outdated warehouse conversions in the nearby city: Fremantle. Due to historical and cultural significance, infill housing will not be socially acceptable there. Also, Armadale and Rockingham are two city centres close to the three of the high population growth SA2s (Table 1. Largest and fastest population growth in Western
Australia between 2014 and 2015). High density developments in these cities could be more affordable for residents than inner city infill housing. Yanchep seems to be an outlier and perhaps better to be developed as a self-sustained region. Subsequently, these multiple developments should be interconnected strategically to enhance economic, sociological and environmental sustainability and hence, planning and transportation policy development will be investigated in the context of the Perth Metropolis.

Table 1. Largest and fastest population growth in Western Australia between 2014 and 2015 [12]

<table>
<thead>
<tr>
<th>Statistical area 2</th>
<th>Population Change 2014-2015 no (%)</th>
<th>Distance to Perth CBD</th>
<th>Local Government</th>
<th>Close main city/town (distance)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Largest growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baldwies</td>
<td>2 800 (10.7)</td>
<td>46km</td>
<td>Rockingham</td>
<td>Rockingham (11km)</td>
</tr>
<tr>
<td>Forrestdale - Harrisdale - Piara</td>
<td>2 600 (20)</td>
<td>30km</td>
<td>Armadale</td>
<td>Armadale (8km)</td>
</tr>
<tr>
<td>Ellenbrook</td>
<td>2 400 (7.6)</td>
<td>21km</td>
<td>Swan</td>
<td>Wanneroo (32km)</td>
</tr>
<tr>
<td>Yanchep</td>
<td>1 700 (14.1)</td>
<td>56km</td>
<td>Wanneroo</td>
<td>Wanneroo (32km)</td>
</tr>
<tr>
<td>Byford</td>
<td>1 500 (12.5)</td>
<td>38km</td>
<td>Armadale</td>
<td>Armadale (8km)</td>
</tr>
<tr>
<td><strong>Fastest growth</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Coogee</td>
<td>320 (22.9)</td>
<td>23km</td>
<td>Cockburn</td>
<td>Fremantle (7.5km)</td>
</tr>
<tr>
<td>Forrestdale - Harrisdale - Piara</td>
<td>2 600 (20)</td>
<td>30km</td>
<td>Armadale</td>
<td>Armadale (8km)</td>
</tr>
<tr>
<td>Yanchep</td>
<td>1 700 (14.1)</td>
<td>56km</td>
<td>Wanneroo</td>
<td>Wanneroo (32km)</td>
</tr>
<tr>
<td>Byford</td>
<td>1 500 (12.5)</td>
<td>38km</td>
<td>Armadale</td>
<td>Armadale (8km)</td>
</tr>
<tr>
<td>Baldwies</td>
<td>2 800 (10.7)</td>
<td>46km</td>
<td>Rockingham</td>
<td>Rockingham (11km)</td>
</tr>
</tbody>
</table>

Since the depth of the research questions are more important than breadth in this investigation, the future study will be carried out via the merits of the qualitative research methods. To answer the aforementioned research questions, firstly, an archival analysis will be conducted to city planning and policy development documents mainly in the selected Local Government Areas (LGAs) of Western Australia, which are: the city of Perth, Cockburn, Fremantle, Wanneroo, Armadale and Rockingham. Transportation planning and policies will be evaluated overall. Following this, there will be a focus group discussion with at least a single representative from each LGA and the Public Transport Authority (PTA). The maximum group size will be limited to eight participants due to practicalities. After that, we will conduct semi-structured in-depth interviews with two key representatives from each LGA to investigate context-specific dependencies in the selected LGAs in detail. This research method will be applied similarly for PTA. Finally, a focus group discussion will be conducted to validate the findings and the need for an objective scientific validation will be identified if necessary.

5 Conclusion

Given the rapid population growth taking place in many Australian cities, it has become increasingly important to convert the historical low-density urban growths into much denser, high-rise developments. Greater Perth however has a significantly lower population density than the Eastern states capitals, the political, cultural and sociological sensitivity of urban regeneration is identified as the major inhibitor for not taking proactive strategies by public authorities to control urban sprawl. While the repercussions of urban sprawl are well-documented, Perth is one of the most livable cities in the world and hence, urban regeneration must be perceived in multiple
perspectives in the process of building a more resilient metropolis for Western Australia, including environmental, cultural and sociological sustainability. The existing Perth-based literature perceives both urban sprawl and regeneration in a limited angle and most studies are better to be categorized as ‘inconclusive’ due to lack of evidence. Urban sprawl/regeneration cannot be diagnosed through population densities only, because the positive correlation between high-density, high-rise developments and enhanced sustainability is diminished in the presence of an overarching effect from the qualitative indicators, such as income levels and consumption habits. Since of an inattention towards these factors, urban regeneration strategies including inner city infill housing developments have not been realized in other Australian cities. Though similar strategies are suggested for Perth, there is a need to investigate the issue of urban sprawl and context-specific urban regeneration strategies holistically.

References

Lean and Green: A Conceptual Model for Integrated Targets Design in Construction Projects

Hussein, M.1* and Palaneeswaran, E.2

Abstract: Both lean and green paradigms were researched and developed independently. Recent researches have revealed that the building sector is responsible for enormous energy consumption and greenhouse gas (GHG) emissions. Many potential opportunities for integrating lean and green targets exist from the early stage of design to maximize cost effectiveness, mitigate environmental impacts and minimize energy consumption. This research aims to develop a conceptual model that integrates lean and green paradigms to be applied at the design stage of construction projects. To achieve this aim, a bibliometric analysis has been conducted within lean and green journal papers relevant to building design and construction. Following that, a comprehensive review of relevant literatures has been conducted. Finally, semi-structured face to face interviews with seven experienced professionals have been conducted to evaluate and improve the model. The model aims at driving the design process to achieve the integrated targets including cost, environmental and energy measurable objectives from the early stage. These targets have initially been derived from literatures; and then improved by the design professionals. The findings from the bibliometric analysis reveal that few researches have been devoted towards integrating lean and green paradigms at the design stage in the construction industry. The preliminary outcomes from the literatures and interviews highlight that the interaction between lean and green targets does exist in a way can maximize design efficiency and enhance sustainable outcomes.

Keywords: Lean Construction; Green Construction; Design Stage; Target Costing; Project Lifecycle.

1* Hussein, M.
Corresponding author: PhD Candidate, Department of Civil and Construction Engineering, Swinburne University of Technology, Melbourne, 3122, Australia
E-mail: hmustafa@swin.edu.au

2 Palaneeswaran, E.
Associate Professor, Department of Civil and Construction Engineering, Swinburne University of Technology, Melbourne, 3122, Australia
E-mail: pekamharam@swin.edu.au
1 Introduction

The construction industry is considered as a major energy consumer and greenhouse gas emitter (GHG). According to UNEP report\(^1\), buildings contribute in more than 40% of global energy use and one third of global GHG emissions in developed and developing countries. This paper endeavours to link lean-green discrete targets at the early stage to produce environmental friendly and efficient design of buildings. While lean thinking endeavours to reduce waste and eliminate non value-adding (NVA) activities\(^2\), green initiatives aim at achieving environmental, economic and social benefits\(^3\). Lean and green paradigms have common substantial targets in terms of eliminating wastes, reducing lifecycle costs, enhancing resource efficiency, improving whole-life performances, and increasing satisfaction of stakeholders\(^4\). However, lean and green targets have been researched and developed independently and separately. This paper intends to develop a conceptual model for integrated targets design in construction projects. In order to achieve this aim, literature review and semi-structured interviews have been used. The model adopts the concepts of target costing and lifecycle thinking. At first, a bibliometric analysis has been conducted to include all “lean” and “green” journal papers in the construction industry published over the period 2000-2017 with a help of Scopus search engine. The findings highlight the most cited journal papers, the outstanding authors and journals in the fields of lean construction and green construction. After that, the literature review based on the Scopus refinement has mainly contributed in setting lean and green targets at the early stage of design. These targets have further been honed through the semi-structured face to face interviews with seven design professionals.

2 Lean and Green Integration

Lean and green have been evolved independently in the manufacturing industry. Both lean and green aim at eliminating waste regardless the type of waste that each paradigm strives to address. According to lean thinking, many types of process wastes were identified by Toyota Production System including: defects, over-processing, waiting, over-production, unnecessary transportation, unnecessary inventory, unnecessary motion and wasted human potential\(^5\). Hence, NVA is deemed to be any wasteful activity which must be identified and eliminated earlier at any process over the life cycle of a project. On the other side, reducing detrimental impacts and thereby protecting the environment are the main concern of green initiatives.

King and Lenox\(^6\) supported the notion that “Lean is Green”. They conducted an empirical study to find the relationship between lean production practices and environmental performance. In addition, Dües, Tan, and Lim\(^7\) stated that lean and green overlap in many aspects although the two paradigms have different targets towards waste elimination. They conducted a systematic review to explore both theoretical and empirical evidences to identify the interaction between lean and green. In the same context, Johansson and Sundin\(^8\) identified similarities and differences between lean and green product development. Moreover, Dhingra, Kress, and Upreti\(^9\) pointed out that lean endeavors to conserve resources extremely concur with green objectives.

In the construction industry, Lapinski, Horman and Riley\(^10\) investigated how lean principles can effectively deliver high performance green facilities. Similarly, Bae and Kim\(^11\) stated sustainable construction practices can be enhanced through lean thinking. Novack\(^12\) explored the relationship between lean and green paradigms over the life cycle of construction projects and
found a robust relationship between them. Recently, Hussein and Palaneeswaran\[4\] pointed out that design professionals can make use of the benefits accruing from synergistic integration of lean and green targets at the design stage. They highlighted that the overlapping between two paradigms at the early stage of design can leverage maximum benefits towards reducing wastes and enhancing whole life performance and design efficiency.

3 Bibliometric Analysis

A bibliometric analysis has been conducted with the journal papers that have been published during the period 2000-2017. The search has been refined with a help of Scopus engine in the following fields as shown in Table 1: (i) lean construction; (ii) green construction; (iii) integrating lean construction and green construction. The search reveals that there are 604 journal papers about lean construction and 2981 journal papers about green construction which exceedingly outweighs lean papers. The bibliometric analysis unfolds that G. Ballard and R. Sacks have the highest number of papers in lean construction with 18 papers for each, and M.R. Hainin has 10 papers, the highest number of papers in green construction. The analysis also reveals the journal that has the most publications in lean construction is Journal of Construction, Engineering and Management with 43 papers, and in green construction is Journal of Green Building with 74 papers.

Furthermore, the findings shown in Table 1 reveal top five most cited papers in the field of lean construction and green construction. Accordingly, the most cited lean paper is Formoso et al.\(2002\) with 118 citations, in comparison with, the most cited green paper is Ding\(2008\) with 357 citations. Noteworthy, the search also reveals only 20 journal papers are existing regarding integrating lean and green in the construction industry. The most cited lean-green paper is Horman et al.\(2006\) with 35 citations. Moreover, the deliberate scrutiny of these 20 papers unfolds that the main focus of these papers is towards the construction and operation stages, while the opportunities of integrating lean and green paradigms at the design stage were almost overlooked.

As a consequence of the bibliometric analysis, integration of lean and green in the construction industry is still evolving and the availability of lean-green literatures is deemed to be a big challenge for researchers in this field. Hence, this current research aims to bridge the gap in the body of knowledge through integrating lean and green paradigms at the design stage of construction projects.

4 Integrated Targets Design Model

4.1 Research Method and Processes

The first stage of this ongoing research includes developing the conceptual model for integrated targets design based on a review of literatures and conducting interviews with design professionals who have essentially contributed in fine-tuning the model. Lean-green integrated targets design model adopts the concepts of target costing and lifecycle thinking. Nicolini et al.\[13\] described target costing as a continuous value engineering aims at balancing functionality against cost through a collaborative and iterative process. Target costing procedures effectively terminate with selecting the best design option that satisfies the client's needs.
Table 1. TOP 5 CITATION LIST OF JOURNAL PAPERS FOR LEAN AND GREEN IN CONSTRUCTION ACCORDING TO SCOPUS SEARCH OVER THE PERIOD 2000-2017.

SEARCH KEYWORDS: “LEAN” AND “CONSTRUCTION”

<table>
<thead>
<tr>
<th>Rank</th>
<th>Title of Paper</th>
<th>Author(s)</th>
<th>Year</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material waste in building industry: Main causes and prevention</td>
<td>Formoso, Soibelman, De Cesare, and Isatto</td>
<td>2002</td>
<td>118</td>
</tr>
<tr>
<td>2</td>
<td>Interaction of lean and building information modeling in construction</td>
<td>Sacks, Koskela, Dave, and Owen</td>
<td>2010</td>
<td>109</td>
</tr>
<tr>
<td>3</td>
<td>Lean processes for sustainable project delivery</td>
<td>Lapinski, Hormann, and Riley</td>
<td>2006</td>
<td>101</td>
</tr>
<tr>
<td>4</td>
<td>4-1 Technology adoption in the BIM implementation for lean architectural practice</td>
<td>Arayici, Coates, Koskela, Kagioglou, Usher, and O'Reilly</td>
<td>2011</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>4-2 Models of manufacturing and the construction process: The genesis of re-engineering construction</td>
<td>Winch</td>
<td>2003</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Lean project management</td>
<td>Ballard and Howell</td>
<td>2003</td>
<td>93</td>
</tr>
</tbody>
</table>

SEARCH KEYWORDS: “GREEN” AND “CONSTRUCTION”

<table>
<thead>
<tr>
<th>Rank</th>
<th>Title of Paper</th>
<th>Author(s)</th>
<th>Year</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sustainable construction: The role of environmental assessment tools</td>
<td>Ding</td>
<td>2008</td>
<td>357</td>
</tr>
<tr>
<td>2</td>
<td>The greening of the concrete industry</td>
<td>Meyer</td>
<td>2009</td>
<td>271</td>
</tr>
<tr>
<td>3</td>
<td>Embodied energy of common and alternative building materials and technologies</td>
<td>Venkatarama Reddy and Jagadish</td>
<td>2003</td>
<td>249</td>
</tr>
<tr>
<td>4</td>
<td>Green house gas emissions due to concrete manufacture</td>
<td>Flower and Sanjayan</td>
<td>2007</td>
<td>163</td>
</tr>
<tr>
<td>5</td>
<td>Solid wastes generation in India and their recycling potential in building materials</td>
<td>Pappu, Saxena, and Asolekar</td>
<td>2007</td>
<td>154</td>
</tr>
</tbody>
</table>

SEARCH KEYWORDS: “LEAN” AND “GREEN” AND “CONSTRUCTION”

<table>
<thead>
<tr>
<th>Rank</th>
<th>Title of Paper</th>
<th>Author(s)</th>
<th>Year</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Delivering green buildings: Process improvements for sustainable construction</td>
<td>Hormann, Riley, Lapinski, ..., Harding, and Dahl</td>
<td>2006</td>
<td>35</td>
</tr>
<tr>
<td>2</td>
<td>Lean management and low carbon emissions in precast concrete factories in Singapore</td>
<td>Wu and Low</td>
<td>2012</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Effects of lean construction on sustainability of modular homebuilding</td>
<td>Nahmens and Ikuma</td>
<td>2012</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>Identification of non-value adding (NVA) activities in precast concrete installation sites to achieve low-carbon installation</td>
<td>Wu, Low and Jin</td>
<td>2013</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>An empirical study of the impact of lean construction techniques on sustainable construction in the UK</td>
<td>Ogunbiyi, Oladapo, and Goulding</td>
<td>2014</td>
<td>10</td>
</tr>
</tbody>
</table>
In the construction industry, target value design (TVD) has been developed based on target costing and lean thinking aims at designing to a specific estimate. Outstanding evidences from US healthcare projects adopted TVD confirm that this method can effectively control project budget, avoid schedule overrun and enhance long-term value for customers\(^\text{[14]}\). While cost is deemed to be a common output of the traditional design, it is set to be an input to the design process in TVD at very early stage\(^\text{[15]}\). Hence, cost target should be derived from feasibility study, not from the estimates. Furthermore, TVD method is being developed to include a wide range of values alongside with the cost. For instance, Russell-Smith et al.\(^\text{[16]}\) combined TVD method with life cycle assessment. They revealed that the environmental performance of buildings can be enhanced through designing to sustainable targets.

In this paper, the qualitative research method has been adopted to provide adequate information about the research phenomenon or contexts with a high flexibility\(^\text{[17]}\). The semi-structured face to face interview has been used as a research instrument that enables participants to use their own words depending on their own time\(^\text{[18]}\). Accordingly, an interview protocol has been developed based on previous studies towards evaluating and improving the conceptual model. The interview includes the following questions:

1. Do you think that the conceptual model contributes to address cost, environmental and energy issues at the early stage of design?;
2. Do you think that the concept of designing to integrated targets is clearly represented in the model in a way contributes to achieve lean-green objectives?;
3. Do you think that the constructs of the proposed model identified under the early stage of design (business plan, feasibility study, design development) reflect a good representation of these stages?;
4. To which extent can this model be effectively applied in construction projects?;
5. Do you have any suggestions towards improving the conceptual model?.

The purposive or judgement sampling has been adopted to recruit design professionals who are deliberately selected based on their experience \(^\text{[17]}\). The semi-structured face to face interviews with seven experienced design professionals have been conducted; their qualifications are shown in Table 2. The interviews include two architects with more than 10 experience years from two design companies in Australia, one structural designer with more than 10 experience years, two mechanical designers have a valuable experience in lean practices, and two sustainability experts with more than 10 experience years. Each interview has been digitally recorded and taken around 45 minutes. Some of the interviews have been conducted in Swinburne University campus and some of them in the interviewees’ offices. Following the interviews, transcriptions are systematically analyzed through using procedures of the thematic analysis\(^\text{[17,19]}\). Our ongoing research will adopt the mixed methods approach that aims at integrating both quantitative and qualitative data to provide empirical evidences that support the proposed model\(^\text{[19]}\).

### 4.2 Interviews Results

The 7-point rating scale is used for the questions 1 to 4. Generally, seven interviewees agree with the conceptual model with averages range between (5-7) points. Furthermore, the preliminary results of the interviews have revealed that regardless the direction of relationship between two paradigms (i.e. does lean lead to green? or does green lead to lean?), there is a consensus among participants that green is complementary and supportive to lean in the construction industry.
The interviewees have stated that considering lean principles from the early stage of design extremely concur with the objectives of green initiatives. The sustainability experts have highlighted that this model can effectively complement the current rating system in Australia Green Star. The lean experts have pointed out that effective implementation of the model in the construction industry mainly depends on owner’s needs, and whether a project is owned by the government or a private sector. The participants suggested the following points towards improving the conceptual model: (i) necessity for designing to social targets at the earliest stage of design, particularly in business plan stage; (ii) adopting Building Information Modeling (BIM) to facilitate collaboration between multidisciplinary team of a project and eliminate all wasteful activities; (iii) providing continuous monitoring and improvement for lean-green targets over the design process; (iv) ensuring quality, safety and legislation as an integral part of the design process.

4.3 Constructs of the Model

Lean-green integrated targets design model shown in Figure 1 includes four key stages: business plan, feasibility study, design development and final design. The outcomes of these stages describe the level of design maturity: design brief, conceptual design, preliminary design and detailed design. The proposed model identifies three sets of lean-green targets under early design stages. The first set of targets should be set at the business plan stage including: identify opportunities for lean-green targets, best alignment of stakeholders’ values, assessing costs and benefits, identifying quality policy, identifying requirements of safety in design, controlling uncertainty over the life cycle of a project and creating sustainable benefits. The second set

<table>
<thead>
<tr>
<th>INTERVIEWEE CODE</th>
<th>PROFESSION</th>
<th>PROFILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>Architect</td>
<td>30 years, currently senior associate in a company, accredited professionals for residential and commercial buildings, committed to environmental and social sustainability.</td>
</tr>
<tr>
<td>I2</td>
<td>Architect</td>
<td>25 years as an architect for residential and commercial buildings, specialist in housing industry, committed to sustainability.</td>
</tr>
<tr>
<td>I3</td>
<td>Structural Designer</td>
<td>28 years as a designer in the construction industry and more than 10 years in academia.</td>
</tr>
<tr>
<td>I4</td>
<td>Mechanical Designer</td>
<td>27 years as a designer of building services, group-engineering manager, valuable experience in sustainable design, asset energy consulting business, project delivery and BIM, developed many industry standards and practices.</td>
</tr>
<tr>
<td>I5</td>
<td>Mechanical Designer</td>
<td>18 years as a designer, currently a general manager, valuable experience in product development, lean processes, Revit and BIM.</td>
</tr>
<tr>
<td>I6</td>
<td>Sustainability Expert</td>
<td>18 years results driven environment and sustainability manager, currently a general manager, valuable experience in infrastructure projects, environmental planning and environmental risk assessment.</td>
</tr>
<tr>
<td>I7</td>
<td>Sustainability Expert</td>
<td>16 years as an environmental sustainability manager in the construction industry, improved an environmental management system, technical advisor for environmental matters.</td>
</tr>
</tbody>
</table>
of targets should be set at the feasibility study stage including integrating cost\textsuperscript{[26]}, environmental\textsuperscript{[27]} and energy\textsuperscript{[28]} measurable objectives to constitute the integrated targets. The third set of targets should be set at the design development stage including: reducing wastes in product design and process design\textsuperscript{[29]}, reducing whole cost of project through considering life cycle cost (LCC)\textsuperscript{[30]}, reducing environmental impacts of buildings through considering life cycle assessment (LCA)\textsuperscript{[31]} and reducing embodied and operational energy use through considering life cycle energy analysis (LCEA)\textsuperscript{[32]}. According to the proposed model, the cost target should be set at the feasibility study stage below the allowable cost, and the latter is defined as what the client is willing and really able to spend to get a desired value\textsuperscript{[30]}. On the other hand, setting environmental and energy targets should be based on reference benchmarks. Over the whole design process, the design team should adhere to achieve environmental and energy targets without exceeding the allowable limits decided by environmental and energy experts. Continuous revision of the whole design is necessary to check if the design process is tracking towards delivering the integrated targets.

**Figure 1. LEAN-GREEN INTEGRATED TARGETS DESIGN MODEL**

### 5 Conclusion

Integration of lean and green targets can maximize design efficiency and enhance sustainable
benefits in the construction industry. The integrated agenda effectively can contribute in reducing all types of wastes in the process design and the product design. The bibliometric analysis based on Scopus search revealed that few research efforts have existed during the last seventeen years towards integrating lean and green in the construction industry. Moreover, the conceptual model for integrated targets design is developed based on literature review and semi-structured face to face interviews with experienced design professionals. The proposed model adopts target costing method and life cycle thinking to drive the design process to achieve cost, environmental and energy targets. In this model, lean and green targets are identified under three sets and distributed over early design stages: business plan, feasibility study, design development. In order to leverage high performance benefits and achieve maximum design efficiency in construction projects, whole performance analysis should make use of various lifecycle techniques from the early stage of design: LCC, LCA and LCEA. Ultimately, the findings from the literatures and interviews support that the interaction between lean and green targets does exist at the design stage in a way contributes in maximizing design efficiency and enhancing sustainable development in the construction industry. The current work represents the first step of an ongoing research and further empirical results are required to support the conceptual model.

References


Causes and impact of work related stress amongst construction health and safety managers

Rogers, G.1, Manu, P.1*, Mahamadu, A.-M.1, and Dziekonski, K.1

Abstract: Work related stress (WRS) is a contributor to absence from work by workers in the construction industry. Whilst there has been research into WRS in the construction sector, there has been limited empirical research focussing on WRS amongst construction health and safety managers (CHSMs). This study therefore investigates the causes and impacts of WRS amongst CHSMs. A qualitative research strategy was used involving 8 semi-structured interviews with CHSMs in the UK. Analysis of the data revealed the main causes of WRS amongst CHSMs to include: travelling/commuting; long working hours; public speaking/presentations; the occurrence of an accident (e.g. fatality); too much paperwork; and work overload. Additionally, the main impacts of WRS include: impact on work performance; drinking alcohol; smoking; sleeplessness; impact on decision making; and impact on family. Whilst the findings reflect issues of WRS similar to those reported in previous WRS studies in the construction industry, aspects also seem more prominent or pertinent to the role of the CHSM, particularly long commuting period as CHSMs often tend not to be based at a single site. Overall, the findings offer insights that could be useful to construction health and safety professionals as well as their employers, occupational safety and health professional bodies, and relevant industry stakeholders in providing appropriate WRS support for CHSMs and other professionals in the industry.

Keywords: occupational safety and health; occupational safety and health managers; work related stress.

1Department of Architecture and the Built Environment
University of the West of England, Frenchay Campus, Bristol, BS16 1QY, United Kingdom
*Corresponding author E-mail: Patrick.manu@uwe.ac.uk
1 Introduction

The UK Health and Safety Executive (HSE) states that WRS develops because an individual cannot cope with certain work demands being placed on them [1]. Many of the ‘knock-on’ effects of WRS have a direct negative influence on work performance [2]. A HSE-commissioned study found that up to 5 million people in the United Kingdom (UK) feel stressed by their work, and a total of 12.8 million official days were lost due to stress, anxiety and depression [3]. Like other industries, the construction industry, is not new to WRS. The construction industry’s key characteristics, for example time constraints and long working hours [4], could aggravate the likelihood of WRS within the industry as shown by previous research [3, 5]. The construction industry is a hugely varied industry in terms of job roles. For example there is a huge difference between the physical factors, mental factors and job specification between construction professionals and construction trade workers [6]. Taking this into account, the types of stress, causes of stress and stress coping strategies could be different [6]. Research conducted in the past has found that architects have the highest levels of stress amongst the construction professionals that were examined, and that site managers have the most sleepless nights [7]. Furthermore, research has found that one of the causes of stress amongst project managers is the amount of interaction they have with various different stakeholders and the constant phone calls and ‘out of hours’ work they have to do [6].

Whilst it is evident that WRS exists in the construction sector and its effects on construction professionals has been researched, limited empirical work has been undertaken to explore WRS amongst construction health and safety managers (CHSMs). CHSMs play a key role in the industry through their contribution to ensuring the safety and health of workers. Fulfilling their duties can be challenging, especially in countries where there is strict enforcement of health and safety legislation, thereby making them prone to WRS. Consequently, this study investigates the causes and impacts of WRS amongst CHSMs. In the section that follows a review of WRS is presented. Subsequently, the research method employed is outlined, followed by the research findings, discussion and concluding remarks.

2 Work Related Stress (WRS)

Research by Cooper [8] suggested that it is difficult to study the term stress as it has different meanings. Roger [9] described stress as a response by the body and mind to either too much or too little pressure. Like the term “stress”, work related stress (WRS) has no single correct definition [2]. The HSE [10] defined WRS as ‘the adverse reaction a person has to excessive pressure or other types of demand placed upon them’. A different definition to this is that WRS is the psychological state which can cause a person to behave dysfunctional at work and results from people’s response to an imbalance between job demands and their abilities to cope [2]. In spite of the different definitions of WRS, it can be viewed as a harmful reaction experienced by an individual as a result of an imbalance between work place demands and the individual’s abilities to meet the demands.

WRS can have several adverse impacts on an individual including emotional, mental, and
behavioural effects. Common emotional effects are: depression; feeling disappointed with yourself; loneliness; loss of motivation; and increased emotional reaction \cite{1}. The mental effects include: confusion; short term memory loss; and lack of concentration \cite{1}. The behavioural effects include: changes in eating habits; increased smoking; increased drinking; mood swings; and changes to sleep pattern \cite{1}. The behavioural effects could also manifest in the victim’s relationship to others such as family. Hicks and Mersherry \cite{11} explains how people go home after work and take their stress out on family. Aside the impact of WRS on the individual, WRS also has work place (i.e. organisational) effects including: reduced productivity or staff performance; poor work relations; increase in mistakes; poor commitment to work; poor decision making; and increased sickness and absence \cite{12}. Hassard et al. \cite{13} is in agreement with these impacts and suggests that exposure to psychological risks can lead to stress among employees, resulting in poor performance. Furthermore, WRS can affect employee turnover and firm performance \cite{14}.

3 WRS in the Construction Industry

WRS is evident in the construction sector. For instance, a survey carried out in 2006 by the CIOB in the UK construction industry found that 5.9% of the 847 participants in the construction industry had taken time off due to what they believed was WRS \cite{3}. The extant literature on WRS in construction shows that there are many different causes of WRS in construction. Bowen et al. \cite{7} identified key causes of WRS in construction as: excessive work overload; onerous paperwork; long working hours; insufficient time with family; tight deadlines; and family responsibilities. Skitmore et al. \cite{15} reported causes including: bureaucracy; work-family conflicts; time to complete tasks; different views from superiors; inadequate recess; and work overload. The CIOB survey also identified causes such as ambitious deadlines, conflicting demands, lack of privacy; work-life balance and inadequate staffing \cite{3}. Regarding the impact of WRS in construction, aside the afore-mentioned impacts of WRS on the individual and organisation, WRS could have impacts at the project level. For instance, Beswich et al. \cite{6} suggests that WRS can affect concentration and could potentially result in a safety breach on a project site. Similarly, Edwards et al. \cite{16} stated that personnel experiencing WRS can become a hazard on site. Furthermore, WRS can affect quality performance of a project \cite{16}.

Whilst, the above demonstrates that WRS has been a subject of several studies in construction, in those studies there has been limited interrogation of the role of the construction health and safety managers (CHSM) as a victim of WRS. However, the work by Beswich et al. \cite{6} revealed that site managers and supervisors/foremen considered being responsible for the safety of others as the most stressful aspect of their job. This suggests that CHSMs, whose primary responsibility is to ensure good occupational health and safety outcomes could be highly prone to WRS. An inquiry into causes and impact WRS amongst CHSMs is thus worthwhile.

4 Research Method

A qualitative research strategy, particularly phenomenology, was used given its suitability for exploring a subject matter based on the lived experiences of others \cite{17}. WRS amongst CHSMs is
under-researched, and therefore to explore the causes and impacts, it was deemed appropriate to interrogate the subject matter by drawing from the experiences of WRS by CHSMs. Consequently, semi-structured interviews were conducted with CHSMs in order to gain their perspective on what causes them to be stressed and what the impacts of the stress are. An interview guide was designed to facilitate the interviews. Essentially, the guide requested interviewees to narrate a work event(s)/incident(s) when they experienced stress. Based on the narration, interviews were then asked to also narrate what they felt caused them to be stressed and what the effects of the stress were. In line with purposive sampling, invitations were sent to 14 CHSMs whose companies operate in the South West region of England. Out of the 14 invitations, eight participants were obtained. The profile of the participants is shown by Table 1 below. The interviews were audio-recorded and subsequently transcribed. Thematic analysis was undertaken whereby the transcripts were read iteratively and coded leading to the identification of relevant issues regarding the causes and impact of WRS.

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Role of participant</th>
<th>Years’ experience in construction</th>
<th>Years’ experience in health and safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CHSM</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>B</td>
<td>CHSM</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>C</td>
<td>CHSM</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>D</td>
<td>CHSM</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>E</td>
<td>CHSM</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td>F</td>
<td>CHSM</td>
<td>3</td>
<td>23</td>
</tr>
<tr>
<td>G</td>
<td>CHSM</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>H</td>
<td>CHSM</td>
<td>16</td>
<td>12</td>
</tr>
</tbody>
</table>

5 Findings

5.1 Causes of WRS amongst CHSMs

From the narration by the CHSMs, several causes of WRS were extracted. However, the analysis showed evidence that causes of WRS in construction for CHSMs managers are not always related to a single incident, but also as a result of several events/activities over a period of time. For example some interviewees commented that:

“...I cannot necessarily think of one particular incident where I have experienced WRS. In fact most of my stress comes as a result of a build up from things like continuous paperwork.”

“I think many people get stressed from continuous causes and pressures being put on them. I don’t think I get stressed on something that has happened.”
In view of this, the causes of WRS can be categorised as: causes related to a single incident/event; and cumulative causal factors. The causes within these categories, together with sample quotations from respondents, are given in Table 2.

### Table 2: Cause of WRS amongst CHSMs

<table>
<thead>
<tr>
<th>Cause of WRS [Category of Cause]</th>
<th>Sample Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure to meet conflicting demands [1]</td>
<td>“…one incident where I felt stressed. That incident was on a project where the standards were not particularly good, bordering on dangerous, where the pressures from the program point of view, a cost point of view and the enforcement bodies were looking very closely at the project. Whatever direction I looked had a consequence” [Participant A]</td>
</tr>
<tr>
<td>Decision making pressure [1]</td>
<td>“There were two times I can remember where the pressure of the decisions I had to make made me feel very stressed” [Participant H]</td>
</tr>
<tr>
<td>Accident on site [1]</td>
<td>“There was a guy that actually worked for the company directly and I was covering one of his sites he was on, I was on my way on the M5 when I had a call that the ambulance was on site and that he had passed away. Initially I was panicking … however looking back it really hit home and I definitely had an element of stress” [Participant J]</td>
</tr>
<tr>
<td>Public speaking / presentations [1]</td>
<td>“…I had to talk in front of about 300 people and I got very stressed building up to the presentation” [Participant D]</td>
</tr>
<tr>
<td>Working long hours [2]</td>
<td>“I get up at 5am some mornings and depending on where I have been working I don’t get in until 8pm” [Participant F]</td>
</tr>
<tr>
<td>Too much paperwork [2]</td>
<td>“I don’t think I would have any stress if it wasn’t for the constant paperwork” [Participant G]</td>
</tr>
<tr>
<td>Commuting / travelling [2]</td>
<td>“…and there are only two health and safety managers covering the west region, and even though we do delegate work, it’s almost impossible to cover all the sites, I spend ‘blooming’ long enough on the road in the first place” [Participant C]</td>
</tr>
<tr>
<td>Work overload [2]</td>
<td>“…too much work given to me at the start when I started here made me stressed, but when you gain experience you can prioritise workload” [Participant A]</td>
</tr>
</tbody>
</table>

*Notes: 1 = Causes related to a single incident/event. 2 = Cumulative causal factors.

### 5.2 Impacts of WRS amongst CHSMs

Like the causes, several impact of WRS were elicited from the interviews and they can be categorised as: direct work impact (i.e. effects related to the victim’s output or behaviour at work); and indirect impact (i.e. effects that mainly manifest out-of-work). The impacts within these categories, together with sample quotations from respondents, are given in Table 3.
Table 3: Impact of WRS amongst CHSMs

<table>
<thead>
<tr>
<th>Impact of WRS [Category of Impact]*</th>
<th>Sample Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced work performance [1]</td>
<td>“…and then sometimes I would go into work and sit at my desk and just not do anything because I couldn’t cope with it anymore” [Participant H]</td>
</tr>
<tr>
<td>Taking stress out on others at work [1]</td>
<td>“Like I said after leaving for work at 5am and not getting home till bloody 8pm some evenings, by the end of the week I snap at people in work and sometimes contractors take the back end of it when I am on site because I won’t be as lenient as normal. I will have zero tolerance” [Participant F]</td>
</tr>
<tr>
<td>Sleeping [2]</td>
<td>“…one of the biggest problem with stress is all the sleepless nights you have” [participant G]</td>
</tr>
<tr>
<td>Emotion [1, 2]</td>
<td>“I remember getting really upset that I was the one that made the decision that ultimately made him kill himself” [participant B]</td>
</tr>
<tr>
<td>Drinking alcohol [2]</td>
<td>“when I got home I would drink a lot more than usual or go straight down the pub” [participant D]</td>
</tr>
<tr>
<td>Increase in smoking [1, 2]</td>
<td>“… and I smoke probably twice as much as I normally do” [participant D]</td>
</tr>
<tr>
<td>Increase in eating [2]</td>
<td>“…at the time when I did feel that element of stress before I cut my days, my wife told me I was gaining weight. I palmed it off at first but then I realised I was just scoffing my face full of crap when I was at work and then getting fast food on my way home as a result of getting home so late” [participant D]</td>
</tr>
<tr>
<td>Domestic/family impacts [2]</td>
<td>“…and then I would just not speak to my children or wife or I would get angry at them” [participant E]</td>
</tr>
</tbody>
</table>

*Notes: 1 = Direct impact. 2 = Indirect impact.

6 Discussions

The causes of WRS identified from the interviews have similarities with those from previous studies. For example Beswich et al. [6] found that project managers, site managers and designers all perceived long working hours to be one of three most stressful aspects of their job. Additionally, designers, supervisor/foremen, site manager, and directors perceived travelling or commuting to be one of three most stressful aspects of their job [6]. The interviews suggest that commuting/travelling could be worse amongst CHSMs as they often tend not to be based on a single project site but rather oversee several project sites which can be in dispersed locations. This is highlighted by the comment by Participant C in Table 2 and also by the following comments.

“…I agree I do get slightly stressed you could call it, when I am travelling from Exeter to Leeds some days and then from Bristol to London other days, it’s just constant and there’s no stopping it” - Participant D.

“My old company was a regional contractor so travelling wasn’t an issue, but now I am with a big contractor the amount of miles I do is phenomenal” - [Participant E]

During the interviews, five out of eight interviewees also explained how commuting or travelling
was causing them stress. Excessive work overload, onerous paperwork, and conflicting demands which emerged from the interviews have also been identified as stressors in construction by previous studies \cite{3, 7, 15}. Altogether, these stressors fall in the category of the cumulative causal factors. However, the causes related to a single incident/event (shown by Table 2) have not be highlighted by previous work e.g. Campbell \cite{3}, Beswich et al. \cite{6}, Bowen et al. \cite{7}, and Skitmore et al. \cite{15}.

Regarding the impacts of WRS amongst the CHSMs, the findings are in sync with the emotional and behavioural impacts described by the HSE \cite{1} e.g. increased smoking, increased drinking and changes in sleep patterns. Sleeplessness was particularly highlighted by five out of the eight participants and thus suggesting that sleeplessness may be a common impact of WRS amongst CHSMs. The domestic/family impact identified from the interviews reflect Hicks and Mcsherry's \cite{11} account of how individuals who are stressed take their stress out on family. The impact of WRS on the performance of CHSMs also concurs with the poor work performance mentioned by Hassard et al. \cite{11} and University of Edinburgh \cite{12}. Altogether, the types of WRS impacts described by the CHSMs reflect individual, organisational (company) and/or project impacts of WRS reported in the extant literature \cite{1, 6, 16}.

7 Conclusions

CHSMs undertake duties that are critical to the safety, health and wellbeing of workers on construction sites. Their role puts them in a position where they have responsibilities for the safety, health and wellbeing of workers as well as the members of the general public who interact with the delivery of construction works. CHSMs can therefore be highly prone to WRS. However, limited insight is available on WRS in relation to CHSMs. Seeking to contribute to the discourse surrounding WRS in the construction sector, this study investigated the causes and impact of WRS amongst CHSMs. The causes of WRS amongst CHSMs can be viewed as being two-pronged: causes related to a single incident/event (e.g. occurrence of an accident on site); and cumulative causal factors (e.g. travelling/commuting). Similarly, the impacts of WRS amongst CHSMs can be categorised as direct work impact (implying effects that manifest at work); and indirect impact (implying effects that mainly manifest out-of-work). Amongst the causes of WRS, travelling/commuting may be prominent amongst CHSMs. Sleeplessness may also be a common effect of WRS amongst CHSMs. Whilst the avoidance of the causes of WRS would be an ideal remedy, it may not be possible to completely eradicate the stressors due to the nature of construction and the job demands placed on CHSMs. Consequently, strategies to assist CHSMs to effectively cope with the stressors would be beneficial.

References

Asymmetric Viewpoints on Solutions Which Enhance Construction Safety: A Social Network Analysis Approach

Li, R. Y. M.¹ Chau, K.W.², Mak, C. K.³, and Leung, T. H.⁴

Abstract: Despite the number of accident rates in Hong Kong has declined in recent years, the rate of construction accidents remains high. According to previous studies, various approaches have been proposed to address this issue. In this research, interviews are conducted with stakeholders in industries related to construction safety. This paper adopts a social network approach to critically address the factors that can enhance construction safety.

Keywords: construction accidents; social network approach; Hong Kong

¹ Li, R.Y.M.
Sustainable Real Estate Research Center / Real Estate and Economics Research Lab, Hong Kong Shue Yan University, Hong Kong
E-mail: ymli@hksyu.edu

² Chau, K.W.
Ronald Coase Centre for Property Rights Research, HKUrbanLab, The University of Hong Kong
Email: hrrbckw@hku.hk

³ Mak, C.K.
Department of Economics and Finance, Hong Kong Shue Yan University
Email: makchokei@yahoo.com.hk

⁴ Leung, T.H.
Global Development Institute, University of Manchester, UK
E-mail: thleung0418@gmail.com
1 Introduction

Safety risk in the construction industry is higher than in many industries. Moreover, when incidents occur, they can be fatal. According to the Labour Department, five major reasons led to industrial fatalities in the construction industry in 2015. Those were “fall from height”, “struck by falling object”, “contact with electricity or electric discharge”, “trapped in or between objects” and “striking against or struck by moving object” (Labour department, 2016). Besides, according to previous research, fatalities are often caused by operational faults on construction sites (Li & Leung, 2017); thus, suggesting that accidents are caused by multiple factors (Li 2018). For example:

1. Risk with height: many safety hazards are associated with working at height and vertical transportation of materials.
2. Lack of awareness: the construction industry is labour intensive and is often associated with inadequate ability and motivation to manage safety issues.
3. Unskilled labour: Less educated workers are often associated with poor safety culture.
4. Asymmetric information: Coordination problem may arise among different stakeholders (e.g., regulators, clients, main contractors, subcontractors and workers) may have coordination problems due to asymmetric information.
5. Lack of incentives: The economic wellbeing of contractors is one of the barriers to better safety measures since contractors have less incentive to increase the cost of safety (Zou & Sunindijo, 2015).

In general, stakeholders have different perspectives due to their different backgrounds. Therefore, this research employs social network analysis, a visualized analytical method, to depict the frameworks among stakeholders.

2 Safety risk management

Despite the global construction industry has slowly adopted more and more automated approach to improve the construction safety on sites and save costs (Li, 2018), the construction industry is still labour intensive. With an increase in several huge construction projects commenced in the public sector after 2009, which are mostly rail and cross-sea bridge projects (Hong Kong Trade Development Council, 2016), it has seen an increase in the number of accidents while a decrease in the accident rate (Hong Kong Trade Development Council, 2016).

Historical records show that not all types of construction sites share the same level of safety risks. For example, there is better construction safety performance among the Housing Authority’s construction sites than others for a long time. Thus, it is sensible to hypothesize that different safety management methods may lead to different safety performance on sites. Figure 1 illustrates the whole process of the Construction (Design and Management) for risk planning from preliminary design to operation and maintenance used by the Housing Authority. The whole process has a large amount of flow of documents and information with various stakeholders including clients, designers, tenderers, contractors, and so on. With the help of it, the safety risks involved in the construction project from start to finish are lowered (Occupational Safety & Heath Council et al., 2006).

3 The Social Theories in Management Culture

There are several management and social theories that influence management culture. This research employs three influential theories among the respondents, which are perceived organizational support (POS), leader membership exchange (LMX) and social exchange theory (SET). These theories explain empowerment throughout the organizational structure. With the theoretical support from these theories, the social network can demonstrate the context inside the organization and be sufficiently integrated.

All these three theories embrace the idea of building trust or causing distrust in the management process. According to Zagenczyk et al. (2010), POS and SET are consistent in the organizational support from a company to workers’ wellbeing; thus, construction safety is a crucial area in perceived support. For organizations to build up trust with employees, discretionary
treatment can strengthen the centripetal force of the company by implementing rewards and punishment for workers’ behaviour (Tsay et al., 2014). Additionally, the linkage would be strengthened in the social network. Indirectly, this can examine the effectiveness of organizational support. Since there is a different linkage between workers and an organization, the bonding between leaders and members is essential to achieve a constructive social network; furthermore, it can imply the outcome of any safety mechanism (Hoppes & Reinelt, 2010). In such an instance, the social network is not a pure top-down approach where an organization announces guidelines and regulations for workers. At management level, team leaders and members have a bonding with empowerment and trust (Kirkman et al., 2004). This implies LMX can effectively enhance analysis in the management process because the relation between manager and worker does not merely involve a single direction of support or regulations. Therefore, in conducting social network analysis (SNA), POS, LMX and SET are the three main pillars to support the formation of an integrated social network.

![Figure 1: Construction Design and Management Process (Occupational Safety & Heath Council et al., 2006)](image)

4 Social Network Analysis

We conduct interviews with various construction practitioners by using social network analysis (SNA). SNA is a common statistical analytic tool for construction project management (Zheng et al., 2016). Thus, it is essentially inspiring to construction safety studies since the risk management process comprises stable patterns of interaction among stakeholders over time (Tortoriello et al., 2011). SNA is applicable to several disciplines such as sociology, anthropology and political science. Recently, it is common in construction management study to specifically outline the contextual and holistic network pattern in the project (Borgatti & Foster, 2003). Also, the capacity of SNA leads it to be capable for further modifications to facilitate specific needs (Zheng et al., 2016).

Figures 2 to 6 provide insights with regard to stakeholders’ perspectives to enhance construction safety. This research assembles the viewpoints of methods to enhance construction safety throughout the whole construction industry. The critical factors are characterized through the visuals from SNA (Lin, 2015). The ties show the connections between two factors which implies the bonded relationship from interviewees’ perspective. Furthermore, the nodes with more ties to others are more centrally located; the stronger the ties, i.e., the more often the factors coexist, the closer their vertices are to one another (Tortoriello et al., 2011). Criteria or sub-criteria with fewer ties and/or weaker ties are more likely to be located around the margin of the network.

The figures show that each vertex in different groups of people has a different degree of centrality, which means that different groups of construction stakeholders have different
viewpoints on the key factors that are likely to enhance construction safety. The arrows show that one single aspect can alleviates construction safety problems. Therefore, the difference in pattern shows the variety of concerns from different stakeholders. On the other hand, the pattern sufficiently describes the characteristics of respondents.

Values in figures 2 to 6 indicate the number of times interviewees say a specific vertex can help combat the problem of construction safety. In brief, unique patterns show characteristics among stakeholders while the vertices indicate point out their concern. Contrary between manager level and on-site worker, the node that states “loyalty” is located in different ways; moreover, the strength of ties are also different. In Figure 2, the highest value of the sub-criteria is “favourable job condition”, indicating 40 interviewees agree that working condition alleviates the safety problem on sites. In Figure 6, we can see all the interviewees’ views on the ways to solve construction safety problems in SNA. The highest value of the criteria is POS with the value 45 mentioned by all respondents (100%), followed by LMX with the value 33 (73.3%) and SET with the value 26 (57.8%). Among all sub-criteria, the most common ways suggested by interviewees is “favourable job condition” with the value 40 (88.9%), followed by Safety Communication with the value 35 (77.8%) and “Organizational Rewards” with the value 34 (75.6%).

In general, vertices of POS, LMX and SET are shared among all groups while the ranks inside each group are different. In Figure 2, the vertices with “safety” hold strong ties; furthermore, the vertices of “punishment” and “rewards” have disparity in strength of ties. This implies the management style of this group tends to oblige the regulation through punishment to failure in safety practices. In Figure 3, the engineer emphasizes the tendency of design of better working environment as a solution for construction safety problems. Similarly, the frontline workers are essentially concerned with the safe environment and communication. Besides, the manager holds an alternative perspective, as Figure 6 shows the concerns on POS, LMX and SET are quite even.

Figure 2: safety officers & environmental officers’ views on the ways to solve construction safety problems.
Figure 3: engineers and surveyors’ viewpoints on the factors which enhance construction safety problems.

Figure 4: Managers’ viewpoints on the ways to solve construction safety problems in SNA
Figure 5: Front-line workers’ viewpoints factors that enhance construction safety.

Figure 6: All interviewees’ views on the ways to solve construction safety problems in SNA.
5 Conclusion

Although the accident rate in Hong Kong is declining in recent few years, the actual number of accidents is still high comparing it with all other industries. Despite there are regulations and guidelines implemented by the government, the construction industry is still the top dangerous industry. If an accident occurs, the possible outcome is severe injuries or even fatalities. At the same time, in contrast to other developed cities, the construction safety in Hong Kong is ultimately worse than others.

Since Hong Kong is having a growing number of construction works on sites, it is necessary to improve the construction safety management in the industry. Previous literatures show that, some essential factors are addressed to enhance safety in construction projects; for example, falling and struck by falling object are common accidents for concern. Meanwhile, there are some other factors potentially affecting the construction safety management such as unawareness of practitioners and asymmetric information.

Different stakeholders from the construction hierarchy are interviewed in this research, from managers in head office to frontline workers. Those insightful data keenly indicate the characteristics of the respondents. Furthermore, by way of SNA, it shows generally that all respondents agree POS, with LMX and SET subsequently, is the most important factor to enhance construction safety throughout all levels of labour. Additionally, several of them state their concern on favourable job condition. Yet, communication and organizational rewards are some important implications to practitioners.

Acknowledgement

This paper is supported by Construction safety index for skyscrapers in Hong Kong: A Multi-criteria decision-making approach UGC/FDS 15/E01/15

Reference

Construction Engineering and Management, 141(5), 04014096.


Research on application maturity evaluation of BIM in construction project

Dong, D. ¹, Wang, G.²*, Huang, Y.³, Duan, H.⁴, Zuo, J. ⁵, Wang, H.⁶

Abstract: In China, BIM had a rapid development in the construction industry, while in the application process it also encountered many challenges. This paper mainly evaluated the application of BIM in the construction project. Through the literature analysis and expert interviews, the main influencing factors of construction project BIM application maturity evaluation can be determined: technology, organizational processes, and contract standards. Then, the BIM application maturity model is established, including BIM application maturity model evaluation index system and weight, evaluation standard. The main results of this paper showed that the weight of the technical factor, organizational process factor and standard contract factor of the criterion layer was 0.54, 0.16, and 0.30, respectively, by the hierarchy process analysis. And the BIM application maturity evaluation model of the construction project was built, the scoring criteria of BIM application maturity index were set. Finally, the characteristics of BIM application of five maturity levels were described. These findings can promote the further development of BIM in the construction industry.

Keywords: Construction project; BIM application; Maturity evaluation; Analytic Hierarchy Process (AHP).

¹ Dong, D.  
School of College of Civil Engineering, Shenzhen University, China

²* Wang, G.  
Corresponding author, Department of College of Civil Engineering, Shenzhen University, China  
E-mail: of820@263.net

³ Huang, Y.  
School of College of Civil Engineering, Shenzhen University, China

⁴ Duan, H.B.  
Department of College of Civil Engineering, Shenzhen University, China

⁵ Zuo, J.  
School of Architecture & Built Environment, the University of Adelaide, Australia

⁶ Wang, H.Y.  
Department of College of Civil Engineering, Shenzhen University, China
1 Introduction

In China, BIM had more rapid development during the decade years, especially in the last three years, national and local governments have promulgated the necessary use of BIM policy [1]. In the past two years, the application of BIM technology has been developing rapidly. “China Construction Industry Information Development Report: BIM Application and Development” has reflected the basic situation of BIM application in China [2]. The report investigated two hundred and twenty-three construction enterprises in China, which were mainly construction units, cost consulting and BIM consulting companies. Among them, construction companies accounted for the vast majority. All the companies surveyed affirmed the application value of BIM, especially in collision detection, deepening design, construction plan optimization and engineering statistics applications, the current application of these BIM is relatively mature. Although the construction companies support BIM, there is no BIM corresponding investment or less investment, indicating that the current stage of the BIM application market is not very mature, many companies put the relevant BIM costs but did not receive the same benefits. Also, the majority of enterprises use BIM in the technical management, cost management, deepening design, the total package of coordinated applications and scheduling management [3]. Currently, large and medium-sized design institutes and some consulting firms are equipped with BIM team, more involved in the application of BIM projects; and construction units do not have specialized BIM talent, the application of BIM is less; there is not equipped with BIM professionals in property management, and almost no use of BIM in the operation stage.

In general, the BIM application is mainly concentrated on the design stage currently, while there is only part of the BIM application in the construction phase. Although the development of BIM has some achievements, there are still many challenges, such as BIM data exchange core issues have not fundamentally resolved, BIM application depth is not enough, mostly stay in the design stage. Real BIM application should run through the entire lifecycle of the project, serving the various stages of the project, using BIM at some stage cannot effectively play BIM's maximum benefit. Also, BIM has only a small amount of application at a particular stage of the project.

According to the importance of BIM technology and the advantages and benefits of BIM application, it can be seen that BIM will be used more and more. Besides, BIM will cause the significant change of construction in our country and achieve the popularity of BIM application. However, in China, there are still many questions including the particular circumstances of BIM technology use in the construction project, the specific challenges of BIM application, the level of BIM development, how to develop it in the future and so on. Therefore, it is necessary to build a construction project BIM application maturity evaluation system to clarify the construction project BIM application level and the difficulties in next stage BIM application, and specify the direction of BIM development in the future.

The maturity of BIM application refers to the development process that BIM has experienced in engineering projects from simple, low to sophisticated and advanced (more mature state). The building information modeling application maturity model (BIMAMM) can be used not only to evaluate whether the process of BIM application in the construction project has the characteristics of process and integration, and it also provides the reference for measuring the level of use of BIM. Some scholars have studied the maturity model of BIM [4-7]. For example, Brayden and David summed up the success cases of BIM in the world, summed up the success factors of these
projects and formed the criteria as a reference for evaluating whether the BIM project was successful [7]. However, the BIMCMM theory is not easy to understand and operate, and it does not apply to China's BIM application evaluation; China BIM application evaluation of the study is mainly on the assessment of general research indicators, and more stay in the qualitative evaluation.

The purpose of this paper is to develop a maturity framework, which can evaluate the stage of current BIM application, this can offer the direction of future BIM development in China's construction industry. Therefore, this paper summarized the factors that influence the maturity of BIM through the literature and the filed research and constructed the BIM application maturity evaluation factor system for the construction project. Finally, this paper also offered some reference or guidance to the application of BIM in China's construction industry.

2 Construction project BIM application maturity evaluation elements

Through literature review and filed research, the construction project BIM application maturity evaluation index system was built including technology, contract criteria and organizational process three main factors. The specific factors that affect the maturity evaluation of the construction project BIM are summarized in Table 1.

| Table 1 Characteristics of construction project BIM application maturity evaluation factors |
|---------------------------------|---------------------------------|
| Level 1 indicators | Level 2 indicators |
| **Technology factor** | Model detail level (model geometry and non-geometric information); Data exchange and information sharing; Application depth based on BIM function (number and effect of application points); The extent to which BIM addresses project management issues (the number and effect of project management issues are addressed); Research and development based on BIM (the development of software platform and BIM software function); |
| **Organizational process factor** | BIM professional level of project participants (owners, designers, constructors, consultants, and operators); Participation of project parties in BIM application (owners, designers, constructors, consultants, and operators); The depth of collaboration among the organizations; The continuity and degree of convergence of BIM application (the level of continuity of BIM work, based on the BIM working system); Work efficiency based on BIM. |
| **Contract standard factor** | BIM contract (clear responsibility for each participant); BIM standards and specifications (uniform standard of BIM application, results in delivery format and depth of BIM project). |

3 Construction of BIM application maturity evaluation model for construction project
3.1 Construction project BIM application maturity evaluation index system and weight

This paper employed the analytic hierarchy process (AHP) method to evaluate the application maturity of BIM for the construction project. When determining the weight of the index, combined with the expert scoring method, so that the weight of the indicators was more reasonable. Through the induction analysis of the maturity index of the application project BIM, the BIM application evaluation index system was established. Table 2 shows that the criterion layer contains three factors: technology factor, contract criteria factor and organizational process factor. The programming layer consists of 12 specific indicators. All the weights are acceptable by calculating the consistency ratio of all judgment matrices.

Table 2 Construction project BIM application maturity evaluation index system and weight

<table>
<thead>
<tr>
<th>Target layer</th>
<th>Criteria layer</th>
<th>Weights</th>
<th>Criteria layer B</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction project BIM application maturity</td>
<td>Technology A1</td>
<td>0.54</td>
<td>Model detail level B1</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Data exchange and degree of information sharing B2</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Application depth based on BIM function B3</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The extent to which BIM addresses project management issues B4</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Organizational process A2</td>
<td>0.16</td>
<td>Research and development based on BIM B5</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BIM professional level of project participants B6</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Participation of project parties in BIM application B7</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The depth of collaboration among the organizations B8</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>The continuity and degree of convergence of BIM application B9</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Contract Standard A3</td>
<td>0.30</td>
<td>Work efficiency based on BIM B10</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BIM contract B11</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>BIM standards and specifications B12</td>
<td>0.10</td>
</tr>
</tbody>
</table>

3.2 Weight analysis

The weight of each factor of the criterion layer is calculated by the analytic hierarchy process software. From Table 2, it can be seen that the weights of technology, organizational process, and contract standard factors are 0.54, 0.16, and 0.30, respectively.

Through the comparison can be found, the weight of technology factor is the highest, it means that technology factor is the most critical to evaluate the BIM application. From another aspect, it can also be seen that there are many technical difficulties did not overcome about BIM application development at the present stage. For example, standardization of BIM model data, BIM software improvement and localization and the development of BIM application software. The organizational process factor is not as important as the other two factors at this stage. As the government vigorously promote the development of BIM, many companies have set up a special
BIM team or department and have a corresponding organizational structure. The current obstacles to the development of BIM application are BIM-related technology and standard issues. The importance of contract criteria is second compared to technology and organizational process factors. BIM standard has been the principal research objective, China has made some achievements, such as the Ministry of Housing and Urban and Rural Construction is about to be released in July 2017 “building information model application of uniform standards.” However, there are a lot of critical technologies are not resolved in the criteria, and they also do not meet the requirements of the development of BIM. Besides, the results of program layer weight analysis are consistent with the target layer (see Table 2). The detailed analysis process is not shown in the paper.

3.3 Construction project BIM application maturity model classification

Construction project BIM application maturity model (BIMAMM) level is used to describe the level of application of BIM in the project, classify the level of BIM application and establish a milestone for each level as a sign of BIM application level to a certain extent, and what work you need to do when achieving this level. Based on the BIM implementation of the framework and BIM maturity stage theory by Succar [8], combined with capability maturity model (CMM) classification method, BIM application maturity is divided into five levels, namely: (1) initial level: BIM application preparation phase; (2) definition level: object-based modeling phase; (3) management level: model-based collaboration phase; (4) integration level: collaboration-based integration stage; (5) optimization level: integrated project delivery phase. With the development of technology, the future development of BIM cannot be being predicted, so this paper does not have an upper limit on BIMAMM.

3.4 Evaluation criteria for BIM application maturity model for construction project

According to the division of the BIM maturity level of the construction project and the expert interview, in this paper, the maturity of each index is divided into five maturity levels, from the number 1-5 to show maturity increased gradually.

In Table 3, the scoring method is by the experts in accordance with the scoring criteria for scoring, respectively, take 1-5 points, 1 points on behalf of the most immature BIM application, 5 points on behalf of the most mature, summed up the experts scoring, and then take the average as the final evaluation score.
<table>
<thead>
<tr>
<th>Number</th>
<th>Index</th>
<th>1 (preliminary)</th>
<th>2 (growing)</th>
<th>3 (raise)</th>
<th>4 (mature)</th>
<th>5 (continuous improvement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Model detail level</td>
<td>Not detailed (with basic shape, rough size, and shape)</td>
<td>Less detailed (approximate geometric size, shape, and direction)</td>
<td>Primary detailed (precise geometry, including some information, such as material, product information, etc.)</td>
<td>More detailed (detailed model entities, it can be made for the manufacture of components. Attached to the construction information, including production, transportation, installation, etc.)</td>
<td>Very detailed (Determine the size of the model, including the information required for the completion of the submission: technical parameters of the equipment, product brochures, maintenance and repair manuals, etc.)</td>
</tr>
<tr>
<td>2</td>
<td>Data exchange and information sharing</td>
<td>No data exchange and sharing</td>
<td>Limited information is converted between software products</td>
<td>Most of the information is converted between software products</td>
<td>More information is converted using IFC format or another similar information exchange formats</td>
<td>All information is converted using IFC or other similar information exchange formats</td>
</tr>
<tr>
<td>3</td>
<td>Application depth based on BIM function</td>
<td>Planning phase: BIM model maintenance, site analysis, building planning</td>
<td>Design phase: program demonstration, visual design, collaborative design, performance analysis, engineering quantity statistics</td>
<td>Construction phase: pipeline synthesis, construction progress simulation, construction organization simulation, digital construction, material tracking, construction site cooperation</td>
<td>Operation phase: delivery of completed model, asset management maintenance plan, space management building system analysis, disaster emergency simulation</td>
<td>Can be applied to the demolition phase of the project, that is, it can achieve the use of the whole life cycle</td>
</tr>
<tr>
<td>4</td>
<td>The extent to which BIM addresses project management issues</td>
<td>Cannot be solved</td>
<td>Can solve some of the problems of project management</td>
<td>Can solve most of the problems of project management</td>
<td>Can basically solve the problems in project management</td>
<td>Can completely solve all the problems of project management, and use BIM to optimize the project management</td>
</tr>
</tbody>
</table>

Table 3 Construction project BIM application maturity index scoring questionnaire

<table>
<thead>
<tr>
<th>Number</th>
<th>Index</th>
<th>1 (preliminary)</th>
<th>2 (growing)</th>
<th>3 (raise)</th>
<th>4 (mature)</th>
<th>5 (continuous improvement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Model detail level</td>
<td>Not detailed (with basic shape, rough size, and shape)</td>
<td>Less detailed (approximate geometric size, shape, and direction)</td>
<td>Primary detailed (precise geometry, including some information, such as material, product information, etc.)</td>
<td>More detailed (detailed model entities, it can be made for the manufacture of components. Attached to the construction information, including production, transportation, installation, etc.)</td>
<td>Very detailed (Determine the size of the model, including the information required for the completion of the submission: technical parameters of the equipment, product brochures, maintenance and repair manuals, etc.)</td>
</tr>
<tr>
<td>2</td>
<td>Data exchange and information sharing</td>
<td>No data exchange and sharing</td>
<td>Limited information is converted between software products</td>
<td>Most of the information is converted between software products</td>
<td>More information is converted using IFC format or another similar information exchange formats</td>
<td>All information is converted using IFC or other similar information exchange formats</td>
</tr>
<tr>
<td>3</td>
<td>Application depth based on BIM function</td>
<td>Planning phase: BIM model maintenance, site analysis, building planning</td>
<td>Design phase: program demonstration, visual design, collaborative design, performance analysis, engineering quantity statistics</td>
<td>Construction phase: pipeline synthesis, construction progress simulation, construction organization simulation, digital construction, material tracking, construction site cooperation</td>
<td>Operation phase: delivery of completed model, asset management maintenance plan, space management building system analysis, disaster emergency simulation</td>
<td>Can be applied to the demolition phase of the project, that is, it can achieve the use of the whole life cycle</td>
</tr>
<tr>
<td>4</td>
<td>The extent to which BIM addresses project management issues</td>
<td>Cannot be solved</td>
<td>Can solve some of the problems of project management</td>
<td>Can solve most of the problems of project management</td>
<td>Can basically solve the problems in project management</td>
<td>Can completely solve all the problems of project management, and use BIM to optimize the project management</td>
</tr>
<tr>
<td>Number</td>
<td>Index</td>
<td>1 (preliminary)</td>
<td>2 (growing)</td>
<td>3 (raise)</td>
<td>4 (mature)</td>
<td>5 (continuous improvement)</td>
</tr>
<tr>
<td>--------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5</td>
<td>Based on BIM research and development</td>
<td>Library development</td>
<td>Secondary development based on BIM software (data interface (API) development)</td>
<td>Database development (for the storage of project resources, tasks, can provide data resources for enterprise quota. Similar to the software of MS Project)</td>
<td>Project management collaborative work platform (model building, construction simulation, data management platform and operation and maintenance management platform, etc.)</td>
<td>Software platform (such as operation and maintenance management platform, combined with the Internet)</td>
</tr>
<tr>
<td>6</td>
<td>The depth of collaboration among the organizations</td>
<td>No cooperation</td>
<td>Have some cooperation, but did not adequately fulfill the relevant obligations</td>
<td>Following the BIM contract to meet obligations</td>
<td>The construction of the parties with a higher degree of collaboration, there are some collaboration outside the contracts</td>
<td>The building of the parties with a high level of cooperation can actively participate in solving the problem</td>
</tr>
<tr>
<td>7</td>
<td>Participation of project parties in BIM application</td>
<td>Participation is very low</td>
<td>Low participation (reference standard: mainly to see the parties in the BIM application of the attitude and the relevant action taken)</td>
<td>Participation in general</td>
<td>High participation</td>
<td>Construction parties are fully involved, and actively use BIM technology</td>
</tr>
<tr>
<td>8</td>
<td>BIM professional level of project participants</td>
<td>Very low</td>
<td>Relatively low (refer to the standard: whether the staff can be skilled use of BIM, can complete all the BIM application)</td>
<td>general</td>
<td>Relatively high</td>
<td>Very high</td>
</tr>
<tr>
<td>9</td>
<td>The continuity and degree of convergence of BIM application</td>
<td>There are only a few BIM application points</td>
<td>BIM does part of work of the project phase</td>
<td>the majority of work of the project phase</td>
<td>the majority of the project phase</td>
<td>All the work of the project phase is completed by BIM and converged</td>
</tr>
</tbody>
</table>
## Continued Table 3 Construction project BIM application maturity index scoring questionnaire

<table>
<thead>
<tr>
<th>Number</th>
<th>Index</th>
<th>Construction project BIM application maturity evaluation index description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 (preliminary)</td>
</tr>
<tr>
<td>10</td>
<td>Work efficiency based on BIM</td>
<td>Very low (mainly depends on the duration, work effects, and reduced work errors)</td>
</tr>
<tr>
<td>11</td>
<td>BIM contract</td>
<td>The primary content of BIM work and the requirements for delivery</td>
</tr>
<tr>
<td>12</td>
<td>BIM standards and specifications</td>
<td>No BIM-related standards, regulations</td>
</tr>
</tbody>
</table>
4 Conclusion

BIM can better achieve the construction project management information, speed up the industrialization and automation. This paper discussed how to evaluate the application level of BIM from the perspective of the whole life cycle and the entire project level. The main contributions of this paper are as follows: (1) The status of BIM application in China was briefly introduced. (2) Literature analysis summarized the influencing factors of BIM application maturity, the main factors are technology, organizational process and contract Standard factors. (3) The weights of each index were calculated by analytic hierarchy process (AHP) method, the technology factor was the most significant factor. Then the BIM application maturity evaluation model was built, including the criteria of each indicator for the BIM application maturity and the BIM application of the characteristics of five maturity levels, then proposed some recommendations to deepen the BIM application. All results of the research provide some guidance for BIM application. In addition, there are many limitations and shortcomings in this study: for example, the applicability of the BIM application maturity evaluation model for construction projects.

References

Demystifying the Socio-technical Context of Deploying Distributed PV Systems within the Building Industry

Weerasinghe R. P. N. P., Yang, R. J.*, Too, E. and Le, T.

Abstract: The distributed photovoltaic (PV) system is a recently emerging concept in the building industry. The system is a promising energy source that could potentially achieve renewable energy targets and carbon reduction strategies. However, there is a significantly less growth on deploying distributed PV system in the building industry. The deployment context is a complex system that interrelate diverse technology artefacts, multiple stakeholders, policies, etc with their attributes. Therefore, the PV deployment requires not only the technical fact but also the social, structures and dynamic interactions. In this regard, the paper focuses to explore the deployment of grid connected distributed PV through a dynamic socio-technical perspective, with a particular focus on identifying complex and dynamic environment through an extensive literature review.

Keywords: Distributed grid connected photovoltaic system; socio technical systems; complexity; dynamic.

1 Introduction

The building industry accounts for 30% of the world total energy consumption and it is the largest energy consuming sector [1]. The commercial and residential buildings in Australia contribute 23% of the greenhouse gas emission [2][11]. Achieving a substantial reduction in energy and greenhouse gas is a serious issue for professionals who implement renewable energy applications and more energy efficient approaches in their buildings [1]. Further, Governments are accelerating on the investment of such projects through policies, regulations and other incentive programmes [2][3]. In line with the Paris Agreement, the Australian government has set a renewable energy target of delivering 23% of Australia’s electricity from renewable energy sources by 2020 [2]. In the Australian context, harnessing solar resources, particularly from PV system has revealed immense benefits and potential in the building industry to achieve energy efficiency targets [3][14][15].

The PV solar energy generation accounts for 2% of the Australia’s total electricity generation and PV generation is growing recently by 23% in 2014–15 [11]. In 2014, more than 15, 000 commercial buildings in Australia have installed a solar power system [17] and more importantly, 17% of the Australian households have installed roof top solar PV systems [11]. However, the deployment of solar PV systems is still slower in the building industry, despite the noteworthy growth in the residential sector in last few years [15][14]. In present, PV applications are being designed in the buildings to self-generate their energy and/or share with others connecting utility grid [5][6][13]. Accordingly, many PV applications are employed in the buildings.

The grid-connected distributed PV system is becoming a more attractive technology together with the centralised power systems [16][18]. The distributed PV system generates energy at or near the point of usage and it creates decentralised power system to meet the local and small energy requirements [16]. This offers significant benefits against the centralised power generation. The system is a sustainable

---

1 Weerasinghe R. P. N. P.
School of Property Construction and Project Management, RMIT University, Australia

2 *Yang, R. J.
Corresponding author; School of Property Construction and Project Management, RMIT University, Australia
Email: rebecca.yang@rmit.edu.au

3 Too, E.
School of Property Construction and Project Management, RMIT University, Australia

4 Le, T.
School of Property Construction and Project Management, RMIT University, Australia
approach to zero environmental pollution in generation, distribution and energy consumption\cite{11} and it is one of the premium ways to achieve net zero energy buildings. Further, the building owners may not require to highly relying upon the utility grid in which they can withstand for infrastructure breakdowns and or other weather-related emergencies \cite{11}\cite{15}. The approach is a major concern for urban planning \cite{11}\cite{16}\cite{22}. Given the opportunities, governments are also encouraging this emerging electricity transformation. Unfortunately, there is a little attempt to embrace the distributed PV system in the building industry \cite{14}.

The deployment of distributed PV system is not only a function of the technological process; rather it is intermediated by a range of stakeholders, technologies, resources, capital expenditure, innovation etc. The deployment of distributed PV system is a complex structure comprised of multiple stakeholders, diverse technology, standards and policies, tasks, resources and their attributes \cite{23}. Given the ambiguities, complex and uncertainty associated with emerging industry developments, socio technical perspective is essential to capture complex social context. Therefore, the interactions of each “actants” are dynamic and create a complex environment. In this regard, it is required to identify the key actants and their interactions to deploy the distributed PV system.

Therefore, the focus of this research paper is to demystify the socio-technical context of deploying distributed PV systems within the Building Industry. This paper is structured in a way to identify the “actants” and their dynamics. A literature review has been carried out to identify the key actors in the social context.

2 Photovoltaic statistic in Australia

Electricity demands in Australia increased at an annual average rate of 2.7% in recent years \cite{111}. Australian governments at federal, states and local government are looking for more renewable energy resources despite the fossil fuel power \cite{111}. The potential of harnessing the solar power is promising green electricity generation in Australia \cite{111}\cite{15}. The annual solar radiation in Australia is nearly ten thousand times larger than Australia’s current annual energy consumption \cite{111}. Australia has the highest average solar radiation per square metre in the world. The country is experiencing rapid growth of PV solar energy applications in the present context. Table 1 shows the growth of PV deployment in Australia over the period from 1992 to 2016 in four sub markets. The four sub markets are i) Off grid domestic PV power system: provide power mainly to households or community, ii) Off grid non-domestic PV power system: use for industrial and agricultural applications, iii) Grid connected distributed PV power system: provide power to customers and excess power supplying to the grid directly to the electricity grid and iv) Grid connected centralised PV power system: perform the function of centralised power stations.

Among the four sub market, there is a huge growth of grid connected distributed PV market from 2011. The grid connected distributed PV system category is further elaborated in Table 2. Table 2 shows the Australian PV power installed during 2016. It is evident that the residential sector is dominating the PV market.

| Table 1: Cumulative installed PV MWp\cite{15} |
| a* | 1.56 | 2.03 | 2.6 | 3.27 | 4.08 | 4.97 | 6.07 | 6.93 | 9.22 | 11.07 | 12.45 | 14.28 | 16.59 |
| b* | 5.76 | 6.87 | 8.08 | 9.38 | 11.52 | 13.32 | 15.08 | 16.36 | 17.06 | 19.17 | 22.74 | 26.06 | 29.64 |
| c* | 0.01 | 0.02 | 0.03 | 0.08 | 0.2 | 0.85 | 1.49 | 2.39 | 2.8 | 3.4 | 4.63 | 5.41 |
| d* | 0.02 | 0.2 | 0.21 | 0.52 | 0.54 | 0.54 | 0.54 | 0.66 | 0.66 |
| Total | 7.30 | 8.9 | 10.7 | 12.7 | 15.7 | 18.7 | 22.52 | 25.32 | 29.21 | 33.58 | 39.13 | 45.63 | 52.30 |

| a* | 19.89 | 23.88 | 27.71 | 32.68 | 40.76 | 44.23 | 54.6 | 64.6 | 74 | 86.9 | 102.9 | 118.3 |
| b* | 33.07 | 36.65 | 38.73 | 40.66 | 43.14 | 43.57 | 46.89 | 53.02 | 58.0 | 61.2 | 70.4 | 91.9 |
| c* | 6.86 | 9.01 | 15.04 | 29.85 | 101.2 | 479 | 1267.9 | 2275.9 | 3070 | 3875 | 4578 | 5326 |
| d* | 0.76 | 0.76 | 1.01 | 1.32 | 2.53 | 3.79 | 7.4 | 21.5 | 24 | 107 | 358.3 | 445.8 |
| Total | 60.58 | 70.30 | 82.49 | 104.5 | 187.6 | 570.9 | 1376.8 | 2415 | 3225 | 4130 | 5109 | 5986 |

Note*: (sm) sub market, (a) Off grid domestic PV power system, (b) Off grid non-domestic PV power system, (c) Grid connected distributed PV power system, (d) system perform the function of centralised power systems
Note*: The Building attached PV (BAPV) applications refers roof top PV systems that mounted on the building structure and Building Integrated PV (BIPV) refers PV system that integrates with buildings (more details in referring section 4).

In fact, one out of every five Australian households is turning to solar electricity [11]. The growth was the direct results of government policies that have provided financial incentives and the falling cost of PV systems in the country [5][15][2]. Further, the network tariffs and climate change mitigation policies, public acceptance of energy efficiency technology and the emergence of small business and their benefits are encouraging for residential to rapidly uptake the PV systems [3][4][3].

However, it is evident that there is a less growth rate of deploying PV system in commercial and industrial buildings compare to the residential sector. In contrast, the commercial and industrial sectors consume more electricity than residential sector. Further, the solar energy still represents 2% of the Australia’s total electricity generation [11]. Therefore, there is a potential for the growth of distributed PV system in the building industry while learning experience from the growth of the residential sector.

3 The concept of distributed PV system

The distributed power is power generated at or near the point of usage and creates decentralised power system to meet the local and small energy requirements [16]. The distributed power system serves a single structure, such as a home or business, or it may be part of a micro grid. The system is small in capacity compared to the centralised power system [16]. Many countries are encouraging distributed power systems mainly due to system efficiency, cost effectiveness, quick production and delivery [3][4][24]. In Australia, the majority of the installed PV systems are distributed systems [4].

3.1 Benefits and Limitations

The distributed PV system is a resource and economically viable approach that matches domestic electricity demand [3]. The system could gradually substitute existing fossil fuel based electricity generation and it is well suited for energy deployment in remote areas [4]. In addition, the system reduces the peak demand, congestion in the utility networks, mitigate risks availability of outage protection, avoid energy generation and environmental costs, and other network investment costs [3][22][26]. Further, the system offers benefits for property owners/customers to lower the energy bills, fewer disruptions for energy usages etc. Accordingly, the distributed PV system creates significant benefits for society and other key stakeholders in this context [3][4].

However, both technical and non-technical issues impose new challenges for the deployment. Integration of distributed system into conventional electricity grids is a key technical challenge. Adoption of new technology, inadequate quality of technology, increase congestions in the utility grid, national and local government policies, not confidence in the reliability of the system are few of them [3][16][24]. Further, the current electricity network rules, regulations and pricing structures are also not still demarcated for proper deployment of grid connected system among building sector [12][14].

3.2 Why Socio Technical Perspectives

It is evident that there is a need of systematic approach for deploying distributed PV systems in the building industry. The deployment of distributed PV system is not only a function of technological process, rather it is intermediated by the range of stakeholders, technologies, resources, capital expenditure, innovation etc [4][27]. Further, the distributed PV system is a complex system composes of interconnected entities of human, technology, resource, information and tasks and with their attributes in varying level of dynamic interactions. The fundamental concern is that technology development emerges from the social interactions among diverse social groups for their interest on multiple artefacts [9][8]. Hence, the sociotechnical concentration is required for fully explore the deployment of distributed PV system context. In this argument, the study employs socio-technical perspectives to understand the social context of the distributed PV system in buildings.

<table>
<thead>
<tr>
<th>Building attached PV*</th>
<th>Residential</th>
<th>654</th>
<th>544</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial</td>
<td>171</td>
<td>208</td>
</tr>
<tr>
<td></td>
<td>Industrial</td>
<td>0</td>
<td>28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Integrated PV*</th>
<th>Residential</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Commercial</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Industrial</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Network theories are the best way to explore the socio technical context of a system. Network theories including social network theory, social construction of technology, actor network theory, and dynamic social network study how the social structure of relationships around a person, group or organization affects beliefs or behaviours covering how social relations affect social entities and content [8][11]. The study selects dynamic social network theory which capable of capturing multi-link, multi nodes, complex and dynamic socio technical context to understand the deployment context [19]. The first step is to explore the dynamic socio technical context of the deployment of distributed PV system context by defining actants and their relationships which are addressed in this study.

4 Abstraction of the socio technical context

PV deployment patterns are diversified and realising the full value of the distributed PV system is required to unravel the actants in the socio technical context. In this regard, the section identifies the actants; technical artefacts, agents, resources in this complex social context.

4.1 Technology Artefacts

Building design features

The BIPV or BAPV are two building design features of the PV system. In BIPV, PV modules are attached to the building structure and functioning as an element of the building structure and as an architectural element to enhance the building appearance. For an example, PV roof, walls, envelops and vertical facades, curtain walls, awnings, windows and skylights. In the present context, most of the building structural elements are replaced by the PV products [23]. In BAPV, the PV modules are mounted on the building structure particularly on the roof top. This is often installed for existing buildings to avoid changes [6]. Despite the user requirement, location, orientation, space and other building characteristics of the building influence the decision of BIPV or BAPV [23].

PV system

A typical PV system comprises of PV modules and balance of system (BOS). The BOS is a set of components connects to the PV modules that varies with the PV applications; utility grid or micro grid connected or energy storage [25][26].

PV Modules: In the present, i) crystalline silicon photovoltaic, ii) thin film and iii) ongoing research are three technology generations in PV modules. 80-85% and 10–15% of the global PV sales use crystalline silicon PV and thin film respectively. Crystalline silicon PVs are made of monocrystalline and polycrystalline materials. Thin-film solar modules are thin layers of semiconductor materials and light in weight [12]. The cost and the efficacy are the major concerns. Ultra-high efficiency solar cells, advanced materials, innovative product development strategies are examples of the ongoing research approach that lead for high efficiency, cost effective and innovative PV modules.

Inverters: Inverters are solid state of electronic devices that convert the DC power into AC power. Mainly, the types of inverters are varying with the system requirements such as off grid, on grid, battery storage, residential and commercial use, capacity and etc [15]. Further, there i number of different technologies for inverter systems such as central, string, multi string, and ac-module configurations [29].

Energy storage batteries: Mainly, Lead-acid (Pb-acid) batteries and nickel/cadmium (Ni/Cd) batteries are used for energy storage while many innovative energy storage products are being introduced in the current market [25]. The main characteristics of energy storage systems for PV building applications are cost, cycle life, availability, ease of operation and maintenance. This is an expensive approach [5]. Battery storage has attracted significant new investment to complement the new uptake [15].

In addition, meter controllers (devices to pass electricity to the grid and domestic use), smart metering (automotive distribute), modules strings arrays and supporting structures, fuses and switches, cables and wires are other items in the BOS. However, the advanced inverters, controllers and interconnection technologies, PV modules, mounting frames, structure, additional metering or cabling, data-logging should be compatible with the Australian standards and codes and match with safety requirements [25][12][15].

Software application: Diverse software applications are supporting initial decisions making process in terms of cost benefit analysis, financial feasibility, design features etc [6]. Further, the software packages provide performance of the system; instant PV generations and consumptions, solar radiation predictions, real time performance, demand side management [6].
4.2 Key stakeholders

Multiple stakeholders perform various tasks in the distributed PV system and their role, inputs; coordination social relations are required for system performance. This section mainly identifies key stakeholders and their roles and attitudes for up taking the distributed PV system.

Property owners or client: The property owners are the focal actor in this context. The residential, commercial and industrial property owners hold diverse perception towards PV installation though they mainly emphasize on green and environmental, aesthetic appearance, economic and financial feasibility and other opportunities for commencing the distributed PV system [10][20][12][8]. Financial viability or cost of buying the PV system is an important determinant of the building owners and the price of the PV system is directly influence the deployment of the PV system [28]. In some cases, facilities management team participates on behalf of the owner. Further, the property owners can be the end users. The end users or occupants are liable for system maintenance, safety, system improvements and etc [20].

Design team: a team consisting of developers/builders, PV consultants, architects/building designers, engineers (civil, structural and service), perform multiple tasks [14]. The PV consultant may ensure the viability of the PV installation. Climatic considerations, building orientation and location, types of applications BIPV or BAPV, types of PV modules and capacity, aesthetics, load diversity, energy efficiency, grid infrastructure and end use etc are examined for the implementation [15][20][22]. The team will suggest an innovative multifunctional approach that suits for the building structure and the user requirements [21]. The design team should focus on lifecycle stages of the PV system for examples, maintenance, and long-term performance criteria, further expansions and etc to minimise the design defects and other maintainability issues [6][13]. Moreover, it is essential to propose a design that complies with the building codes, policies and standards despite the client requirements [15].

Installation team: The PV system installers such as electricians along with the other construction parties, roofers, building service suppliers and etc involved in mounting or attaching the systems as per the design [14]. The connection to the utility grid or micro grid and a meter change/reconfiguration are two tasks to complete by the energy supplier/utility supplier [20]. The size of the PV system and the technical characteristics should be matched with the grid standards [14][20]. The registered electrician or a solar panel installation specialist are required to perform the testing and cleaning every five years depending on the system capabilities locations and local environmental factors [18][20]. Further, the relevant authorities conduct audits to ensure the system standards [15]. In addition, recyclers, waste collectors are set of parties that meet in disposal stage. The energy storage (battery) manufacturer is responsible for collecting and transporting, probably through the incorporation of collectively supported PV-module recycling entities.

PV industry: PV industry mostly includes PV cell manufacturer; PV module manufacturer mainly prefabricated manufactures, BOS equipment manufacturers, retailers who sell PV products and services, equipment assembling, product testing and etc [18][21]. In Australia, the local and foreign PV cell manufacturer supply PV modules [18]. The BOS components are from mature electrical markets and the majority of the BOS and supporting structures produce locally [15]. Small and medium entities perform various tasks in the solar marker such as selling solar products, designing and installing systems [15]. However, the Clean Energy Council (CEC) recommends selecting accredited solar retailers, solar designers and installers. According to the CEC, the designers and installers of the PV system must be accredited by the CEC to be eligible for the government incentives for solar credits [29][15][20]. Accordingly, a number of individuals and entities has been arisen in the PV industry to offer PV related products and services creating huge employability opportunities which also contributes to the economy by payment of income taxes and GST [13].

Electricity Sector: In the Australian context, most part of the country is organised for centralised power distribution and remote areas use decentralised systems [4][15][11]. The utility suppliers, distributors or retailers maintain and ensure the reliable, safety of the electricity network [15]. The utility companies or retailers have a major concern over the PV installation. The suppliers offer different pricing strategies [15][20][18]. However, the high demand for grid connected PV production is a threat to the utility suppliers as it will increase the penetration level of the grid and more importantly reduce their income generation [26][15]. Imposition of levies, prohibition of metering, restrictions of system size is some strategies that have been taken to decelerate the PV installation [15]. In contrast, utility retailers sell solar power systems and offer other opportunities such as reduced grid service infrastructure requirements, selling green, and reduced operational costs on a smart-portfolio diversified grid [26][11].
Government: Government and other territory government are the key policy makers. The government actively influences in owner’s decisions towards the PV system installation. Federal government clean energy regulator, state government electrical safety bodies, State-based consumer protection bodies, Australian Renewable Energy Agency (ARENA), Clean Energy Council are current regulatory bodies in the solar industry in Australia. The CEC accredits the installers, designers and retailers and conduct audits for the grid connected PV system. Australian PV Institute (APVI) and Australian Solar Council (ASC) withstand for PV deployment in Australia. The government has implemented different incentives to deploy the PV industry in Australia. For example,

- RET (Renewable energy target): to promote both small scale renewable energy scheme (SRES) and the large scale renewable energy target (LRET) PV systems.
- FiT is one of the key financial benefits given by the government for solar selling prices which is financially attractive for home owners and businesses.

Green electricity schemes, renewable portfolio standards, funds, net metering, green mortgages, renewable energy targets are other initiative programmes. In addition, government, local governments also have introduced different policies and regulations to maintain standard of the PV systems. However, still, there is lack of regulations for buildings integrations particularly in BIPV installation. AS/NZS5033 - Installation of PV arrays, AS/NZS 4777- Grid connection of energy systems via inverter set points, voltage drop, power factor etc, AS3000- Wiring rules are some of the rules and regulations adhering in the Australian context.

In present, some standards are developing for an example AS/NZS 5139, Electrical Installations – Safety of battery systems for use in inverter energy systems. However, still there is a lack of standards in the Australian government particular in standards of technology and battery storage.

Financial sector: Financial institutes, bank and other investors are keen to fund for the PV application. Funding methods such as leasing, power purchasing agreement have been currently floating in the industry prior to government and local government initiatives. Further, investment entities, PV insurance companies, green financing, have been emerged in this context to attract the PV installation.

Non-governmental Organisations: international organisations influence in the use of PV system. For example, Australian committee is also involved in IEC working group which they adhere their standards. In addition, academic research associations, industrial associations and the organisations conducting special activities for PV deployment. Universities other government organisational bodies conduct a number of research and developments to develop innovative system an industry development.

Public: The social effect also directly influenced the decision of buying PV system. In addition, community blogs, international agencies and media promote and educate about the system.

5 Dynamics of the context

This section discusses the dynamic interrelationship between differing actants which contribute the deployment of distributed PV in the building sector.

The stakeholders play diversified role and task in this context. The property owner is the key decision maker in this context. The decision influences the actions of electricity providers, policy makers and government and the other artefacts. The government initiatives such as FiT and Rebate programme, financial schemes have increasingly attracted more PV placements in the industry. Further, the electricity suppliers’ acts such as the requirement for the size of the PV system, the different tariff may negatively influence the grid connection. In addition, new industry players such as innovative product manufacturers, financial institutes, insurance companies, non-government organisations, software developers are entering the industry while some of them are leaving resulting different results for the deployment of distributed PV system. Accordingly, multiple stakeholders gain diverse benefits and interfere differently to the deployment depend on the nature and/or the scope of their role. The stakeholders’ behaviours and their relations are complex and dynamic creating the fragmented environment.

Number of policies and standards are being enacted to ensure the efficient deployment. The changes in policies, standards or regulations often impact the deployment rate. However, there is a significant overlapping between government policies and stakeholders’ perceptions. Moreover, the technological developments are penetrating in the deployment. The prefabricated PV modules
technologies, energy storage battery systems, inverter technologies and other system components are rapidly leveraging the industry facilitating speedy growth deployment. In addition, building design technologies and design features are evolving to support the diffusion of PV generation. In contrast, problems such as shortages of roof spaces, access to maintenance, retrofitting buildings modify the PV design features, building codes and regulations often hinder the PV deployment.

Generally, the upfront cost of the PV system is high and also unpredictable. In present, the prices of both BOS and PV modules are declining which encourage property owners to acquire the PV system. In addition, connection cost for the grid also a barrier for the domestic generation. However, technological advancement and the declining cost have created opportunities to widely spread PV in the industry.

The PV market is volatile particularly; interest rates, inflation rates and changes to energy tariffs are creating great uncertainty for owners over the lifetime of the project. In addition, the PV industry contributes for the economy in terms of business, employment and energy generation. Further, the political actions may directly administrate the industry.

The aforementioned dynamic interactions between various actant affect the growth of PV deployment in the building industry and there are much more to discover such dynamics to well deploy the distributed PV systems in the building sector.

6. Conclusion

The distributed PV is an emerging technology in the building industry. Many countries are encouraging the deployment of PV system as a solution for climate change impacts. However, the deployment of PV poses a number of sociotechnical factors. In fact, this is a complex system that composes of interconnected entities/actant of human, technology, resource, information and tasks. The interactions between these actants and their attributes create number of dynamics and uncertain environment. The socio-technical system approach is well-matched in this context to understand the deployment of distributed PV in the building industry. As an initial stage, the study reveals key actants and their dynamic interactions. Developing a network of actants adhering to their complexity and dynamics is the next step of this study to explore the key characteristics of the system deployments. The dynamic network analysis theory will be used to explore the complex socio technical context. It is apparent that there is a rapid progress in deploying PV in the Australian context in which this study would greatly contributes to policy development in for the PV deployment in the building industry.

7. Reference


[15] APIV (2014), National Survey Report of PV power Applications in Australia,


[18] Herig, C. (2008), Photovoltaics as a Distributed Resource - Making the Value Connection


[24] CSIRO Report (2009), intelligent grid; a value proposition for distributed energy in Australia, National research flag ship


[26] IEA (2008), Analysis of PV system’s values beyond energy -by Country and Stakeholder,

[27] Lo, C., Wang C., and Huang (2013), The national innovation system in the Taiwanese photovoltaic industry: A multiple stakeholder perspective, Technological Forecasting & Social Change, 80, 893–906


[29] Noone, B, (2013), PV Integration on Australian Distribution Networks, APIV association
Sustainable Construction Waste Management in Adelaide

Li, R.Y.M. and Leung, T.H.

Abstract: The goal of moving towards a circular economy is important in many different modern countries. Numerous modern technologies are developed around the world that are believed to provide excellent solutions to reduce waste, particularly in the design process, where, for example, virtual simulation, robotics, RFID and 3D printing are used, as recorded in previous studies. Nevertheless, the reality differs in practice. Despite the existence of alternative technologies, construction waste management still tends to choose traditional methods. Do those traditional methods imply effectiveness or efficiency? This paper endeavours to investigate sustainable waste management in the construction industry; hence, interviews are conducted with several experienced stakeholders in Adelaide. The result provides implications in the industry perspective towards the above-mentioned questions.

Keywords: Construction waste; Information Technology; Adelaide
1 Introduction

“I am content to defend the profit motive but there are also many organizations and individuals who operate within the market economy who are not just motivated by the maximization of gain.” (Booth, 2011).

Construction and demolition (C&D) waste refers to waste that arises from renovation, construction and demolition activities. It includes surplus and damaged or temporarily used materials for on-site activities. The European Waste Catalogue (EWC) classifies construction waste in accordance with the composite seven categories, which are wood, glass and plastic; concrete, bituminous mixtures, bricks, tiles and ceramics; insulation materials and asbestos-containing construction materials; coal tar and tarred products; metals; soil, stones and dredging spoil; gypsum-based construction material; and, so forth (Environmental Protection Agency, 2002). In Hong Kong, construction waste is classified as inert and non-inert. The inert waste comprises materials such as rocks, broken concrete, earth, soil and slurry silt while the non-inert materials include packaging waste, timber, metals and plastics (Lu et al., 2016).

Many case studies show that design validation through building information modeling (BIM) can effectively lower on-site construction waste. Practically, BIM enhances the design process to optimize the budget of construction materials. Moreover, during the construction process, BIM further helps to monitor the efficiency of materials usage. Evidentially, in two construction sites located in South Korea, 381 and 136 design errors were detected by BIM, thereupon, it successfully prevented 4.3% to 15.2% of construction waste (Won et al., 2016).

2 Moving Towards Circular Economy: A Global Perspective

With the vision to better waste management, there are two major frameworks can practically be implemented into urban planning. The core concept is closed-loop resources flow system to assure the best use of materials. In New Zealand, the government announced the Zero Waste New Zealand Trust in 1997. This Trust voiced a goal to create a closed-loop materials economy where all products can be recycled, repaired, and reused. Ultimately, with achievement of those targets, waste can sufficiently be eliminated (Zaman, 2015). Furthermore, zero waste implies incentive for the construction industry that it recognizes the strong business needs to improve resource productivity.

Circular economy (CE) is a framework propagated by the European Union (EU). It attempts to retain the added value in products as much as possible and eliminate waste. It targets to reduce waste disposal in 2050 by half as compared with that in 2000 by reducing waste, enhancing waste recovery through reuse, recycle and energy recovery. Specifically, zero waste program in Europe provides visionary concepts for solving waste problems (Smol et al., 2015).

3 Sustainable Construction Waste Management

Sustainability is an overwhelming concern in modern society. While it influences the society thoroughly, the construction industry is inspired spectacularly. In Australia, C&D waste contributed 38% of the 43.8 million tons of waste generated in 2007. Finally, 43% of the C&D waste ended up into landfill. In contrast, Australia was underperformed in recycling rate around the world (Pullen, 2010; Pullen et al., 2012).

Sustainable construction is achieved by striking a balance among economy, society, and environment. Several previous research studies embrace sustainable principles in construction project, whilst, some of them contend sustainable principles can increase profit. Alternatively, some studies regard sustainability as environmental oriented goals. Basically, such difference among insights entails the unalignment of concern between environmental benefits in long run and economic operational goals in short run. In fact, the idea of sustainable construction includes various methods which are beneficial to all stakeholders and the environment (Shen et al., 2010). For instance, construction firm adopted sustainable principles would concern better waste management to minimize damages to the environment. Additionally, by reusing construction resources, it would utilize the usage of material to avoid waste generation.

3.1 IT Application on Construction Waste Management and Reduction
This section provides the application of advanced information technology in construction industry. By making use of advanced technology, it can enhance the on-site safety, productivity, efficiency, accuracy, and so on (Li, 2018; Li & Leung, 2017). Beyond the various applications of advanced technology, albeit the majority of such new applications is targeting on efficiency and safety management, there are several of them effectively countering the waste problems in construction industry.

3.1.1 Radio Frequency Identification (RFID)

Rule-based Reasoning and RFID technology helps companies in tracing, planning, and handling waste movement to avoid fly-tipping and improve management efficiency. Detailed procedure for smart plasterboard waste management system is outlined, including the Rule-based Reasoning system design. This technology provides a solution for company to monitor the waste status and facilitate real time decision support automatically (Zhang & Atkins, 2014). RFID provides spontaneous and simultaneous response to sort out waste, therefore, it can facilitate the classification process for recycling.

3.1.2 Robotic

Automation and robotics technology enhances productivity, minimizes the need for labor, and lessens the harmful effects on our environment (Son et al., 2010). A robotic system and method performs tasks autonomously on real world objects (RWOs) upon the receipt of inputs from a virtual reality (VR) environment. A VR computer uses sensor data to generate virtual world objects (VWOs) and representative of RWOs (Parker, 2015). For example, the ZenRobotics Recycler (ZRR) is an intelligent robotic system that separates construction materials on a conveyer belt, pluck out the materials which can be recycled and deposit them in match-type collection bins. The ZRR identifies different types of waste using "sensor fusion" process. By analyzing the relevant data, the sensors sort the objects on the belt and distribute them to chutes nearby. The sensor fusion system collaborates spectrometer analysis, 3D scanning, and tactile assessment method to establish the sorting mechanism. ZenRobotics eases the burden of the repetitive and dangerous job of waste filtration as the waste can be hazardous, poisonous, sharp, and heavy (McNicoll & Blendis, 2013).

3.1.3 Virtual Simulation

3D visualization of construction operation provides valuable insight to stakeholders with regards to the project aspects and enhances their understanding on project process before it begins. Modelled construction operation can be visualized in virtual environment in various ways, for instance, construction virtual prototyping (CVP) visualizes project assembly in 3D environment before execution (Rohani et al., 2014). With virtual simulation, the projects and processes can be visualized before it would have been built. Some of the design problems can be detected and visualized before construction. Hence, consequently, reduce waste as a result.

3.1.4 3D Printer

3D printing joins the materials to make 3D model, layer upon layer. It derives from prototyping which was developed in the late 1980s. The process begins with digital modelling a blueprint of an object according to a design program, slices the object into layers and sends the information to a 3D printer which constructs the object in action as repeated passes. The printer deposits a thin layer of material onto the materials previously deposited. The printing process is flexible in size and lessens the time required. Additionally, the 3D printing fabrication can be realized at affordable prices.

Pegna firstly proposed the usage of 3D printing in construction in the late 1990s (Pegna, 1997). He investigated a system of layered fabrication of small masonry structures by depositing a layer of Portland cement over a layer of silica, activated by water vapor. The first attempt to apply this 3D technology would be dated back to the early 2000s for a large-scale combined extrusion and trowel automated construction system called Contour Crafting (Oberti & Plantamura, 2015). Recently, Win Sun Decoration Design Engineering, as a pioneer, used four giant 3D printers to build houses in Shanghai; by using a mix of cement and construction waste to construct the walls layer by layer. Each of these houses is 10 meters wide and 6.6 meters high (Mpofu et al., 2014).

Unlike the back-end waste management, 3D printing provides substitute for construction materials. 3D printing increases environmental sustainability in many ways, for example, raw materials optimization, the possibility of using local materials, recycled, reused or rapid renewable such that it can reduce/eliminate
construction waste, reduce air pollutants emission during construction (Oberti & Plantamura, 2015). Henceforth, with the adoption of 3D printing technology, construction waste can be reduced substantially at the source.

4 The Interview in Adelaide

After the concise introduction of the latest technologies which are significantly boosting the sustainable construction atmosphere. Evidently, it is observed that construction companies have no idea on the advanced technologies which can enhance better waste management like those mentioned above. Note that, such technological breakthrough requires efforts from institutional sector (Li et al., upcoming). With the awareness and intention to achieve circular economy, there is ambivalence between their visions and actual practices. It is notable to mention that there is a lag between invention and application. There are several reasons behind the lag of application. First, in economics, there are path dependence in industry such that construction firm has incentive to adopt new system while it has already established its system. Apart from that, in legal sector, the application of new technology implies potential conflicts. Therefore, well-concerned legislation process is a premise for effective perpetuating technology into industry. Otherwise, if accident happens, it would lead to sophisticated legal conflict to define the responsibility claimant. Individuals inside construction industry have probably low incentive to adopt really new technologies because the first mover has to bear the legal risk. Nonetheless, it is crucial to investigate the industry perspective towards sustainable construction management.

In this circumstance, the traditional quantitative analysis has defect in this situation. Since the available models are capable to measure the efficiency of existing waste management. Hence, yet to analysis, it is necessary to have data to be observed while the industry in Adelaide is being passive in adopting those new technologies. However, it does not imply the industry has no intention to produce in sustainable way. Back to the origin, it has to measure the core ideas in sustainable development. Under the global perspective mentioned above, both of the circular economy and zero waste consist the value of recycle and reuse. Therefore, the alternative qualitative research is applicable in this condition, thereby, this research applies semi-structured interview. Significantly, it can focus on the existence of obligation in recycling and reuse practices. The rationales behind the application of semi-structured interview are coherent with the arguments raised previously. The context in construction industry can be complex to establish a defined questionnaire. Such that, insightful ideas could be omitted unless the interview design allows open-ended response (Cohen & Crabtree, 2006). Fortunately, the aim in this research is to examine the adaptability of idea of sustainability. In respect of the clear purpose, the interview design can be interactive that information can flow between interviewer and interviewees (Wengraf, 2001). Therefore, this research concentrate into understand the interviewees perception in recycling and reuse rather than the progress or performance of recycling activities. Furthermore, semi-structured interview provides adequate amount of information inside industry so that there are several methods to possible quantitative analysis in the future in a reliable basis. Unlike the structured interview, this research does not bound the ideas from interviewee so that respondents are passively answering questions but actively contributing insights and explaining their thoughts (Case, 1990). With that advantage, it is easier for us to depict whether there is coherent framework towards sustainable development among different level of expertise.

As result, in research design, it attempts to: 1) Identify the best solution to achieve the goal of waste reduction which can help us to attain the circular economy in Adelaide is the traditional method or the modern approach with the information technology; 2) Effectiveness of waste reduction by using that method; and 3) Study the implication of these methods on costs and quality of construction.

4.2 Results of the Interview

The best method to reduce construction waste in procurement stage

4.2.1 Recycle

Director A believed that the most effective method which reduces construction waste in procurement is recycling. Nevertheless, it may be rare to use on other sites. It is believed that 5% of waste could be reduced by recycling. A senior mechanical engineer convinced that there are couple of effective methods which reduces construction waste. First, recycle whatever we can recycle. Second, policies written in the contract can reduce construction waste. Detailed procedures must fill in the procedures of processing construction waste. Third, we should use existing materials for another project. Around 86% of wastes can be reduced by recycling, for example, electric
cable, concrete, steel, and so on. It can thus reduce the waste to landfill and steel as well as concrete can be reused for based.

4.2.2 Waste Sorting

A construction manager thought that the most effective method that reduces construction waste is sorting waste. It can reduce 25% of the total waste. Modulation is the most effective method that reduces construction waste in procurement in the eyes of an architect. The cut of materials can be minimized by specifying materials and optimized design plan. If the building materials, such as the beam are too long, it should be shortened. Hence, better design, modulation of the building it can reduce the waste.

When it comes to the most effective method which reduces construction waste in procurement, KESAB Clean site program agreed that separating waste on sites is always considered as a good practice. Subcontractor put excess concrete in concrete bin cup and get involved in recycling activities on sites. It can reduce 90% of all discarded materials. Everything has to be recycled are separated and recycled although there are averagely 5 to 10% unrecyclable materials at the end.

A project manager believed that designated bins to recycle and offsite sorting is the most effective method which reduces construction waste in procurement. Waste is sent offsite for sorting and recycling. He strongly believes that this mechanism can achieve 100% recycle rate among all the subcontractors and head contractors. The head-contractor communicates with the subcontractors about recycling waste. Even one-man bank sub-contractors have obligation to join this induction program which usually take place on site and can reduce construction waste through offsite sorting waste.

A senior construction manager and a logistic manager believed that separation by different bins is the effective method. It lowers most of the construction waste albeit it is hard to estimate how much waste can be reduced. Besides, logistic manager also suggested that outsources the recycling to contractors, it passes the costs (and obligations) to contractors who pay for their own packaging and negotiate with the suppliers and various companies who can buy the waste.

4.2.3 Formal Institution: Contract

A project director of design and construction deemed that contract management is the most effective method which reduces construction waste in procurement. However, it can hardly estimate how much waste can be reduced by having better contract management. We can put the performance requirement against the head contractor with a focus on waste reduction and main contractor control the subcontractor on waste reduction.

Nevertheless, Quality, Health, Safety, and Environment (QHSE) manager convinced that the most effective method which reduces construction waste in procurement is tender. The contract should state clear about what they have to clean the site, provide rubbish bin, and remove rubbish. Subcontractors have to provide bins for timber, plastic, and general waste. It is estimated 90% of construction waste can be reduced. An architect considered building specification in the building contract is the most effective method which reduces construction waste. To tender for a project, it has to document all the drawings and specify all the specifications about the work that will be done. It is estimated that about 30 to 40% of waste can be reduced. All the waste reduction method should be specified as requirements and obligation in work where builders need to follow. If they do not, the owner may sue them.

A project manager who handles the time, costs and quality of the whole project thought that procurement of the projects and safety standards is the most effective method which reduces construction waste in procurement. He guessed that about 15% of construction waste can be reduced. Management help alleviate the construction waste problem. By providing effective management, all staffs can do their best to help reduce the construction waste.

5 Conclusion

Even though the literatures mentioned many different types of waste reduction methods, the best solution to achieve the goal of waste reduction which can help us to attain the circular economy in Adelaide is the traditional method such as waste sorting, contract and recycle. Perception on how these methods can reduce waste varies from 15 to 100%. Nevertheless, quite a number of these methods leads to higher costs, leading to hurdle in applying them.
On another side, from the in-depth interviews with different levels of practitioners in Adelaide’s construction industry, it has several inspiring insights can be found. First, the perception of waste management is various regarding to their level of position. There are some critical differences in view among managers, contractors, and sub-contractors. When the level of subcontracting is high, the manager tends to use contract to regulate the waste management. It implies intentions to source out the legal responsibility to lower level contractors. Thus, the estimations in waste reduction among top level manager are generally uncertain. It is because the contract guarantees the waste to be eliminated while managers have only ambiguous concept in waste reduction practice. When it moves down to project manager or contractor level, it shows the practical cognition on material budget and on-site practices. Therefore, the respondents tend to provide constructive actions such as sorting waste and setting recycling bins.

Second, the impact of effective method of waste reduction is uncertain in cost. Generally, extra schedule means extra cost. However, some of the interviewee claimed the cost of landfill is higher than recycling. Meanwhile, it is valuable to note that the cost can occasionally reduce when the method is related to optimize the material budget.

Finally, throughout the interviews, respondents in Adelaide show the awareness of sustainable development. Furthermore, all participants have certain understanding in waste management. However, the waste management is Adelaide seems to present as an outsource program in responsibility. Even though the contract terms, obligations, and regulations are effective legal enforcement to comply sustainable development. It has a disadvantage that the lower level sub-contractors are the actual implementer of waste management. Although there are new technologies available to facilitate better waste management, the low level sub-contractors are not capable enough to adopt such high cost methods. At the same time, the top-level managers have vague concept on waste management process and the recycling rate is already satisfactory. Consequently, it has difficulties to raise the incentive to adopt advanced technologies in industry.

This research found that the insights from industry in highly useful and helpful to outline the industry’s perspective towards sustainable development in Adelaide. This research aims to be the first step to investigate the sustainable development studies with management perspective. Since this research analysis provides a reliable basis to conduct further quantitative analyses, there are several directions as follow-up in the future. For example, since the research can figure out the framework of the mindset in construction devolution hierarchy, some in-depth research on the subcontracting structure in construction industry are feasible and contributory. Moreover, the relation between industry and institution is complex so that there are more researches have to be conducted to examine the interactions between regulation and actual implementation.

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Size of company</th>
<th>Level of subcontracting</th>
<th>The most effective method of reduce waste on sites</th>
<th>Percentage waste reduction</th>
<th>Estimated sum of money spent on this item</th>
<th>Impact on time, quality, and costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Director A</td>
<td>Small to medium</td>
<td>High</td>
<td>Recycling</td>
<td>Hard to estimate</td>
<td>0</td>
<td>Higher costs</td>
</tr>
<tr>
<td>Construction manager B</td>
<td>Large</td>
<td>High</td>
<td>Sorting waste</td>
<td>25%</td>
<td>4000 per 1.8 million</td>
<td>Nil</td>
</tr>
<tr>
<td>Architect C</td>
<td>Large</td>
<td>High</td>
<td>Modulation</td>
<td>Not sure</td>
<td>n/a</td>
<td>Better quality, efficiency is also higher. Time is less.</td>
</tr>
<tr>
<td>Senior mechanical engineer D</td>
<td>Small to medium</td>
<td>Medium</td>
<td>Recycling</td>
<td>85%</td>
<td>n/a</td>
<td>Higher costs but landfill costs more. No implication on</td>
</tr>
<tr>
<td>Role</td>
<td>Location</td>
<td>Level</td>
<td>Stage</td>
<td>Impact on time and quality</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
<td>--------</td>
<td>------------------------------</td>
<td>----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Project director – design and</td>
<td>Small Medium</td>
<td>Contract</td>
<td>management n/a n/a Nil</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>construction E</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean site program manager F</td>
<td>Large High</td>
<td>On site</td>
<td>waste separation 90% of all</td>
<td>Not involve in contract sum</td>
<td>It saves money but more time is needed to separate the waste. No effect on</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>discarded materials</td>
<td></td>
<td>quality.</td>
<td></td>
</tr>
<tr>
<td>Architect G</td>
<td>Large High</td>
<td>Building</td>
<td>specification 30 to 40%</td>
<td>Relatively small sum of</td>
<td>Money can be saved. No impact on time, quality, and costs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>money only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project manager H</td>
<td>Medium to large</td>
<td>High</td>
<td>Procurement of the projects 15%</td>
<td>2% Implication on time and quality.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and safety standards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project manager I</td>
<td>Large Medium</td>
<td>Medium</td>
<td>Designated bins to recycle 100%</td>
<td>n/a No extra time but more</td>
<td>No extra time but more expensive to dispose concrete. It may entail better</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and offsite sorting</td>
<td>time and quality</td>
<td>construction quality.</td>
<td></td>
</tr>
<tr>
<td>Senior construction manager J</td>
<td>Large Large</td>
<td>Large</td>
<td>Separation by different bins Hard to estimate n/a More expenditure. No impact on others.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QHSE manager K</td>
<td>Large Large</td>
<td>Tender</td>
<td>90%</td>
<td>n/a Nil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logistic manager L</td>
<td>Largest in Adelaide Large On site waste separation Hard to estimate n/a No implication on time. Costs increases, quality is enhanced.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
References


Addressing the human cost in sustainability rating tools

Tsita, H.¹ and Smallwood, J.J.²*

Abstract: Construction and related processes evolve over years, and so too green building, which is assessed by rating tools. South Africa is also transitioning in terms of green building, and as a result evolved a socio-economic category to supplement the Green Star SA rating tool.

The aim of the study reported on was to address H&S issues experienced by construction workers within the context of traditional and green building, and possibly motivate increased focus on H&S in green building rating tools. Data was collected using questionnaire surveys circulated to site managers (SMs), and Construction Health and Safety Officers (CHSOs) in the employ of general contractors.

The salient findings conclude that despite legislative interventions in the industry to address H&S issues, H&S performance is still poor. Workers still experience ergonomic problems, are exposed to hazardous materials / substances and processes, and fall from heights.

The paper concludes that there is a need for projects to focus on H&S, and that the status afforded H&S in the GBCSA Socio-Economic category is inadequate. It is recommended that the GBCSA revises its tool to enhance the status of H&S.

Keywords: Construction; Green Building; Health and Safety; Sustainability.

1 Introduction

Over the decades, ‘revolution’ has been experienced in the economy, and with each revolution in the economy, new jobs are created, but often these jobs are accompanied by tragic consequences [1]. The construction industry is one sector in the economy that has witnessed these changes, as in the 19th century, a rise of worker deaths from asbestosis, silicosis, brown lung disease, mine cave-ins, polluting factories, and more has been witnessed [1].

In the 21st century, the industry now looks forward to a new revolution courtesy of green building, ushering in much-needed ‘green jobs’ [1]. Chen [1] further adds that with this change, H&S should be addressed to make sure that these jobs are healthy and safe, for both workers and communities.

To address environmental issues faced by the built environment, green building evolved and the term ‘sustainable construction’ was coined. The main objective of green building is to avoid resource depletion of energy, water, and raw material and to prevent environmental degradation

¹ Tsita, H.
Department of Construction Management, Nelson Mandela University, South Africa

² Smallwood, J.J.
Corresponding author, Department of Construction Management, Nelson Mandela University, South Africa
E-mail: john.smallwood@mandela.ac.za
caused by facilities and infrastructure throughout their life cycle [2]. To set benchmarks for green building, various assessment and certification schemes that measure the sustainability of buildings have been in use for several years in many countries, one being the Green Star South Africa rating system, which rates the sustainability of the buildings, built or redesigned based on ‘green building’ specifications, which is based on the Australian rating system known as Green Star, but customised within the context of South Africa [3].

While green building offers the potential for improved environmental performance, ultimately, it is not sustainable if it compromises the H&S, or quality of life of constructors, the occupants, or the workers who operate and maintain the products thereof [4]. Gambatese et al. [5] in turn states that current rating tools do not appear to explicitly account for worker H&S. Then, although Green Star SA has incorporated a new category entitled ‘Socio-Economic Category’ (SEC), H&S was only allocated 1 point, which constitutes 8% of the category [3].

Therefore, there is a need to address the ‘human cost’ in rating tools, which constitute the benchmark for everything green. The marginalisation of H&S by the rating tools is attributable to narrow thinking in the industry, which led to the focus being on the ‘traditional’ sustainability issues in the rating tools.

In conclusion, a reasonable consideration of workers’ health and well-being should be accommodated in green building certification in the quest to develop increasingly more sustainable facilities, thus avoiding potential pitfalls that threaten the health, safety, and quality of life of the workers who build, use, and maintain them, in addition to the occupants.

Given the aforementioned, the objectives of the study reported on were to determine the:
- Frequency at which workers experience ergonomics problems;
- Frequency at which workers are exposed to certain materials / substances, and
- Extent to which causes contribute to falls from heights.

2 Review of the Literature

2.1 The Green Star SA Socio-economic Category

The aim of the H&S credit is to encourage and recognise actions taken to improve the primary health of construction workers, and to promote better H&S practices, and understanding and appreciation of H&S in the construction industry, including clients, and design teams [3]. One point is awarded where a primary health programme for construction site employees has been implemented, which includes the conducting of health assessments for all consenting construction-related employees, including subcontractors’ employees, at least once during the construction phase and preferably at the beginning of the project, and the referral of employees for further medical examination or treatment where problems are identified. A further requirement is the conducting of a basic health awareness programme for employees, particularly the addressing of the key health issues identified such as alcohol and drug abuse, HIV and AIDS, malaria, and tuberculosis. However, there are prerequisites to be eligible for the credit, namely that the requirements of the Occupational Health and Safety Act (OH&S), and the Construction Regulations have been complied with, and that design hazard identification and risk assessments (HIRAs) have been conducted.

2.2 Ergonomics and Musculoskeletal Disorders
Human body motions have been studied for decades with the purpose of enhancing occupational well-being and performance of workers [6]. The deterioration of workers' physical health and loss of workdays not only impacts their well-being and quality of life, but also impacts on the country's economy. According to Sass and Smallwood [7], construction workers are exposed to many ergonomic and H&S hazards which can cause them to become ill, experience stress, experience WMSDs, experience injuries and in some cases death, and be absent from work. Many workers, as a result, leave the industry early due to the mentioned issues [8].

2.3 Green Building and Construction H&S

According to Gambatese et al. [5], the design and construction of buildings using current green building practices do not always benefit construction workers’ H&S. Green building practices often consist of insulated spaces to save energy, which compromises ventilation, as a result, workers are exposed to organic compounds, such as adhesives, and paint, together with crystalline silica, which is harmful to worker’s health [9].

Retrofitting of older buildings is used as one of the measures of green building to install energy efficient systems into existing buildings, and systems such as heating water systems [10]. Retrofitting increases exposure of workers to silica dust and asbestos, and because of it, involving work such as ventilation and heating; HVAC technicians may specialise in the job due to retrofitting activities being carried out more frequently, which further increases exposure to these hazards [11]. Designers influence H&S directly and indirectly. Directly through general design, choice of structural frames, specification of materials and finishes, and indirectly through selection of procurement systems, decisions concerning project duration, and preparation of contract documentation [12].

A review of 450 construction accidents that resulted in fatalities and disabling injuries in the USA, determined that in 33.6% of the cases, the hazard that contributed to the incident could have been eliminated or reduced if ‘design-for-H&S’ measures had been implemented [13]. There is a greater use of skylights and atriums in green buildings to increase the amount of natural light and heating, thereby reducing electricity usage, however, a significant number of injuries and fatalities result from workers falling through skylights [1]. Skylights are usually not designed to withstand heavy loads and do not have guardrails that may protect workers from falls [1]. The atriums, on the other hand, are designed with large glass panes that can be heavy and difficult to carry [1].

3 Research

3.1 Research Method

The sample stratum consisted of Site Managers (SMs) and H&S Officers, in the employ of the regional entities of national general contractors (5 No.), and Port Elizabeth based medium to large firms who are members of the East Cape Master Builders Association (ECMBA) (10 No.), which equates to a total of 15 firms. Two identical questionnaires were evolved, and consisted of 11 questions and 59 sub-questions. 10 SMs, and 8 H&S Officers responded, which equates to a response rate of 60%.

3.2 Research Findings
Table 1 presents a comparison in terms of the frequency at which workers experience ergonomics problems according to SMs and H&S Officers. MSs > 3.00 indicate that workers are exposed to these ergonomics problems frequently as opposed to infrequently, as in the case of MSs ≤ 3.00. It is notable that 13 / 18 (72.2%) have MSs > 3.00, and that the rankings based upon the MSs for the top ten ergonomics problems are the same. In terms of the mean, all the ergonomics problems ranked in the top six have MSs > 4.20 ≤ 5.00, which indicates that workers are exposed to these ergonomics problems on a weekly to daily / daily basis.

The ergonomics problems ranked seventh to eleventh, have MSs between > 3.40 to ≤ 4.20, which indicates that workers are exposed to these problems on a fortnightly to weekly / weekly basis. The ergonomics problems ranked twelfth to sixteenth have MSs between > 2.60 to ≤ 3.40, which indicates that workers are exposed to these problems on a monthly to fortnightly / fortnightly basis.

The remaining ergonomics problems have mean MSs ≤ 3.00, which indicates that they occur infrequently as opposed to frequently. It is notable that only working while injured or hurt has a mean MS of ≥ 1.00 to ≤ 1.80, which indicates that workers experience this problem between never to monthly.

Table 1. Frequency at which workers experience ergonomics problems according to SMs and H&S Officers

<table>
<thead>
<tr>
<th>Ergonomic problem</th>
<th>SMs</th>
<th>Rank</th>
<th>H&amp;S Officers</th>
<th>Rank</th>
<th>Mean</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetitive movements</td>
<td>5.00</td>
<td>1=</td>
<td>5.00</td>
<td>1=</td>
<td>5.00</td>
<td>1=</td>
</tr>
<tr>
<td>Climbing up and down</td>
<td>5.00</td>
<td>1=</td>
<td>5.00</td>
<td>1=</td>
<td>5.00</td>
<td>1=</td>
</tr>
<tr>
<td>Bending or twisting your back</td>
<td>4.88</td>
<td>3=</td>
<td>4.88</td>
<td>3=</td>
<td>4.88</td>
<td>3=</td>
</tr>
<tr>
<td>Exposure to noise</td>
<td>4.88</td>
<td>3=</td>
<td>4.88</td>
<td>3=</td>
<td>4.88</td>
<td>3=</td>
</tr>
<tr>
<td>Reaching away from your body</td>
<td>4.75</td>
<td>5</td>
<td>4.88</td>
<td>3=</td>
<td>4.82</td>
<td>5</td>
</tr>
<tr>
<td>Reaching over your head</td>
<td>4.63</td>
<td>6</td>
<td>4.88</td>
<td>3=</td>
<td>4.76</td>
<td>6</td>
</tr>
<tr>
<td>Handling heavy equipment</td>
<td>4.00</td>
<td>7</td>
<td>4.13</td>
<td>7</td>
<td>4.07</td>
<td>7</td>
</tr>
<tr>
<td>Working in awkward positions</td>
<td>3.88</td>
<td>8</td>
<td>4.00</td>
<td>8</td>
<td>3.94</td>
<td>8</td>
</tr>
<tr>
<td>Handling heavy material</td>
<td>3.88</td>
<td>9</td>
<td>3.63</td>
<td>9</td>
<td>3.76</td>
<td>9</td>
</tr>
<tr>
<td>Working in hot conditions</td>
<td>3.88</td>
<td>10</td>
<td>3.50</td>
<td>10</td>
<td>3.69</td>
<td>10</td>
</tr>
<tr>
<td>Working in the same position for a long period</td>
<td>3.88</td>
<td>11</td>
<td>3.00</td>
<td>12</td>
<td>3.44</td>
<td>11</td>
</tr>
<tr>
<td>Use of body force</td>
<td>3.75</td>
<td>12</td>
<td>2.63</td>
<td>13</td>
<td>3.19</td>
<td>12=</td>
</tr>
<tr>
<td>Working with vibrating tools or equipment</td>
<td>3.13</td>
<td>13</td>
<td>3.25</td>
<td>11</td>
<td>3.19</td>
<td>12=</td>
</tr>
<tr>
<td>Working in confined spaces</td>
<td>3.00</td>
<td>14</td>
<td>2.25</td>
<td>15</td>
<td>2.63</td>
<td>14=</td>
</tr>
<tr>
<td>Working in cold conditions</td>
<td>2.75</td>
<td>16</td>
<td>2.50</td>
<td>14=</td>
<td>2.63</td>
<td>14=</td>
</tr>
<tr>
<td>Working in humid conditions</td>
<td>3.00</td>
<td>15</td>
<td>1.75</td>
<td>16=</td>
<td>2.38</td>
<td>16</td>
</tr>
<tr>
<td>Working in wet conditions</td>
<td>2.63</td>
<td>17</td>
<td>1.75</td>
<td>16=</td>
<td>2.19</td>
<td>17</td>
</tr>
<tr>
<td>Working while injured or hurt</td>
<td>1.13</td>
<td>18</td>
<td>1.25</td>
<td>18</td>
<td>1.19</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 2 presents a comparison in terms of the frequency at which workers are exposed to materials / substances according to SMs and H&S Officers. MSs > 3.00 indicate that workers are exposed to...
these material / substances frequently as opposed to infrequently, as in the case of MSs ≤ 3.00. It is notable that 10 / 19 (52.6 %) materials / substances have mean MSs > 3.00. More than half (50%) of both functions agree that workers are exposed to these frequently, thus increasing chances of them contracting occupational diseases. Therefore, OH awareness interventions that link occupational diseases and materials / substances are necessary to ensure the health of workers.

Cement mortar, cement dust, concrete additives, and concrete dust are ranked first to fourth (20%) in terms of mean MSs, which are > 4.20 to ≤ 5.00, which indicates that workers are exposed to these materials / substances on a weekly to daily / daily basis.

A further 4 / 20 (20%) have mean MSs > 3.40 to ≤ 4.20, which indicates that workers are exposed to these materials / substances on a fortnightly to weekly / weekly basis.

4 / 20 (20%) have mean MSs > 2.60 to ≤ 3.40, which indicates that workers are exposed to these materials / substances on a monthly to fortnightly / fortnightly basis – vapours (adhesives / paints / solvents), carpeting, acids / alkalis, and epoxy-resins.

4 / 20 (20%) have mean MSs > 1.80 ≤ 2.60, which indicates that workers are exposed to these on a never to monthly / monthly basis – waterproofing fumes, soldering / welding fumes, bitumen / pitch / tar, and mineral wools.

4 / 20 (20%) have mean MSs ≥ 1.00 ≤ 1.80, which indicates that workers are exposed to these between never to monthly –insulation (polyurethane), handling treated wood, quartz dust, and asbestos dust.

Table 2. Frequency at which workers are exposed to certain material / substances according to both SMs and H&S Officers

<table>
<thead>
<tr>
<th>Material / substance</th>
<th>SMs</th>
<th>H&amp;S Officers</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MS</td>
<td>Rank</td>
<td>MS</td>
</tr>
<tr>
<td>Cement mortar</td>
<td>5.00</td>
<td>1</td>
<td>4.70</td>
</tr>
<tr>
<td>Concrete</td>
<td>3.63</td>
<td>7</td>
<td>4.20</td>
</tr>
<tr>
<td>Concrete additives e.g. plasticizers or retarders</td>
<td>4.38</td>
<td>2</td>
<td>4.20</td>
</tr>
<tr>
<td>Chemicals:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids / Alkalis</td>
<td>3.25</td>
<td>10</td>
<td>2.50</td>
</tr>
<tr>
<td>Bitumen / Pitch / Tar</td>
<td>2.88</td>
<td>14</td>
<td>1.30</td>
</tr>
<tr>
<td>Epoxy-resins</td>
<td>2.88</td>
<td>12</td>
<td>2.50</td>
</tr>
<tr>
<td>Fumes:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal cutting</td>
<td>3.88</td>
<td>8</td>
<td>3.50</td>
</tr>
<tr>
<td>Soldering / Welding</td>
<td>2.88</td>
<td>16</td>
<td>2.00</td>
</tr>
<tr>
<td>Waterproofing</td>
<td>2.88</td>
<td>15</td>
<td>2.30</td>
</tr>
<tr>
<td>Mineral wools</td>
<td>2.38</td>
<td>13</td>
<td>1.50</td>
</tr>
<tr>
<td>Oils / Petrol</td>
<td>3.75</td>
<td>6</td>
<td>4.30</td>
</tr>
<tr>
<td>Vapours (adhesives / paints / solvents)</td>
<td>2.88</td>
<td>9</td>
<td>3.70</td>
</tr>
<tr>
<td>Dust:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asbestos</td>
<td>1.00</td>
<td>20</td>
<td>1.00</td>
</tr>
<tr>
<td>Block / Brick</td>
<td>3.88</td>
<td>5</td>
<td>4.50</td>
</tr>
<tr>
<td>Cement</td>
<td>4.13</td>
<td>4</td>
<td>4.50</td>
</tr>
<tr>
<td>Concrete</td>
<td>4.25</td>
<td>3</td>
<td>4.50</td>
</tr>
</tbody>
</table>
Table 3 presents a comparison in terms of the extent to which causes contribute to falls from height according to SMs and H&S Officers. Mean MSs > 3.00 indicate that causes are a major as opposed to a minor contributor, as in the case of mean MSs ≤ 3.00. It is notable that 8 / 9 (88.9 %) of the mean MSs > 3.00. It is notable that in terms of mean MSs, only two aspects, which are failure to obey work procedures, and workers’ negligence, have MSs > 4.20 ≤ 5.00, which indicates that the extent to which these contribute to falls from height is between a near major extent to major / major extent. It is notable that according to SMs, failure to obey work procedures is the leading cause, while H&S Officers ranked workers’ negligence as the leading cause, both of which have MSs > 4.20 to ≤ 5.00.

Failure to use PPE, incorrect work procedures, and negative attitude of workers all have MSs > 3.40 to ≤ 4.20, which indicate that these causes contributes to falls from height between some extent to a near major / near major extent. Lack of workers’ knowledge and skills, and poor site management have MSs > 2.60 to ≤ 3.40, which indicates that the contribution by these causes to falls is between a near minor extent to some extent / some extent.

Only equipment without safety devices, and nature of work being performed at height have MSs > 1.80 to ≤ 2.60, which indicates that these causes contribute to falls from height, between a minor to near minor / near minor extent.

**Table 3. Extent to which causes contribute to falls from height according to SMs and H&S Officers**

<table>
<thead>
<tr>
<th>Cause</th>
<th>SMs</th>
<th>Rank</th>
<th>MS</th>
<th>Rank</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure to obey work procedures</td>
<td>4.88</td>
<td>1</td>
<td>3.90</td>
<td>2=</td>
<td>4.39</td>
<td>1</td>
</tr>
<tr>
<td>Worker’s negligence</td>
<td>4.38</td>
<td>2</td>
<td>4.30</td>
<td>1</td>
<td>4.34</td>
<td>2</td>
</tr>
<tr>
<td>Failure to use PPE</td>
<td>3.88</td>
<td>4</td>
<td>3.90</td>
<td>2=</td>
<td>3.89</td>
<td>3</td>
</tr>
<tr>
<td>Incorrect work procedures</td>
<td>4.00</td>
<td>3</td>
<td>3.10</td>
<td>5</td>
<td>3.55</td>
<td>4</td>
</tr>
<tr>
<td>Negative attitude of workers</td>
<td>3.50</td>
<td>7=</td>
<td>3.40</td>
<td>4</td>
<td>3.45</td>
<td>5</td>
</tr>
<tr>
<td>Lack of workers’ knowledge and skills</td>
<td>3.75</td>
<td>5</td>
<td>2.90</td>
<td>7</td>
<td>3.33</td>
<td>6</td>
</tr>
<tr>
<td>Poor site management</td>
<td>3.63</td>
<td>6</td>
<td>3.00</td>
<td>6</td>
<td>3.32</td>
<td>7</td>
</tr>
<tr>
<td>Equipment without safety devices</td>
<td>3.50</td>
<td>7=</td>
<td>2.60</td>
<td>8</td>
<td>3.05</td>
<td>8</td>
</tr>
<tr>
<td>Nature of work being performed at height</td>
<td>2.38</td>
<td>9</td>
<td>2.50</td>
<td>9</td>
<td>2.44</td>
<td>9</td>
</tr>
</tbody>
</table>

**Conclusions and Recommendations**

Given the size of the sample stratum, the study is best described as exploratory. Furthermore, workers could not have completed a self-administered questionnaire, and the lead author was unable to conduct interviews of workers, and therefore workers were not included in the study.

There are two fundamental issues to be noted concerning the construction industry. The first one is that construction is labour intensive due to its processes, which require a lot of manual
handling. Around 70% of the labour employed in the construction industry is semi-skilled or general labour, with a low level of skills. Given this, it should be noted that in terms of traditional construction, non-conformance to H&S standards has been experienced, with an uneducated workforce being the major contributing factor.

Green building entails new activities and tasks that require a certain degree of education to understand the processes, as it involves products, procedures and hazards that the current workforce is unfamiliar with. In the case of green building, there is the integration of both traditional, and new H&S related issues and thus there are more hazards in green building, such as increased work at heights [1].

Despite legislative interventions in the industry to address H&S issues, H&S performance is still poor. Workers are still being exposed to hazardous materials / substances and processes, experience ergonomic problems, and occupational diseases, and fall from heights. This reality, amplifies the need for green building and sustainability interventions in the industry to not only include construction H&S, but to focus thereon.

South Africa is still in a transitional period in terms of green projects, but since this is where construction is heading globally, it is important that South Africa revises its tool during the transitional phase to explicitly address H&S. The Green Star SA rating tool should be revised to include the following two aspects:

- With respect to the allocated 8%, 90% accuracy should be a minimum requirement for a building to be considered for a rating, and
- The overall H&S points should be increased to increase its impact on the final rating.

This would pressure clients to ensure that H&S is fully addressed at the planning and design stages, and is effective enough not to compromise the project. Therefore, the contractors in turn would adopt procurement practices that promote H&S. Furthermore, designers who are ultimately responsible for all the material specified and equipment used, should innovate to find a way to balance construction workers’ ergonomics and H&S, with sustainability objectives.

References


Carbon emission analysis during the life-cycle of prefabricated buildings: a case study in Shenzhen, China

Gao, Y.1, Yu, B.2, Li, Z.D.3, Wang, J.Y.4*

Abstract: A calculation method was presented to quantify the carbon emission of prefabricated construction based on Life Cycle Assessment (LCA). The model was applied to analyze the carbon emission in prefabricated construction in Shenzhen, including prefabricated components manufacturing, transportation and construction three phases. The results indicate that the major carbon emissions comes from manufacturing phase, followed by the stage of transport due to vehicle exhaust, and the carbon emissions of construction is relatively small. The conclusions can provide basic data for the energy saving and emission reduction of the prefabricated construction and promote healthy development.

Keywords: prefabricated construction; carbon emissions; life cycle

---

1Gao, Y.
College of Civil Engineering, Shenzhen University, Shenzhen, China

2Yu, B.
College of Civil Engineering, Shenzhen University, Shenzhen, China

3Li, Z.D.
College of Civil Engineering, Shenzhen University, Shenzhen, China

4* Wang, J.Y.
Corresponding author, College of Civil Engineering, Shenzhen University, Shenzhen, China
E-mail: wangjy@szu.edu.cn
1 Introduction

Construction-related environmental issues have attracted a multitude of concerns worldwide \(^1\). According to international energy agency (IEA) report, global energy-related CO\(_2\) emissions reached up to 31.6 gigatonnes in 2012\(^2\). The data from the World watch Institute showed that the building construction annually consumes 40% of the stone, sand and gravel, 25% of the timber and 16% of the water in the world \(^3,4\). What is more, the manufacturing and transporting of building materials, and the construction of buildings consume large amount of energy and emit great quantities of greenhouse gases (GHG) \(^4\). The report by the Inter government Panel on Climate Change (IPCC), the building sector accounted for up to 40% of the total energy consumption and contributed a quarter of the global total CO\(_2\) emissions, which makes it as a key player in the domain.

As a pioneer in China’s reform and opening up, Shenzhen takes the lead in achieving urbanization. However, some problems still exist in Shenzhen, it is witnessing a series of dilemmas and constraints, including time, safety, labour shortages, environment protection and quality concerns. One of the effective solutions to solve the issues related to construction is prefabricated construction, which has become increasingly important in the entire construction industry \(^1\). Prefabrication is a manufacturing process that combines various basic materials to form the component parts of the final installation in a specialized facility \(^5\), which is used to distinguished from traditional construction practice transporting the basic materials to the construction site. It has long been recognized internationally to have numerous advantages over traditional construction technologies: (1) significant savings in construction schedule since concrete maintenance is not needed for components on-site\(^6\); (2) better on-site construction environment as a result of more optimal material usage, recycling, noise capture and dust capture\(^1,7\); (3) Lower energy consumption, water and air pollution; (4) more control over the engineering standard\(^8\). Therefore, prefabrication is recommended as a key vehicle in promoting efficient construction as well as in alleviating the adverse environmental impact of conventional cast in-situ construction within developed construction industries \(^9\).

In the recent one year, the Chinese government at all levels had issued a series of measures to further enhance the promotion of prefabricated building (Figure 1). Consequently, considerable demand for prefabrication exists which is bound to result in large energy consumes and environmental problems. In order to quantify the environment impact potential of prefabricated construction, this study based on LCA to established carbon emissions model to assess the prefabrication buildings greenhouse gas (GHG) emissions.

2. Methodology

Life Cycle Assessment (LCA) is a research methodology that evaluates its environmental impact over the entire lifecycle of a product and has been widely used in engineering, materials, and equipment. Assembly process involves more processes, and with the consumption of energy and materials. In this research, therefore, the LCA theory was applied to the assembly of carbon emissions and energy consumption analysis can quantitatively evaluate the carbon emissions of their processes. Life cycle assessment is divided into four basic steps: the purpose and scope of the determination, inventory analysis, impact assessment and interpretation of the results, as shown in Fig. 2. The four steps are described separately below.
Fig. 1. The measures issued by Chinese government

2.1 Goal and scope

The main goal of this research is to assess the environmental impacts of prefabricated building and the system scope was defined as shown in Fig. 3. All activities involving carbon emissions should be taken into account in the calculation of the life-cycle carbon emissions of prefabricated buildings. Its life-cycle is divided into production, transportation, construction, maintenance and demolition. However, the prefabricated building in Shenzhen is still in the promotion stage, with little case of maintenance and demolition. In order to facilitate the analysis of carbon emission and energy consumption, the system boundaries need to be simplified. Therefore, the research only consider the pre-assembly process before the completion, taking production, transportation and construction as the boundary of research system.

There are many types of structural components involved in assembly buildings, and their sizes are different, and the carbon emissions of their life cycle are quite different. In order to facilitate the comparison of different components of carbon emission type, select 1m³ as the evaluation indexes of 1 functional units, the assessment of the size of carbon emissions will be more accurate.
2.2 Inventory analysis

Inventory analysis is a vital part of life cycle assessment. Through the classification of materials, energy input and other data classification statistics, and the collection of building materials required for the construction of carbon emissions factors such as data, unified to the list, data processing and calculation, access to the list of life cycle.

(1) Data type

Data type includes “material consumption and mechanical energy consumption inventory data of prefabricated building in production stage” and “component transport inventory data”.

(2) Carbon emission and energy consumption calculation model

The prefabricated building life-cycle carbon emission and energy consumption model is the sum of the greenhouse gases converted to carbon dioxide equivalent and energy consumption for each stage, as shown in equation (1):

\[ Q = Q_m + Q_t + Q_c \]  

(1)  

Where \( Q \) refers to the total carbon emission in life-cycle; \( Q_m \) refers to the carbon emission in the production stage; \( Q_t \) refers to the carbon emission in the transportation stage; \( Q_c \) stands for the carbon emission in construction and installation.

2.3 Impact evaluation and explanation of results

At the end of the inventory analysis, there are detailed results on resource consumption, energy consumption and carbon emissions in different stages of the assembly building. The impact evaluation is based on the results of the inventory analysis, which qualitatively quantifies the environmental impact caused by the construction of the building and qualitative assessment. Through the analysis of the first three stages, the environmental impact of different stages is identified and analyzed.

3. Case study

In this study, based on the site investigation, a case study was conducted to calculate the carbon emissions during prefabricated building’s life cycle. This project is 100km from the factory and the main prefabricated components are balcony partition board, prefabricated shear wall, prefabricated filling wall (exterior wall), prefabricated filling wall (internal wall), laminated plate, laminated beam, balcony and staircase. The list of quantities is shown in Table 1 inventory analysis for prefabricated components. And Table 2 is the list of carbon emission factors that may be involved.

| Table 1 inventory analysis | Table 2 the summary of carbon emission factors |
The method of calculating carbon emission in the life-cycle of prefabricated buildings is to explore how to calculate the carbon emission in the manufacturing phase, transportation phase and construction phase. The key of the life cycle inventory analysis is to calculate the input and output of different prefabricated component. Input refers to material and energy consumption, and output refers to carbon emission. The process of energy consumption and carbon emission is shown in Fig4.

<table>
<thead>
<tr>
<th>Components</th>
<th>Quantities</th>
<th>Unit</th>
<th>Types</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>balcony partition board</td>
<td>49.64</td>
<td>m³</td>
<td>Hot rolled steel (carbon steel) (kg CO₂ eq /t)</td>
<td>2617</td>
</tr>
<tr>
<td>prefabricated shear wall</td>
<td>1330.53</td>
<td>m³</td>
<td>C30 Concrete (kg CO₂ eq / m³)</td>
<td>321.3</td>
</tr>
<tr>
<td>prefabricated filling wall (exterior)</td>
<td>292.88</td>
<td>m³</td>
<td>Steel plate (kg CO₂ eq /t)</td>
<td>2702</td>
</tr>
<tr>
<td>prefabricated filling wall (internal)</td>
<td>158.04</td>
<td>m³</td>
<td>PVC (kg CO₂ eq CO₂ eq / kg)</td>
<td>3.254</td>
</tr>
<tr>
<td>laminated plate</td>
<td>363.9</td>
<td>m³</td>
<td>Polystyrene (kg CO2 eq /kg)</td>
<td>4.487</td>
</tr>
<tr>
<td>laminated beam</td>
<td>12.38</td>
<td>m³</td>
<td>Aluminum (CO2 eq /t)</td>
<td>22.67</td>
</tr>
<tr>
<td>balcony</td>
<td>24.75</td>
<td>m³</td>
<td>Gasoline (kg CO2 eq /L)</td>
<td>2.26</td>
</tr>
<tr>
<td>staircase</td>
<td>165.6</td>
<td>m³</td>
<td>Diesel (kg CO2 eq/L)</td>
<td>2.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Electricity (kg CO2 eq/kwh)</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heavy Duty Trucks (30t)</td>
<td>0.0578</td>
</tr>
</tbody>
</table>

**LCA model**

![Fig. 4. Carbon emission and energy consumption process](image)

**Prefabrication manufacturing**

Carbon emissions from prefabricated components manufacturing include two parts. The first part is the carbon emissions from raw material consumption. By calculating the unit material...
consumption in the components, analysing the unit energy consumption and carbon emission coefficient of various material, the carbon emission from raw materials can be obtained. The second part is the carbon emissions during the process of production, mainly from the machines running in the production line.

\[ Q_{m1} = \sum_{i=1}^{n} q_i \times e_i \quad (2) \quad Q_{m2} = \sum_{i=1}^{n} \left( F_{id} \times M_d + F_{ig} \times M_g + F_{ie} \times M_e \right) \quad (3) \]

Where \( Q_{m1} \) indicates the total carbon emission of raw material; \( Q_{m2} \) refers to the total carbon emission of prefabricated components during production process; \( q_i \) - material consumption; \( e_i \) - carbon emission coefficient; \( i = 1, 2, \ldots, n \) stands for different prefabricated component; \( F_{id}, F_{ig}, F_{ie} \), stands for the diesel, gasoline, electricity, consumption of produce prefabricated component \( i \). \( M_d, M_g, M_e \) refer to diesel, gasoline and electricity carbon emission coefficient respectively.

Accordingly, the total carbon emission during the production stage is

\[ Q_m = Q_{m1} + Q_{m2} \quad (4) \]

**Transportation**

The transportation process refers to the process in which the prefabricated components are transported to the site after the production is completed in the factory. In the transport process, the transport will consume energy, and produce a certain exhaust. In this study, assume full transport, no load return. The return of other materials or other means of transport is not within the system boundaries of the study. In this study, empty return factor needs to be corrected. That is, the actual distance \( D_{\text{trans}} = \text{one-way transport distance} \times F_y \). According to existing research, the environmental load at no load is 0.67 times the full load and thus, the empty return factor \( F_y = 1.67 \).

The carbon emissions during transport are calculated using equation (5):

\[ Q_t = \sum_{i=1}^{n} E_{t(i)} \times W_{t(i)} \times D_{t(i)} \quad (5) \]

Where \( Q_t \) refers to the total carbon emission during transportation; \( E_{t(i)} \) stands for the carbon emission factor of prefabricated component \( i \) in transportation; \( W_{t(i)} \) refers to the quality of prefabricated component \( i \); \( D_{t(i)} \) refers to transport distance.

**Construction**

Construction stage mainly contains the lifting and assembly of prefabricated components, which considers the energy consumption and water consumption of construction equipment. According to the construction project budget quota and bill of quantities, the number of classes consumed by machinery can be attained. Through the monitoring of energy consumption of construction machinery to get energy consumption, and energy consumption into a unit of cubic components of the construction of energy consumption, and the corresponding energy carbon emission factor multiplication, the construction process can be calculated in the unit square meter construction of carbon emissions.

\[ Q_c = \sum_{i=1}^{n} (F_{id} \times M_d + F_{ig} \times M_g + F_{ie} \times M_e + F_{iw} \times M_w) \quad (6) \]

Where \( Q_c \) stands for the carbon emission of unit volume of prefabricated component in the construction stage; \( i \) refers to different prefabricated component; \( F_{id}, F_{ig}, F_{ie}, F_{iw} \) stands for the diesel, gasoline, electricity, water consumption of install prefabricated component \( i \). \( M_d, M_g, M_e, M_w \) refer to the carbon emission coefficient diesel, gasoline, electricity and water respectively.

**4. Results and discussion**

Prefabricated components are assembly line production and the mechanical energy consumption types are electrical energy. The raw material of the project in the amount of
prefabricated components are investigated through project. By statistical analysis, taking into account the material loss and error, according to the table 1 and formula 2, 3 and 4, calculate per unit volume of per prefabricated components’ carbon emissions during manufacturing phase, transport phase and construction phase, shown in Fig.5.

![Fig. 5. Carbon emissions per unit volume per component](image)

The results column 1 showed that in the manufacturing phase, the largest prefabricated carbon emissions is precast shear wall rating of 1115.90kg/m³. Through investigation, the respondents stated that due to shear wall use plenty of raw materials and the production process is complex and have numerous embedded parts, it caused large carbon emission. The second is the laminated beam, carbon emissions rating of 1101.62kg/m³. The internal filling wall is the smallest emission rating of 792.34kg/m³. The line 2 showed transport phase, exterior filling wall and internal filling wall are the largest carbon emission source due to the weight per unit cubic walls is lighter than the others. The volume of the truck is fixed, 30T, the smaller the density, the greater the carbon emissions. The following line 3 revealed construction phase. As shown in the figure, the wall’s carbon emissions are generally larger than other components especially the prefabricated shear wall and exterior filling wall, due to the installation process is more complicated and consumes large power. Combined with the bill of quantities of this case, carbon emissions can be calculated at each stage showed in the following Fig.6.

From the perspective of life cycle, the largest carbon emission is manufacturing phase, accounting for 88% in the life cycle, and the following is transport phase, accounting for 11% and the rest part are construction phase ratio was only 1%. Therefore, the manufacturing stage is the key stage of assembly building carbon emission reduction, it should pay more attention to this stage. Refining the production process and reducing carbon emissions as much as possible from the source. The transportation stage is mainly related to the amount of the component quantities and the distance of the transportation. As a consequence, nearby factories should give priority to selection to reduce the carbon emissions. From the point of view of component, the large amount of component in the project should be focused on to save or to recycle. What is more, some materials with larger carbon emission coefficients, such as aluminum, should improve material utilization and reduce waste. At the same time, it can be considered to choose smaller coefficients alternative materials to reduce carbon emissions effectively.
5. Conclusions

This study develops a model based on LCA method to quantify environmental assessment and the model was applied a project in Shenzhen, China, to analysis the carbon emissions. The results indicate that prefabricated building’s carbon reduction should be focused on manufacturing stage, since the transport stage and construction stage account for small. On the one hand, it can be improved the environmental impact caused by the production of building materials through reduce the waster of materials especially the steel and concrete, on the other hand, by improving production processes, such as develop new environmentally friendly materials to influences.

References

Barriers to the Implementation of Occupational Health and Safety Legislation in the Nigerian Construction Industry

Adeyemo, O.¹ and Smallwood, J.J.²*

Abstract: The performance of construction projects can be improved by addressing occupational health and safety (H&S) to safeguard the H&S of workers, and the entire community. A range of studies have addressed the role, implementation, and enforcement of H&S legislation relative to the construction industry. However, fatalities and injuries remain issues in the industry. Consequently, this study seeks to determine the barriers to the implementation of occupational H&S legislation and its impact on H&S performance.

Data was collected using questionnaire surveys among construction professionals, and descriptive statistics were computed.

The study reveals that: Nigerian occupational H&S legislation is not specifically designed for the construction industry, and therefore, does not positively influence H&S performance in the construction industry; a range of problems affect the implementation of H&S legislation in the Nigerian construction industry, and limitations in current H&S legislation impact on overall project performance.

The study concludes that to promote an H&S culture that would promote continuous H&S performance improvement on construction projects, H&S legislation must be specific, strictly monitored, and enforced. Recommendations include that: H&S legislation must meet the current realities in the construction industry, and be enforced at the local level, and that the government must address corruption.

Keywords: Construction; Health and Safety; Performance; Project.

1 Introduction

According to Olatunji & Bashorun [¹], the Nigerian construction industry contributes 5.8% of the nation’s Gross Development Product (GDP), provides employment for 3 million of the 160 million population in the country (Osmani et al.,) [²], and has the potential to contribute much more due to the rapid rate of urbanisation. Despite the importance of this industry, it has been classified as one of the most hazardous sectors [³, ⁴], which is highly susceptible to accidents due to the simultaneous involvement of personnel, and plant and equipment on projects says Idoro [⁵].

¹ Adeyemo, O.
Department of Construction Management, Nelson Mandela University, South Africa

² Smallwood, J.J.
Corresponding author, Department of Construction Management, Nelson Mandela University, South Africa
E-mail: john.smallwood@mandela.ac.za
The causes of accidents on construction sites, according to research studies are attributable to: the poor H&S attitude of construction firms; workers’ disregard for H&S standards; errors by workers based on lack of awareness or understanding of H&S manuals and instructions; disorganised labour, a high rate of turnover resulting in little or no training for new entrants; lack of a proactive approach to risk management; substandard personal protective equipment (PPE), and inappropriate use of machines or operation at very high speed. Sibani et al. [9] opine that technical weaknesses of building designs were initially the main cause of accidents on sites, but despite new equipment having been evolved to expedite such design, accidents still recur, and thus it became apparent that the main cause of accidents on construction sites is attributable to inadequate management.

This situation is further compounded by the fact that most temporary or casual workers employed are not registered with a social security scheme in developing countries, and as such, employers do not pay on behalf of their temporary staff into the social based fund, therefore, these workers receive no social benefits and have no protection against loss of pay during the period of unemployment, ill health, injury, accident, or upon retirement [10]. Furthermore, H&S legislation in developing countries is rare, and if it does exist, authorities in charge of enforcement fail to implement the legislation effectively [9].

Nigeria as a developing country currently has a flourishing construction industry with booming construction activities [11]. According to the National Bureau of Statistics [12], Nigeria has the most competitive economy in West Africa and especially when compared to other African countries. However, its construction industry suffers from poor H&S practices. The H&S structures are irregular, lopsided, and ineffective, which makes construction sites even more dangerous opines [9].

However, accidents and injuries on construction sites can be mitigated by developing proper H&S legislation for construction, and by authorities enforcing the related H&S standards. Therefore, implementing H&S legislation to help curb accidents for future projects would be beneficial for the required pre-project preparations and budget allocations, which will contribute to the minimisation of damage to organisations’ financial stability because of accidents and the enhancement of performance on their construction projects. An innovative approach to the management of H&S legislation is therefore required.

2 Review of the Literature

2.1 A review of H&S Legislation in Nigeria

Idoro [5] opines that H&S legislation is targeted at ensuring the H&S of lives and property of each citizen within the country. Looking critically at H&S legislation in Nigeria, almost all the legislation concerning occupational H&S originated from developed countries, and hence the argument that Nigeria depends on recognition from its colonial master even after independence [13; 14]. Despite this, two notable regulations that relate to occupational H&S in Nigeria are the Factory Act, 1990, and Employees Compensation Act, 2010.

The Nigerian Factory Act 1990 is the localised version of the UK Factory Act of 1961, which was adopted to address H&S in the Nigerian context. To prevent workers from health hazards, Parts II, III, and IV are concerned with the H&S as well as the welfare of the workers. The act deals with offences, penalties, and legal proceedings, and empowers the inspector even in
cases where a person is not a legal practitioner to present and defend any offence arising from the provision of the Act. However, the reality relative to this act is that very few cases are prosecuted, as almost all the cases that exist in relation to the Factory Act are English laws [15]. Furthermore, Idoro [5] argues that the Act is limited by its definition of factory, which excludes all the activities and operations of construction sites. Thus, authors such as Idoro [5] and Galbraith [13] state that there is no H&S legislation regulating construction practices in Nigeria, which contractors can adopt, and which could promote H&S practices, and thus they commit little or no resources in terms of sustaining a healthy and safe work environment.

The Employees’ Compensation Act (ECA) 2010 is targeted towards the payment of compensation to workers that sustain injuries or suffer from occupational diseases or death at their workplace in the process of carrying out their duties [16]. The law provides speedy and adequate means of compensation without recourse to the court of law; it accommodates workers with mental stress, and the funds are managed by the National Social Insurance Trust (NSIT) and are made regardless of the organisation’s financial position and most importantly, the scheme covers employees, part-time, temporary, or casual, both in the public and private sector, which also extends to the dependent(s) of the deceased [5]. Although this Act was promulgated to ensure a better quality of life for the citizens of Nigeria working in various capacities, it is very reactive, as it is aimed at remedying harm, injury or death after occurrence, whereas, the focus as a country according to Tanko & Anigbogu [17] should be on proactive preventative measures, which should be channeled towards abating or minimising ill-health, deaths, and injuries.

2.2 Implementation of H&S Legislation

The implementation of H&S legislation requires issuing of warnings or notices to offenders, and thereafter, the sealing of defaulting sites, and the penalisation of defaulters [18]. Regrettably, this is not practicable in Nigeria in that the resources required for enforcement are inadequate and not available. In affirmation, Okojie [18] confirms that the sealing of premises is a rare form of forceful H&S implementation in Nigeria. Furthermore, Adeogun & Okafor [19] note that unhealthy exposures to risks of workers in organisations make it evident that H&S legislation is not enforced in Nigeria. The argument, therefore, is that there should be daily inspection of workplaces by factory inspectors and monthly reports to the Federal Ministry of Labour and Productivity [18], but this is often farfetched. Moreover, authors such as Ezenwa [20] and Idubor and Oisamoje [21] record that the number of enforcement officers in Nigeria is insignificant compared to the number of factories in Nigeria. Keith et al. [17] believe that lack of personnel and lack of commitment to ensuring better enforcement on the part of the enforcement authorities, hinders the optimum enforcement of H&S regulations.

Then, a study conducted by Diugwu et al. [22] determined that most construction workers in Nigeria are unaware of the body responsible for enforcing H&S regulations in the industry. During the study, 79.5% of the respondents could not identify the correct body responsible for H&S implementation in Nigeria. This implies a lack of knowledge regarding H&S, and its ineffective enforcement. Given these highlighted deficiencies, it is pertinent to further examine the barriers to the successful implementation of H&S regulations in Nigeria; thus, the subsequent section addresses this.
2.3 Barriers to the Implementation of H&S Legislation

The Nigeria, the largest African country is beleaguered with corruption, and Transparency International [23] ranks the country 139 out of 176 in terms of the corruption perception index. According to Onyeozili [24], regulatory institutions and the police force have been proven to be corrupt, which prevents effective implementation of legislation in the country as the activities of authorities responsible for enforcing the laws are questionable. For instance, Langford et al. [25] refer to situations where firms with poor H&S practices achieve pass marks after inspection because they have bribed the enforcement officers. Keith et al. [17] confirm that enforcement officers do this due for selfish financial reasons, thereby marginalising the aims of the regulations, and promoting non-compliance.

Lack of skilled personnel is also another major barrier to the effective implementation of H&S in Nigeria [19; 21; 22]. This view is further supported by Omojokun [26] who identifies insufficient enforcement officers among the challenges to effective food regulation and enforcement in Nigeria. In a similar vein, Rantanen [27] states that an insufficient number of competent occupational health services experts hinders the development of occupational health services globally.

Consequently, implementation of H&S legislation requires funds to be available for effective provision of adequate facilities and recruitment of training officers who enforce the laws. However, Ezenwa [21] argues that the number of technical and transport equipment is inadequate, which hinders the implementation of H&S legislation in Nigeria. The argument here is that if the ministry experiences insufficient funding, adequate enforcement will be farfetched; it may also contribute to corruption. Cheung et al. [28] concur with the identification of insufficient funding being viewed as a barrier to the implementation of H&S legislation. Furthermore, Rantanen [27] notes financial constraints as one of the factors that hinder the development of health services.

3 Research Method

The sample strata for the study included contractors, subcontractors, public sector clients, and consultants in the form of architects, and quantity surveyors. The contractor sample strata included H&S managers, site engineers, project managers, and site operatives who often experience construction hazards. The questionnaires that were administered were designed to investigate the implementation of H&S legislation and its impact on construction project performance in Nigeria.

Out of 60 questionnaires administered, 55 were returned completed, of which 49 (81.7%) were valid for analysis, which constitutes an acceptable response rate.

4 Research Findings

With respect to qualifications, 14.3% of respondents have a National Diploma or Ordinary National Diploma (ND/HND), 22.5% have a Bachelor of Science degree (BSc), 46.9% a Master of Science degree (MSc), and 16.3% a doctoral degree (PhD). In terms of their work experience, 48.9% of the respondents have experience ranging from 11-20 years, followed by 21-30 years (20.4%), 6-10 years (16%), 0-5 years (10.2%), and > 31 years (4.1%). 30.6% of the respondents represent construction firms, 24.5% quantity surveying firms, 20.4% H&S firms, 16.3%
architectural firms, and 8.2% public / government offices. This is so because some public office holders were reluctant to provide information relative to this study, despite the author’s reassurance of confidentiality. Of the 49 respondents, 20.4% are consultants, 16.3% are contractors, 42.9% are H&S Officers, 8.2% are clients, and 12.2% are skilled operatives.

Table 1 presents the extent to which problems affect the successful implementation of H&S legislation in the Nigerian construction industry. It is notable that all the mean scores (MSs) are > 3.00, which indicates that the problems do so to a major as opposed to a minor extent. Furthermore, the mean MS of the twelve problems is 3.69, which indicates that on average they do so between some extent to a near major / near major extent. The top two problems, namely ‘limitations in the present H&S laws’, and ‘corruption and bribery’ have MSs > 4.20 ≤ 5.00, which indicates they do so between a near major to major / major extent. 8 / 12 (66.7%) of the MSs are > 3.40 ≤ 4.20, namely those ranked third to joint ninth, which indicates that they do so between some extent to a near major / near major extent. The problems that do so to the least extent are ‘inadequate coordination and integration within the inspectorate division’, and ‘lack of skilled staff’.

All stakeholders are generally of the opinion that H&S is still an evolving concept in Nigeria, that is, it is still at its formative stage because there is no national legislation that mandates stakeholders and regulators alike. Furthermore, the non-inclusion of the construction industry in the Nigerian Factory Act (2004) makes it difficult for construction stakeholders to adopt the regulations in Nigeria. Thus, many construction workers are left at the mercy of fate, and construction clients are forced to use their discretion in managing H&S on site. H&S respondents believe that the H&S legislation in the Nigerian construction industry is limited, that is, there are no specific laws that specifically encompass all hazards in the Nigerian construction industry. The recently passed Labour, Welfare and Safety Bill, 2012 by the Nigerian Senate is yet to be passed into law. It is hoped that this bill will address the deficiencies of the Nigerian Factory Act (2004), and address all construction site needs.

Table 1. Extent to which problems affect the implementation of H&S legislation in the Nigerian construction industry

<table>
<thead>
<tr>
<th>Problem</th>
<th>MS</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limitations in the present H&amp;S laws</td>
<td>4.45</td>
<td>1</td>
</tr>
<tr>
<td>Corruption and bribery</td>
<td>4.28</td>
<td>2</td>
</tr>
<tr>
<td>Poor H&amp;S culture among construction stakeholders</td>
<td>4.08</td>
<td>3</td>
</tr>
<tr>
<td>High level of insecurity</td>
<td>3.67</td>
<td>4=</td>
</tr>
<tr>
<td>Severity of penalties to offenders</td>
<td>3.67</td>
<td>4=</td>
</tr>
<tr>
<td>Inadequate funding of facilities and equipment</td>
<td>3.67</td>
<td>4=</td>
</tr>
<tr>
<td>Outdated H&amp;S laws that do not address present-day hazards</td>
<td>3.62</td>
<td>7=</td>
</tr>
<tr>
<td>Weak judiciary system and structure</td>
<td>3.62</td>
<td>7=</td>
</tr>
<tr>
<td>Political influence</td>
<td>3.44</td>
<td>9=</td>
</tr>
<tr>
<td>Inadequate government commitment</td>
<td>3.44</td>
<td>9=</td>
</tr>
<tr>
<td>Lack of skilled staff</td>
<td>3.32</td>
<td>11</td>
</tr>
<tr>
<td>Inadequate coordination and integration within the inspectorate division</td>
<td>3.03</td>
<td>12</td>
</tr>
<tr>
<td>Mean</td>
<td>3.69</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 indicates the impact of the limitations in current H&S legislation on overall project performance. Using the relative importance index method (RII), the impact resulting from the limitations in current H&S legislation was ranked by scores from 1 to 5, where one represents least important and five most important. The RII was computed as per Cheung et al. [28]:

\[
RII = \frac{\sum W}{A \times N}
\]

Where \( W \) is the weight given to each factor by the respondents and ranges from 1 to 5; \( A \) – the highest weight = 5, and \( N \) = the total number of respondents.

In terms of the mean RII, ‘cost overruns’ was ranked first with a relative index of 0.840 followed by ‘time loss during project execution’, ‘poor labour productivity’, ‘quality non-conformances’, and ‘frequent changes in design’. These findings concur with those arising from a similar study conducted by Kouskili & Kartan [29], which indicates that accidents not only injure construction workers, but marginalise productivity, and engender material wastage, which lead to an overrun in construction cost. It is notable that poor labour productivity is ranked first relative to contractors, whereas ‘cost overruns’ is ranked first relative to both consultants and clients. In terms of the mean ‘impact’ RII per stakeholder, the contractors (0.830) are ranked first, followed by clients, and consultants. It is notable that the clients’ mean RII (0.784) is higher than that of the consultants (0.726). The difference in terms of the highest RRIs is also notable – contractors (0.899) versus clients (0.873), and consultants (0.793).

### Table 2. Impact of the limitations in current H&S legislation on overall project performance

<table>
<thead>
<tr>
<th>Impact</th>
<th>Consultants</th>
<th>Contractors</th>
<th>Clients</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RII Rank</td>
<td>RII Rank</td>
<td>RII Rank</td>
<td>RII Rank</td>
</tr>
<tr>
<td>Cost overruns</td>
<td>0.793 1</td>
<td>0.855 3</td>
<td>0.873 1</td>
<td>0.840 1</td>
</tr>
<tr>
<td>Time loss during project execution</td>
<td>0.764 2=</td>
<td>0.866 2</td>
<td>0.764 3=</td>
<td>0.798 2</td>
</tr>
<tr>
<td>Poor labour productivity</td>
<td>0.603 5</td>
<td>0.899 1</td>
<td>0.803 2</td>
<td>0.768 3</td>
</tr>
<tr>
<td>Quality non-conformances</td>
<td>0.764 2=</td>
<td>0.754 5</td>
<td>0.764 3=</td>
<td>0.761 4</td>
</tr>
<tr>
<td>Frequent changes in design</td>
<td>0.707 4</td>
<td>0.777 4</td>
<td>0.717 5</td>
<td>0.734 5</td>
</tr>
<tr>
<td>Mean</td>
<td>0.726 3</td>
<td>0.830 1</td>
<td>0.784 2</td>
<td>0.780</td>
</tr>
</tbody>
</table>

### Conclusions and Recommendations

The aim of the study reported on in this paper is to determine the barriers to the implementation of occupational H&S legislation, and to a lesser extent, the impact of the limitations in current H&S legislation on overall project performance. It demonstrates the ineffective enforcement of H&S legislation in Nigeria, and identifies the limitations in the present H&S legislation, and the poor H&S culture among stakeholders as the most severe problems affecting the successful implementation of H&S legislation in the construction industry. It is recommended that there should be new H&S legislation that would meet the current realities in the construction industry. Secondly, enforcement of H&S legislation should start at the local level where there are many unskilled operatives who work on construction sites. Local government establishments should also be involved in the enforcement of H&S legislation, and H&S inspectors should be recruited into the construction management system solely for ensuring that construction sites adhere to H&S legislation. Thirdly, the government must address corruption...
from the lowest to the highest level, and penalise construction firms that fail to comply with H&S legislation.

In conclusion, to improve performance in the construction industry, H&S legislation must be specific, monitored, and enforced. This means that the incorporation of H&S procedures into the overall management system within the construction industry will lead to a cost effective, highly productive, and quality assured safe working environment for construction employees, and construction projects in general.

References


Empirical Study of Knowledge Management Enablers in Large Construction Organisations

Chan, E.M.Y. and Mohamed, S.

Abstract: Knowledge management (KM) is a method of acquiring strategic knowledge to drive sustainable business benefits. However, empirical evidence regarding the direct and indirect relationships among essential knowledge management enablers (KMEs) is limited in the literature. This study focused on large construction organisations operating in Hong Kong and adopted a structural equation modelling (SEM) approach to identify and develop the structural cause-and-effect relationship among various KMEs. A mixed-methods research framework was used, combining evidence from a questionnaire-based survey study and a multiple case study. This research identifies organisational Leadership as the major driver of successful KM implementation. Other identified enablers include KM Strategies, Organisational Culture, Innovation, and Processes and Activities, all of which, in the local context, have emerged as critical KMEs. The paper findings provide a snapshot of cause-and-effect relationships among various KMEs, the strength of these relationships and practical suggestions for construction practitioners about designing and implementing appropriate policies to ensure successful KM implementation.

Keywords: knowledge management; enablers; Hong Kong.

1 Introduction

A total of seven knowledge management enablers (KMEs) have been identified in the literature as critical for successfully implementing knowledge management (KM) initiatives in large construction contracting organisations operating in Hong Kong[1]. Using the combination of a focus group with industry practitioners and the interpretive structural modelling (ISM) technique, these seven identified KMEs were ranked based on their driving power and dependence levels[1]. The KMEs are Leadership (L), Strategies (S), Organisational Culture (C), KM Processes and Activities (A), People (P), Innovation (I) and Technology (T).

To better understand how each KME influences (and is influenced by) other KMEs, this paper empirically investigates the interactions among these seven KMEs. It adopts a questionnaire-based survey and structural equation modelling (SEM) technique to develop a model depicting the relationships between the KMEs. The paper is structured as follows: first, it presents the adopted research methodology and statistical analysis; it then explores the SEM analysis and multiple case study to validate the model results. The paper concludes with a discussion of its theoretical contributions.

---

1* Chan, E.M.Y
Corresponding author, School of Engineering, Griffith University/Gold Coast, Australia
E-mail: myedechan@yahoo.com.hk

2 Mohamed, S.
School of Engineering, Griffith University/Gold Coast, Australia
E-mail: s.mohamed@griffith.edu.au
2 Research Methodology, Measures and Statistical Analysis

The research methodology adopted for this study largely involved a questionnaire survey and factor analysis. The former method sought answers from local construction practitioners to a list of pre-determined questions about KMEs, and the latter investigated variable relationship(s) between the KMEs. A questionnaire-based survey and SEM technique were used to develop a model depicting the relationships among the seven KMEs. The survey comprised 91 items/questions in an attempt to measure these KMEs\(^2,3\). Multi-item scales measured the research enablers using a five-point Likert scale, with responses ranging from 1 = strongly disagree to 5 = strongly agree. This study relied greatly on a quantitative-based questionnaire as a means of systematically examining the KMEs. The robust questionnaire was based on a set of measures derived from operationally defined constructs, and was pre-tested using the expert-review method.

The questionnaire survey targeted construction professionals employed in 10 large construction organisations in Hong Kong. A total of 380 questionnaires were distributed. The results of the descriptions analysis reveal that the data obtained from 120 survey respondents could be adequately generalisable to the wider population in the local construction industry. The average research experience of the respondents within the construction industry was 18.5 years.

To examine the reliability of the KMEs, factor analysis was used to assess the validity of the measurement scales used in the questionnaire survey. The analysis was performed using two sequential techniques: exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). These factor analyses were applied to each scale to verify the factor structure that truly represented each model construct. The EFA identified the number of factors, conceptually and statistically, for the set of items in each model construct, for which Cronbach’s alpha coefficients were employed to assess internal consistency across the variables of a within a measurement scale. The EFA was performed using an R factor analysis. The CFA was employed to strengthen the validity of the measurement scale from the EFA and test how the hypothesised factor structure matched the actual data; this was achieved using the statistical package SPSS.

After reliability was established, SEM was used to examine the model’s cause and effect following the CFA, followed by a path analysis with latent variables. In this study, SEM was conducted using AMOS version 7.0. The EFA provided a preliminary factor analysis, while the CFA refined the identified factor structure. The model developed in previous research using the ISM technique was statistically tested for its fit with the data collected by SEM via empirical survey. Finally, SEM was used to assess and refine the model.

As a standalone survey study has limited ability to adequately represent overall industry situation\(^4\), and given that practitioners’ construction contexts and experiences are critical to increasing the practical relevance of the findings, an explanatory multiple case study design was used to investigate the contemporary phenomenon of a KMEs model in the natural setting of Hong Kong construction organisations. A theoretical sampling approach\(^4\) was used to reveal the model’s insights into KMEs in an empirical context.

3 Structural Equation Modelling Analysis

SEM was undertaken for path analysis of the research model in this study. SEM has been used by other researchers in various contexts\(^5\). Several indices are used to measure the model fit. The
statistics usually reported in SEM are chi-square ($\chi^2$), degrees of freedom, p-value, goodness-of-fit index (GFI) and comparative fit index (CFI). The $\chi^2$ statistic is an overall test of how well the hypothesised model fits the data—a significant $\chi^2$ indicates a model that does not fit well, because the $\chi^2$-statistic assumes multivariate normality and is affected by large sample size (i.e., a model with relatively good fit for a large data set can still be rejected). Additional indices of fit (i.e., GFI and CFI) must be used to make a judgement about the model’s fit. The GFI and CFI should have values over 0.90[6]. The square multiple correlations of individual observed variables—that is, $R^2$ value of the predicting observed variable by latent variables—should be greater than 0.5. These GFI statistics only offer information regarding the model’s lack of fit to the data used.

3.1 SEM results

The empirical data used in this study to statistically test the model fit (as developed through ISM methodology in previous research) was collected using a structured questionnaire.

When the model was statistically tested using AMOS 7.0, the cause-and-effect relationship of all the variables taken in the study did not emerge as statistically significant. The values of various fit indices, such as GFI and CFI, for the overall model were less than 0.90, and are required to be greater than 0.90[6]. In addition, the square multiple correlations of individual observed variables—that is, $R^2$ value of the predicting observed variable by latent variables—were also less than 0.5. Figure 1 shows the best-fit model (Final Model) derived from the available sample data.

The final model statistically establishes that Leadership leads to Organisational Culture, Strategies, Processes and Activities and Innovation; that Strategies affect Organisational Culture and People; and further, that these factors affect the Innovation of Hong Kong’s construction organisations. The overall fit of the model was adequate, with GFI as 0.971 and CFI as 0.988.

![Figure 1. Final Model for KMEs](image)

Notes: GFI, goodness-of-fit = 0.971; CFI, comparative fit index = 0.988; IFI, incremental fit index = 0.988; RFI, relative fit index = 0.886; RMSEA, root mean square error of approximation = 0.046; AIC, Akaike information criterion = 48.569; chi-square = 12.569

3.2 SEM results and discussion

The EFA, CFA and SEM results show that seven out of the 12 path coefficients for the hypothesised effect of one construct on the other were statistically significant. The effect of C on P was insignificant, with a path coefficient of 0.107. This $C \rightarrow P$ link was therefore removed from
the model (see Figure 1). The striking feature of this KME relationship, which differs from that shown in previous research, appears to be unique to the local construction industry in Hong Kong, where the vast majority of building projects and/or infrastructure projects are purely project-based, multicultural and non-culture driven. In a construction context, particularly for infrastructure or mega infrastructures, a management team comprises team members of multi-national expertise and experience, who come from different cultures and are temporary employees. Therefore, the culture-driven aim to achieve project goals is relatively weak. Highly commercialised projects in Hong Kong limit a strong degree of creativity, but complicate employees’ mindset, values, behaviour patterns and perceptions, rendering culture-driven projects almost impossible. Perhaps this is one plausible way to explain why there is little or to no effect of a single organisational culture on people in the local construction industry. Under these circumstances, it takes time to develop or establish trust, an important element of culture, within an organisation and among those involved in its projects. It follows that a clear lack of long-term firm commitment to achieving project goals exists throughout an organisation. A classic example is Hong Kong’s safety culture at construction sites, which explains, in part, why Hong Kong’s construction industry is hazardous in terms of safety at work. More importantly, given the multi-national nature of infrastructure projects—particularly joint venture (JV) projects—among mainland China, Hong Kong, the United Kingdom and the United States, JV organisational culture is highly influenced by the dominant national culture of the management team in China.

4 Case Study

To ensure the generalisability of the empirical results derived from the quantitative analysis, a qualitative validation process was conducted to determine whether the relationships depicted in the empirical model could be sufficiently explained by the actual phenomena observed within the sampled organisations. To achieve this, explanatory case study research was conducted with five construction organisations in Hong Kong. These case studies provide two important findings that support the model’s validity.

Following the suggestion of Barratt[7], interviews were conducted within five organisations to capture the complexity of the ‘real world’, while facilitating cognitive progression of the information over a four month-period thus allowing the researchers to sufficiently gather and assess the information. The case organisations are referred to here as organisations A, B, C, D and E to maintain their anonymity. A total of 19 construction professionals participated in the interviews, with four members each from organisations A, B, C and D, and three members from organisation E. These participants represented a combination of managerial, senior and junior staff members who specialised in building or engineering construction, with the junior staff having an average of four years’ experience each, and the senior and managerial staff having more than 15 years’ experience each. All participants also held at least a master’s degree relevant to their field of expertise and were qualified as professional engineers. Therefore, they were considered knowledgeable and likely to provide reliable, accurate and insightful information relevant to the topic of investigation. The interviews with each group lasted from 20 to 60 minutes, with an average duration of 40 minutes. Five interviews were conducted by the first author on a group basis (three or four nominees from each organisation). In each case, two sources of evidence—interview transcripts and the organisation’s KM operational documentation—were
collected for data triangulation purposes. Semi-structured face-to-face interviews were undertaken to provide opportunities for clarifying ambiguous questions and observing the environment of the organisation being studied. All interviews were recorded and transcribed. A pattern-matching technique was used to strengthen the case study's internal validity\[4\].

4.1 Case study results

The final model only supports seven ISM links out of 12; however, the study provides a limited explanation for the context in which the proposed relationships emerge. Five ISM links failed to provide significant additional explanations for the KM implementation, but four new and significant links were added. In view of this, the case study was undertaken to increase the reliability and validity of the findings and, in particular, to investigate the real-life research context.

The case study data analysis procedure consisted of two key steps: within-case and cross-case analyses\[4\]. The results of both analyses were presented to the interviewees for validation. At the same time, further phenomena associated with the findings (e.g., patterns) were collected.

4.2 Within-case analysis

The within-case analysis evaluated the collected data and reported the findings of each case. The findings reveal insightful events and phenomena that reflect how the underlying attributes of the survey factors and constructs were perceived within the empirical context of a real-life setting. This outcome is presented as a qualitative rating of these factors and constructs. By using descriptive coding, each piece of evidence (in a documentary format) was assigned a reference number, while its content was coded so that it could be classified according to relevant factors.

A matrix of categories was thus created that represented the survey study factors, with the evidence sorted into categories, documentation of written notes and record tapes. The evidence was subsequently evaluated through a systematic rating procedure in which each of the factors was classified, based on its corresponding evidence, as one of the following rating indicators: high (H), moderate (M) or low (L). To ensure the rating reliability and consistency, a set of qualitative assessment matrices was developed to serve as the criteria for classifying the factors into one of the above three indicators. To match a factor with a particular rating indicator, the evidence had to demonstrate a close match to the details of a statement within the relevant criteria. Once the individual factors had been rated, they were qualitatively aggregated to represent the overall rating of their respective construct.

Table 1 summarises the within-case analysis results, and presents, for each case, the rating levels determined for the seven constructs, derived from the qualitative findings. The results from the within-case analysis demonstrate that almost all the model factors that represent the constructs (Leadership, Strategies, Organisational Culture, Processes and Activities, People, Innovation and Technology) are consistently well correlated across all of the sampled organisations. This indicates that the factors are reliable for measuring the actual phenomena, thus reinforcing the robustness of the model’s factor structure as verified by the EFA and CFA.
Table 1. Summary of the within-case analysis results for seven constructs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Leadership (L)</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Strategies (S)</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Organisational Culture (C)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Processes and Activities (A)</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>People (P)</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Innovation (I)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Technology (T)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>H</td>
</tr>
</tbody>
</table>

In the above table, an overall summary of the ratings based on the within-case analysis results for the five interviews is provided for each of the model constructs.

4.3 Cross-case analysis

The purpose of the subsequent cross-case analysis was to yield insightful information about how specific routines and performance outcomes at the workplace emerged with the pattern of interaction relationships; a pattern-matching technique\([4]\) was used to link the collected data to the theoretical propositions. The patterns of qualitatively categorised circumstances were compared with the predicted patterns supported by the SEM final model (Model X), as detailed in Figure 2 and Table 2. According to Yin\([4]\), a pattern-matching procedure does not involve using precise comparisons or quantitative/statistical criteria to judge a pattern. Instead, it deals only with either gross matches or mismatches; detecting very subtle patterns is avoided. During the analysis, patterns were developed using the codified high (H), moderate (M) and low (L) values, following a study by Nicholson and Kiel\([8]\).

![Figure 2. Model X](image)

Table 2. Predicted patterns of relationships between constructs of Model X (SEM link)

<table>
<thead>
<tr>
<th>Predicted pattern (PP)</th>
<th>L</th>
<th>S</th>
<th>C</th>
<th>I</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP1</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>PP2</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>PP3</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
</tbody>
</table>
The model predicted that a higher level of L would lead to a higher level of S (see Table 2). In addition, simultaneously achieving higher levels of both L and S would substantially influence the level of C, with L having a stronger effect than S. Subsequently, a higher level of C would lead to a higher level of I, which would in turn contribute to a higher level of T. In the same manner, a lower level of L would result in lower levels of S and C, thus leading to a lower level of I and, eventually, a lower level of T.

4.4 Cross-case analysis results

Table 3 summarises the cross-case analysis results and presents the overall finding from the cross-case analysis, which used a pattern-matching technique shows a strong correlation between the quantitatively and qualitatively represented construct relationships. Of the five cases, four show a good to perfect match and one shows a partial match to the predicted patterns of the relationships between the model constructs. These results indicate that the empirical model could be explained by the qualitative case study findings.

Table 3. Cross-case analysis results for Model X

<table>
<thead>
<tr>
<th>Case</th>
<th>L</th>
<th>S</th>
<th>C</th>
<th>I</th>
<th>T</th>
<th>Matching result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Org. A</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>Perfect match to PP1</td>
</tr>
<tr>
<td>Org. B</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Partial match to PP2</td>
</tr>
<tr>
<td>Org. C</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>Good match to PP1</td>
</tr>
<tr>
<td>Org. D</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Good match to PP2</td>
</tr>
<tr>
<td>Org. E</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>Perfect match to PP1</td>
</tr>
</tbody>
</table>

It should be noted that although a few case-based relationships show a mismatch to the predicted patterns, these appear to be attributable to other firm-specific factors. These factors might account for a certain amount of unexplained variance in the model. Taking this into account, the empirical model’s validity is confirmed by the case study findings, as the model is shown to represent the real life situation in the studied organisations.

5 Discussion and Conclusion

The study aimed to gain a better understanding of which factors are critical to successfully implementing KM defined by many KM theory developers covered in the literature review, to unravel the complex relationships among the seven constructs and to test the SEM model. This empirical study contributes to validating some of the assumptions made regarding enabler factors and their effect on the successful KM of large (more than 1,500 employees) construction organisations in Hong Kong.

First, the study proves that key enabler factors—Leadership, Strategy, Organisational Culture, KM Processes and Activities, People, Innovation and Technology—positively influence successful KM. In terms of the Cronbach’s alpha for the measurement scale, the research findings indicate that measurement items for seven enablers are statistically supported and significantly related to successful KM.

The results reveal Leadership as the most vital factor for successful KM, the striking finding of this research study. Top management plays a vital role in successful KM initiatives. It should believe in and wholeheartedly support strategies that can facilitate an internal environment where
knowledge capture, creation, sharing, and transfer can flourish (L → S; L → A).

A second key factor is Strategies. Strategies are especially important for creating and sustaining competitive advantage; many organisations understand the strategic importance of knowledge for building and maintaining a sustainable competitive advantage, and thus have well-developed strategic models (codification- or people-centric) that integrate KM process with business strategy.

The third group of key factors comprises Organisational Culture, People, and Processes and Activities. Thus, building and supporting a culture that rewards and encourages employees for seeking, sharing and creating knowledge attributes will likely lead to successful KM implementation.

According to the literature, staff in any organisation are also essential to determining successful KM. In particular, people can create new knowledge and many important people-related issues. However, it is also desirable to consider less important key factors, such as Innovation.

Finally, it is indisputable that information technologies can facilitate KM. Nevertheless, this study reveals that technology does not significantly contribute to successful KM within an organisation. Information technology should not be seen as the sole driver of KM, since it is only a tool. This may explain why other researchers have also perceived it as the least important enabler[3].

References

Opportunities for Improving Construction Health and Safety Using Real-time H&S Management Innovations

Chathuri Gunarathna, Rebecca Jing Yang*, Vanessa McDermott, Helen Lingard

Abstract: The deployment of geotechnical innovations could help to address endemic health and safety (H&S) problems in construction. However, the uptake has been limited and the potential H&S benefits of advanced technologies are not currently being optimized. This research aims to understand social, economic and technical factors facilitating the uptake of geotechnical technologies for improving construction H&S. An extensive literature review is undertaken to examine the socio-technical barriers and facilitators of advanced geotechnical technology being used to improve H&S in construction. Adequate accuracy, wireless application, robust communication and data storage ability are some of the common technical benefits of automated technologies. An effective safety management can only be achieved by selecting the most appropriate real-time safety management technique as per the site conditions, the investment capability of the construction company and with the endorsement of workers. The research outcomes will contribute to the improvements in productivity and performance associated with construction H&S.

Keywords: Geotechnical technologies, Health and safety, Construction sites.

---

1 Gunarathna, C. School of Property, Construction and Project Management, RMIT University, Melbourne, Australia
2 Yang, R.J. School of Property, Construction and Project Management, RMIT University, Melbourne, Australia. Email: Rebecca.yang@rmit.edu.au
3 McDermott, V. School of Property, Construction and Project Management, RMIT University, Melbourne, Australia
4 Lingard, H School of Property, Construction and Project Management, RMIT University, Melbourne, Australia
1 Introduction

According to Safe Work Australia’s ‘Construction Industry Profile’ (2015), in 2012–13 the construction industry had the 4th highest incidence rate of serious claims per 1000 employees and 5th highest fatality rate per 100 000 workers in 2013–14. Safety officers often use a checklist to manage construction safety by identifying and recording violations (Lin et al., 2014). In the absence of technological support, however, it is impractical to monitor the whole of sites at once in this way due to their large size and dynamic environment. The application of geotechnical technologies to facilitate real time safety management has generated considerable research and industry interest (Jiang et al., 2015; Lee et al., 2012; Wu et al., 2010). These technologies mainly include onsite tracking systems, sensors combined with visualization tools (Hwang et al., 2016; Nasr et al., 2013).

Receiving real time safety information is highly beneficial to support construction stakeholders in making timely and accurate decisions (Cheng & Teizer, 2013). Further, using automated systems can help to avoid the weaknesses of manual safety management such as human errors, high time consumption, requirement of more labour and subjective judgment (Zhang et al., 2015). In addition, the automated systems provide a better performance in a systematic manner (Jiang et al., 2015; Kelm et al., 2013). However, construction is a slow adopter of new technologies in that it is relatively undercapitalized, fragmented and based on sub-contract employment systems. Thus, the benefits of the new technologies are not well optimized in the construction safety management. This research aims to understand social, economic and technical factors facilitating the uptake of advanced technologies for improving construction H&S. It employs a socio-technical method to identify the critical social attributes, structure and organizational characteristics that influence the uptake of advanced technologies.

2 Research Methodology and Process

This study applied the Social Construction of Technology (SCOT) approach to analyze the interactions between the technology and the relative social groups. The SCOT approach presents a detailed illustration of the selected technology by considering four aspects; technology, the social groups who utilize or interpret the technology, the problems encountered by each social group and the solutions or mechanisms to solve those problems (Klein & Kleinman, 2002). A SCOT analysis examines the shape of the technology and how it is shaped by its social aspects (Boyd, Larsen and Schweber, 2015). The study uses the SCOT approach to analyze the selected technologies, the technical, economic and social issues faced by stakeholders and the potential solutions to overcome those issues. Considering these aspects is important because the implementation, development and continuation of these new technologies in the industry will rely on the technical capacity, economic viability and stakeholders’ social awareness (Surry & Baker, 2015). However, adopting and using these new technologies places demands on the prevailing technical capacity, economic stability and social willingness of groups involved in the construction sector.

This paper conducts a thorough literature review that considers real time safety management technologies under three main aspects; technical, economic and social. The study is limited to journal papers and conference articles published between 2000-2016, which was sourced using Google scholar, Web of Science and relevant journals. This resulted in the collection of 55 papers...
that specifically discuss real time safety management technology. Each source was subjected to a thorough analysis in order to find the technical aspects, economical aspects and social aspects of the technology. The study mainly focuses on the key issues with regard to these three aspects and proposed solutions.

3 Location-based Tracking Systems

3.1 Signal-based Tracking Technologies

Labour tracking is recognized as one of the main technologies used to avoid human errors on construction sites (Zhang et al., 2015). Tracking technologies provide sophisticated results in proximity detection and ability to pinpoint workers’ location (Golovina, Teizer, & Pradhananga, 2016). Global Positioning System (GPS), Radio Frequency Identification (RFID), Ultra Wide Band (UWB) and Wireless Local Area Network (WLAN) are highly recommended in literature (Jiang et al., 2015). GPS, RFID and UWB integrate with tags (sensors) which can be attached to a safety helmet or workers’ safety vest, heavy equipment and vehicles or installed in a mobile device such as smart phone or Personal Digital Assistant (PDA) (Golovina et al., 2016; Yang, Chew, Wu, Zhou, & Li, 2012). These three systems track objects by measuring signal transmitting time between senders and receivers. In contrast, WLAN locates objects by measuring the radio frequency strength (Woo et al., 2011). It can also act as a media of communication.

GPS and WLAN have a wider communication range in comparison to RFID and UWB technologies. GPS has an unlimited coverage area (approximately the entire surface of the earth), thus only requires a portable receiver onsite to establish the tracking system (Jiang et al., 2015). WLAN has a wide signal range (approximately 100 m) which enables long distance tracking and thus performs well in large construction sites (Carbonari, Giretti, & Naticchia, 2011; Jiang et al., 2015; Woo et al., 2011). Even though most of the signal-based technologies require a direct line-of-sight for accurate results, both RFID and WLAN do not require a direct line-of-sight during the tracking process (Kelm et al., 2013; Li & Becerik-Gerber, 2011; Yang et al., 2012). Hence, there is no strict requirement of having obstacle-free environment for RFID and WLAN to perform accurately (Jiang et al., 2015; Yang et al., 2012). UWB obtains the highest localization accuracy (both indoor and outdoor) due to the reliable Time Difference of Arrival (TDOA) usage and low power consumption of tags (Giretti, Carbonari, Naticchia, & De Grassi, 2009).

The most critical technical limitation of GPS is the inability of using it in indoor environment (Teizer & Vela, 2009). The satellite signals cannot go through the buildings without any disturbance, which reduces the level of accuracy in an indoor environment (Papapostolou & Chaouchi, 2011). However, indoor GPS technology, which consists of several indoor transmitters rather than satellites, is one solution to this problem (Park & Brilakis, 2012). In terms of RFID, the most critical technical limitation is its inability to interface with non-conductive materials (Kelm et al., 2013; Li & Becerik-Gerber, 2011; Papapostolou & Chaouchi, 2011). These non-conductive materials prevent the tags being recognized by the reader even when they are in the correct zone. This is because of the disturbance to the radio frequency signals from non-conductive materials (Kelm et al. 2013). Future research is underway to find permanent solutions to issues related to non-conductive materials (Li & Becerik-Gerber, 2011). One difficulty with UWB technology is that it requires a direct line of sight for better performance (Carbonari et al., 2011). One solution to this problem is for the system to use a pre-designed architecture for
sensor infrastructure installation (Nasr et al., 2013). This pre-designing will also provide a sufficient number of receivers to one zone fulfilling the requirement of the minimum number of receivers for better accuracy. The main technical limitation of WLAN is that it requires a certain number of Access Points (AP) for better accuracy (Giretti et al., 2009). If this certain number is not fulfilled, the data collected will be unreliable. As a solution, a sufficient number of APs should be provided after the installation of the system has been properly designed (Giretti et al., 2009; Woo et al., 2011).

All the tracking technologies discussed are considered to be economical, although in different ways. The highly accurate advanced GPS technology is not affordable for construction sector (Pradhananga & Teizer, 2013), yet the low-cost GPS loggers which are attachable, small and easy to implement tend to be the most economical GPS technology for use in construction safety management (Golovina et al., 2016). Scholars (e.g. Kelm et al., 2013; Nasr et al., 2013; Lee et al., 2012; Wu et al., 2010; Yang et al., 2012) consider RFID to be an economical technology due to its low procurement and implementation costs. The operating costs of UWB are considerably low due to the almost all-digital architecture (Nasr et al., 2013). WLAN based systems acquire low installation and maintenance cost due to the limited number of hardware and inexpensive system adjustments (Woo et al., 2011). Using WLAN in an indoor environment is more highly cost effective than any other technology (Xuesong et al., 2008). A common economic issue of all four technologies is the need to tag each and every worker as well as equipment (Zhu, Park, Koch, Soltni, Hammad, & Davari, 2016). This generates considerable additional costs for projects with a large force and equipment. Zhu et al. (2016) suggests that vision tracking provides a solution to these high deployment costs because a single vision tracker can track multiple workers and equipment simultaneously. This appears to be an effective solution for large construction projects consisting of numerous workers and equipment (Park & Brilakis, 2012). However, it should be noted that although vision trackers provide a better solution economically, it contains its own technical errors that should be taken into consideration; which will be explained in a separate section (Teizer & Vela, 2009).

It can be seen that GPS and RFID share a common social benefit in that they are familiar to construction stakeholders (Li & Becerik-Gerber, 2011; Zhu et al., 2016). GPS technology has now become a standard application in smart phones so that it is easier to explain to the workers regarding how they are being tracked (Jiang et al., 2015). On the other hand, RFID is well known by construction stakeholders due to its wide use in the industry for purposes other than health and safety management (Li & Becerik-Gerber, 2011). UWB is used for worker training because of its data recording and visualization capabilities, which help workers identify errors and mistakes that will lead them to dangerous situations (Teizer, Cheng, & Fang, 2013). WLAN systems enable safety officers to monitor the site in real time even when they are not in the site (Nuntasunti & Bernold, 2006). However, GPS, RFID and UWB technologies have several significant social issues that require consideration. Tagging workers has the potential to activate the union resistance based on health issues that could result from the constant physical attachment of the technology (Zhu et al., 2016). Vision trackers are one way to resolve this issue (Park & Brilakis, 2012). As this technology does not require any physical attachments, workers’ concern for health issues can be addressed (Zhu et al., 2016). On the other hand, the researchers confirm that the tags are perfectly safe to wear since they emit less power than a mobile phone (Teizer et al., 2013). Thus, an explanation, training and knowledge should be provided to workers to address their concerns.
and hesitations about using these technologies. In terms of use of WLAN technology, one common social issue is the effort required by safety engineers to implement the access points in complex and congested sites (Jiang et al. 2015). Research and experiments to identify effortless WLAN installation is ongoing.

3.2 Image-based Tracking Technologies (Vision Trackers)

Vision tracking is a real-time tracking technology that uses video images or recordings to rapidly detect, model and track workers on site (Teizer, Caldas, & Haas, 2007). The main technical benefit of vision tracking is its ability to cover the entire construction site with a limited number of cameras that can be controlled remotely. This means that a single tracker can cover a wide area because the camera view can be often changed, either by rotating it or zooming in/out (Park & Brilakis, 2012). One of the main technical limitations of vision trackers is that it only detects the predetermined body postures of workers (Park, Elsafty, & Zhu, 2015). Therefore, if a worker is in an undetermined posture, he will not be detected by the system until he reaches a determined posture. To overcome this issue, Park et al. (2015) suggested including different posture templates to the system. Each posture of the workers should contain its own template in order to cover all possible postures.

The main economic benefit of vision trackers is that there is no requirement for individual tagging or any other sensor installation on the entities to be tracked (Zhu et al., 2016). This reduces implementation cost significantly including avoiding any additional costs due to the increase of labour or equipment as per the demand or misplacing of tags. Since a single camera can cover a wide area, the limited hardware requirements also significantly reduce implementation costs (Teizer & Vela, 2009). However, if the construction site is complex and congested, more cameras will be required to avoid occlusions and this will generate some additional costs (Park et al., 2015). Nevertheless, by using the cameras’ ability to rotate around its axis, zoom functions and installing cameras in such a way that they could provide multiple views could help to eliminate costs incurred for additional cameras, related hardware and infrastructure required to avoid occlusion (Park & Brilakis, 2012).

One of the most important social benefits of vision trackers is that there is no any kind of physical tagging which could create any union resistance (Zhu et al., 2016). The most critical social limitation of vision trackers is that it may reduce the requirement of more labour, such as for safety monitoring and providing security services. Even though this provides some economic benefits, it may reduce job opportunities thus will generate a significant social issue with no solid solution (Park & Brilakis, 2012). In addition, it may again create a huge union resistance.

4 Sensor-based Systems

Two main sensor based safety management systems are discussed in the literature; mobile sensing devices with multiple sensors and workers’ health assessment sensors such as activity trackers with Photoplethysmography (PPG) sensors and Electroencephalography (EEG) safety helmets (Hwang et al., 2016; Lee, Kim, Cho, & Kang, 2009). Mobile sensing devices consist of a number of sensors such as ultrasonic (US) and infrared (IR) sensors which are used to measure the distance and recognize the workers during the tracking (Lee et al., 2009). In addition, there are other sensors such as gyroscope, accelerometer, magnetometer, barometer, proximity sensors and
light sensors that can be used for onsite safety management (Akhavian & Behzadan, 2016). Activity trackers are equipped with PPG sensors which monitor the heart rate of the workers (Hwang et al., 2016). EEG safety helmets consist of an electrocardiography (ECG) sensor and a pulse sensor to check the mental condition and stability of the workers by conducting a neural time-frequency analysis (Chen, Song, & Lin, 2016).

4.1 Mobile Sensing Devices

One major technical benefit of a mobile sensing device is that there is no requirement for any individual physical tagging of workers (Lee et al., 2009). Further, the device can be easily installed and removed whenever necessary. However, mobile sensing technology does have certain technical limitations. For example, the ultrasonic sensors are very sensitive to temperature variance and multipath signals and sensitive to water vapor, which will compromise its performance and limit its main function (Lee et al., 2009; Luo, O’Brien, & Julien, 2011). To overcome the issue of high sensitivity of ultrasonic sensors, new methods such as radio frequency technologies that measure the signal strength can be used (Luo et al., 2011). On the other hand, Lee et al. (2009) suggest that additional ventilation methods for closed areas can be used to control the water vapory atmosphere in order to avoid the disturbance it creates for proper functioning of ultrasonic sensors.

Mobile sensing devices are recognized as a low cost affordable safety management technology (Akhavian & Behzadan, 2016). Since there are number of sensors embedded in the mobile device, it can be used for several purposes, thus require no advanced and unique equipment for each and every purpose separately. However, the device requires special care when ultrasonic sensors are embedded due to its high sensitivity, which will generate some additional costs (Lee et al., 2009). As a solution, a low cost radio frequency technology can be used to replace ultrasonic sensors (Luo et al., 2011). The main social benefit of this system is that the safety manager could receive the accident related details promptly to his personal mobile phone even if he is not available on site. However, Akhavian and Behzadan (2016) discussed two main social issues; the inconvenience of wearing the mobile device on the arm and the possibility that some may be unwilling to wear the device. Further research is needed to overcome issues of inconvenience of wearing the device.

4.2 Health Assessment Sensors

Health assessment sensors are used to ensure worker safety by monitoring their physical and mental condition (Chen et al., 2016; Hwang et al., 2016). One of the main benefits of PPG system is that it monitors workers’ heart rate in real-time with real-time feedback whether the worker should proceed or should rest (Hwang et al., 2016). EEG system can differentiate tasks with diverse levels of complexity and tasks requiring high human memory while providing quantitative information regarding the mental work load (Chen et al., 2016). However, the accuracy of the PPG and EEG systems is still not up to the required standard due to the signal noises generated from workers’ movements (Chen et al., 2016; Hwang et al., 2016). As a solution, noise cancellation algorithms and noise filters can be used yet they are still in the experimental stage.

Although both systems have been identified as economical in the long run in comparison to other similar systems, they have a high implementation cost in terms of hardware, expertise, labour, proper training and education (Chen et al., 2016; Hwang et al., 2016). On the other hand,
the cost of the system must be considered in terms of the costs involved measured against the
requirements of the construction companies and their ability to invest in adoption of the
technology (Hwang et al., 2016). Therefore, a more effective approach might be to promote the
value of the system and its long term financial benefits while also providing information to
construction stakeholders.

It is well-known that in order to effectively support a holistic approach to occupational health and
safety, it is crucial to consider the physical and mental condition of the workers. Hence, the main
social benefit of both systems is that they contribute to maintaining and supporting holistic
management of occupational health and safety on site (Hwang et al., 2016). However, Hwang et al.
(2016) note that critical social issue of the system concerns potential security and privacy
violations. For example, any misuse of workers’ personal health information could create conflicts
and potentially result in workers’ reluctance to use the technology. Further, EEG system that
requires wearing a helmet with electrodes stick to the scalp represents a significant disturbance to
the worker’s performance (Chen et al., 2016). Future research is working towards finding reliable
solutions to aforementioned issues.

5 Discussion and Conclusions

Occupational health and safety has an important place in the construction sector due to the
associated high risk of fatalities. Almost all construction sites use either manual or automated
safety methods and follow the safety rules and regulations mandated by the authorities. However,
manual safety inspection is considered to be time consuming, subjective and inefficient. Hence,
the demand for automated safety management systems is increasing. Adequate accuracy, wireless
application, robust communication and data storage ability are some of the common technical
benefits of automated technologies. Importantly, an effective safety management can only be
achieved by selecting the most appropriate real time safety management technique as per the site
conditions, the investment capability of the construction company and with the endorsement of
workers. The technical, economic and social benefits and limitations of each technology will
decide their suitability to a particular project. As discussed in previous sections, each technology
can be classified based on their suitability for different projects.

Many researchers have discussed safety management systems with combined technologies and
considered ways for improvement by reducing the prevailing weaknesses. Further, combining
several technologies enhances the performance of safety management systems by adding new
facilities to the system. For example, Zhang et al. (2015) combined GPS and Building Information
Modeling (BIM) to identify, analyze and visualize work space requirements. They note that, GPS
provides location data and the formalization, analysis and visualization of data while the reuse of
historical information is provided by BIM. Lee et al. (2012) discussed a RFID based Real Time
Locating System (RTLS) for safety management and noted that the system uses a Time of Arrival
(TOA) method for localization and Chirp spread spectrum for wireless networking and an
assistant tag to maintain the adequate signal availability. This system uses the benefits of RFID to
provide more practical safety management for construction sites. Yang et al. (2012) and Wu et al.
(2010) considered a ZigBee-RFID sensor network that combines WSN technology and RFID
technology and discussed the way that. RFID is used for real time location tracking, access control
and storing safety information with WSN used for data transmission. Cheng, Teizer, Migliaccio,
and Gatti (2013) combined UWB and Physiological Status Monitoring (PSM) technologies to monitor the position, posture and physiological status of the workers automatically. Cheng and Teizer (2013) described an effective safety management system that combines UWB and virtual reality (VR) and where UWB is used for onsite data collection and VR is used for visualization of the collected safety information. Teizer et al. (2007) discuss a safety management system that uses vision trackers and 3D CAD models, with 3D models used to model, detect and track the workers’ static positions and movements depending on the video data obtained on site using vision trackers. It is well noted that research continues to explore ways to solve the technical issues of the technologies discussed here. However, attention to solving the economic and social issues is relatively low in comparison. Hence, this paper recommends that a cost benefit analysis of these technologies be conducted in order to determine their cost efficiency and viability to the project, including ways to solve social barriers to their use. Future research directions should be aimed both at socio-economic and socio-technical aspects of the technologies.

REFERENCES


Safety training in construction: a review of training methods and effectiveness

Yuan, C. and Feng, Y.*

Abstract: Construction site accidents often result in serious injuries or death. Effective safety management is always a focus for the project. One of the most effective ways to promote safety in the workplace is to provide the employees with ongoing safety training. This paper aims to provide a comprehensive review of theories and practices in construction safety training in recent 10 years. About 80 research papers were identified from 2006 to 2016 by searching the key words including safety training, construction safety and safety management. Four main aspects of research on safety training were discussed. They are: (1) the medium and method of safety training; (2) effectiveness of safety training; and (3) BIM in safety training. We introduced BIM in safety training to provide a visual construction motion environment. Based on the BIM safety training platform, the training specialists can give direct instructions on how to improve the ability safety risk perception and safety risk control ability. Based on the theory of “motion attracts attention”, a safety training cycle with BIM demonstration is proposed.

Keywords: Construction, review, safety, safety training.

1 Yuan, C.
School of Civil Engineering, Chang’an University, China

2 Feng, Y.
Corresponding author, School of Computing, Engineering and Mathematics, Western Sydney University, Australia
Email: y.feng@uws.edu.au
1 Introduction

One of the most effective ways to promote safety in the workplace is to provide the employees with ongoing safety training. Safety training serves 2 major purposes: (1) to ensure that employees know how to work safely and why safety is important; and (2) to demonstrate the management’s commitment to safety (Goetsch, 2013). Safety training plays a very important role on construction safety management. Cooper (2000) argued that “training safety” is an area where the research lags behind practical developments and proposed a program of future research to meet this need.

This paper aims to provide a comprehensive review of theories and practices in construction safety training in resent 10 years. About 80 research papers were identified from 2006 to 2016 by searching the key words including safety training, construction safety and safety management. Three main aspects of research on safety training were discussed. They are: (1) the medium and method of safety training; (2) effectiveness of safety training; and (3) BIM in safety training.

2 Media and methods of safety training

The main idea of safety training is to transform the basic safety knowledge and risk perception to the trainees. Li et al. (2012) described a new proactive construction management system (PCMS) to train precast installation workers. The system can provide real-time feedback and post-event visualization analysis in a training environment. Le et al. (2014) proposed a social networks system for sharing construction safety and health knowledge (SNSS). He proposed an online social virtual reality system framework which enables the students to perform role-playing, dialogic learning, and social interaction for construction safety and health education.

People always believe that workers prefer to receive the information in a visual format. Many researchers introduced different immerse modes for the construction site environment. Guo et al (2013) used a real-life case study to demonstrate how to implement the VP-based safety management platform and evaluate its feasibility and validity. Kawakami (2011) provided practical training for those involved in the informal economy workplaces. The participatory training programs were developed consisted of action-checklists associated with illustrations, good example photo sheets, and texts explaining practical, low-cost improvement measures.

With development of the technology, many models introduced the virtual construction conditions into safety training. Researchers illustrated that these models can provide good visualization for the trainees during safety training. Guo et al. (2012) found that game technology-based safety training platforms have the potential to overcome this problem in a virtual environment. The platform can improve the process and performance of the safety training involved in their operation. Lingard et al. (2015) found that reflexive participatory video can enable workers and managers view their practices from a different perspective. Sacks et al. (2013) conducted a test on the immersive virtual reality safety training, and found that VR is more effective especially in the context of cast-in-situ concrete work.

Virtual environment for safety training has its basic merit for directly transforming basic safety knowledge and it is convenient to conduct some demonstration during the training session. The virtual construction environment can help the practitioner to get across the safe or hazardous conditions and enhance their safety perceptions. The media used for safety training has experienced a further development in recent years. Tab.1 summarizes the media and methods of
safety training which were published in 2006-2015.

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Safety training media and methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>Lingard et al.</td>
<td>Participatory video</td>
</tr>
<tr>
<td>2015</td>
<td>Le et al.</td>
<td>Online social virtual reality system framework</td>
</tr>
<tr>
<td>2015</td>
<td>Le et al.</td>
<td>Social virtual reality based construction safety education system</td>
</tr>
<tr>
<td>2015</td>
<td>Ulubeyli et al.</td>
<td>Semiotic analysis of cartoons about occupational health and safety issues</td>
</tr>
<tr>
<td>2014</td>
<td>Le et al.</td>
<td>Social networks system</td>
</tr>
<tr>
<td>2013</td>
<td>Guo et al.</td>
<td>Game technology-based safety training platforms</td>
</tr>
<tr>
<td>2012</td>
<td>Guo et al.</td>
<td>VP-based safety management</td>
</tr>
<tr>
<td>2013</td>
<td>Ho and Dzeng</td>
<td>E-Learning</td>
</tr>
<tr>
<td>2013</td>
<td>Teizer et al.</td>
<td>Location tracking and data visualization technology</td>
</tr>
<tr>
<td>2013</td>
<td>Sacks et al.</td>
<td>Immersive virtual reality of safety training</td>
</tr>
<tr>
<td>2012</td>
<td>Guo et al.</td>
<td>Game technologies</td>
</tr>
<tr>
<td>2012</td>
<td>Li et al.</td>
<td>Multiuser Virtual Safety Training System</td>
</tr>
<tr>
<td>2011</td>
<td>Evia</td>
<td>Localizing and designing computer-based safety training solutions</td>
</tr>
<tr>
<td>2011</td>
<td>Kawakami et al.</td>
<td>Participatory approach</td>
</tr>
<tr>
<td>2010</td>
<td>Williams et al.</td>
<td>Peer-led participatory health and safety training program</td>
</tr>
<tr>
<td>2006</td>
<td>Ciesielski</td>
<td>OSHA Cards and Instruction</td>
</tr>
</tbody>
</table>

3 Effectiveness of safety training

Many researchers discussed the role of safety perception training in the construction industry. Alsamadani et al. (2013) used a cross-case comparison and revealed that the frequency and method of communication are important differentiators between project teams with low and high accident rates. Kaskutas et al (2012) suggested that construction workers’ training should target safety communication and mentoring skills with workers who are leading work crews. Hammer et al (2015) suggested that an intervention focused on supervisory support training and a team effectiveness process for planning and problem solving should be further refined and utilized in order to improve employee health with additional research on the beneficial effects on worker safety. Demirkesen and Ardiy (2015) found that safety learning can be achieved, sustained and improved by addressing organizational, feedback, content, process, and worker issues in training sessions. Li et al (2015) designed a proposed safety training system for the trainees better than those using the traditional method. Kim et al (2011) developed a framework available for use in the construction industry. Flach et al (2015) developed a theoretical framework based on dynamic systems theory as a practical guide for generalizing from basic research to work domains and for generalizing across alternative work domains to better understand how patterns of communication and decision-making impact system safety. Flynn and Sampson (2012) recommended that safety trainings incorporate unique messages for new workers, experienced workers and management in an effort to motivate each group to work safely as well as provide them with solutions to overcome the identified barriers. Albert and Hallowel (2013) discussed the cognitive processes of adult learning and essential components of effective training programs and developed a reliable framework for the training and transfer of safety knowledge. They provided valuable information
on developing effective hazard recognition. Sunindijo and Zou (2013) investigated the constitution of the project management personnel’s conceptual skill and how this skill can be developed and applied in the context of construction safety. They concluded that conceptual skills may help project management personnel to implement safety management tasks, which in turn promotes an onsite safety climate.

Some researchers found that most safety trainings in the construction industry were focused on practitioners’ safety perceptions and safety consciousness. Wilkins (2011) identified workers’ perception of the training and found that the trainees were more likely to respond positively to training programs when adult learning theories were integrated into safety trainer readiness programs. Chen et al. (2011) found that safety managers have the highest perception of safety on the construction and reinforcing the perception of construction personnel is important. Government also implemented some safety requirements or rules to promote safety training. Chan et al (2010) conducted a survey on the benefits of implementing pay for safety scheme (PFSS), and found that adopting PFSS can increase safety training, enhance safety awareness, encourage the development of safety management system and improve safety commitment. Choi et al (2011) presented that the benefits of implementing PFSS include: (1) enhancing safety climate and attitude; (2) promoting effective safety-related communication; (3) streamlining the safety procedures; and (4) ensuring adequate safety training.

Bena et al. (2009) assessed the impact of the training programmes on injury rates at a major railway construction project according to the time-series model. Chiaburu (2005) investigated individual and contextual antecedents of learning, transfer of learning, training generalization and training maintenance in a work context. Practitioners interested in designing interventions directed at increasing similar training. Based on the current results, practitioners can manage selectively the performance goal orientation of their trainees, given its differential relationship with training outcomes. Shin et al (2014) developed a model to examine the effectiveness of three safety improvement policies: incentives for safe behaviors, increased levels of communication and immersion in accidents. Application of the model verifies the strong potential of the developed model to provide a better understanding of how to eliminate unsafe acts, and to function as a robust test-bed to assess the effectiveness of safety programs or training sessions before their implementation. When assessing safety training effectiveness, it is not objective to use the accident rates on the construction site because the accidents are the results of interactions of muti-factors. How to assess the training effectiveness is worth further investigation in future research.

4 BIM in safety training

BIM has been wildly used in the construction industry and it will bring a new revolution for the construction just as CAD. Many researchers attempted to improve safety management with BIM. Azhar (2013) investigated the effectiveness of BIM technologies in developing, communicating and implementing a construction site safety plan and found that 3D or 4D dynamic tools are more effective in safety planning and management because they closely simulate actual jobsite conditions. Researchers try to find a way to address ‘real’ health and safety site issues with the full aid of visualization, which will be easy to be understood by practitioners. Sattineni (2014) presents the creation of a decision support framework for site supervision based on monitoring
construction workers by combining RFID technology with BIM. A proof-of-concept virtual prototype was created to track the movement of construction workers using RFID and BIM. Enshassi et al (2016) indicated that ‘hazard identification and minimization’ and ‘safety training and education’ are the most important safety-related applications provided by BIM tools to improve safety performance in construction. However, the lack of universal use in the construction sector and insufficient training availability are the highest ranked barriers for adopting BIM in construction to improve safety. Sulankivi (2010) argued the main objective of the BIM safety research project is to develop procedures and use of BIM technology for safety planning, management, and communications, as part of the 4D-construction planning. Kiviniemi (2011) provided the sources for an improved understanding to apply BIM technologies with the purpose of site safety planning and management by experiment.

Clevenger et al (2014) discussed the use of BIM to enhance safety for construction workers, building users during renovations expansions and building end-users. They demonstrated that BIM can be used to foresee potential construction hazards and motivates and informs future tool and process development. Park and Kim (2013) proposed a framework for a novel safety management and visualization system (SMVS) that integrates building information modeling (BIM), location tracking, augmented reality (AR), and game technologies. The potentials and technical limitations of the prototype SMVS have been evaluated by site safety experts. A case study was also implemented, whose results show that the SMVS has a great potential to improve the identification of field safety risks, increase the risk recognition capacity of workers, and enhance the real-time communication between construction future manager and workers.

BIM has been developed as the best toolkit for dynamic engineering design and construction, and it has brought a revolution model for project management. BIM for safety training is also needed to be pushed. Clevenger et al. (2014) used the interoperable learning leveraging building information modeling in construction education. The use of BIM in education is beneficial to students and professionals.

5 Model of safety training

On the construction site, many accidents and hazard always occurred in a dynamic condition; and many safety risk factors hided in the construction process. During the safety training, it is more clear and easy to illustrate safety conditions in the process of the construction and the motion of the building machine, so a dynamic construction model is better for the trainers to show the latent risk and the causes of accidents. Motion can attract attention, and the information is provided by movement. Detecting motion in peripheral vision usually triggers an eye movement to “see” the object. Movement provides information about shape, size and depth. The change in perspective causes accidental properties on the retina to change while invariant properties remain (ecological perspective). Movement and motion perception are essential for interaction with our environment. In the future safety training research, the theory that “motion attracts attention” deserves much attention. The best manner that can demonstrate the construction motion is “BIM”, which can not only provide the general illusion of the construction, but also give the details of the construction process and the construction site image. Thus, a training cycle for safety training design with BIM demonstration is described in Figure 1. In the safety training cycle, the trainees are required to acquire the safety risk perception and the accurate safety risk decision making abilities. The first
stage is strategic risk assessment, to identify training need and then plan and design training. The second stage is to deliver training which is dynamic. The last stage is effectiveness assessment.

Fig. 1 The training cycle with BIM demonstration

6 Conclusions

Many researches had provided different types of the visual construction environment. BIM can be the best choice because of its integration of design, planning and construction. It can not only provide the visual construction site, but also the detailed construction process. We introduced BIM in safety training to provide a visual construction motion environment. Based on the BIM safety training platform, the training specialists can give direct instructions on how to improve the ability safety risk perception and safety risk control ability. Construction safety training should not just focus on hazard identification; and it should also focused on improving the safety risk perception ability. Based on the theory of “motion attracts attention”, a safety training cycle with BIM demonstration is proposed.

References

of Doctor of Philosophy, September 2014


Crane Dismantlement. Journal Of Computing In Civil Engineering, 26(5), 638-647.
Design Factors Influencing Energy Performance Gap in Building Retrofit Projects

Alam, M.1*, Wagle, D.2, and Zou, P.X.W.3

Abstract: The disparity found between the predicted energy consumption in the design stage of buildings and the energy use during operation is known as energy performance gap. According to recent studies, the actual consumption can be twice to five times higher than predicted by the model. This mismatch is particularly significant in building energy retrofitting project where it can have significant financial and environmental impact. This study aimed to address this issue by identifying the design factors that contribute to the energy performance gap in building energy retrofit projects, and finding solutions that will help close the gap. The design factors that contributes to performance gap were collected from existing literature and from interviews of relevant professionals. Factors collected from the study were categorised into seven groups. Possible strategies of coping with the factors were also identified through literature review and interview. The study will help designers to be well-informed of the factors causing energy performance gap and guide them in addressing the factors while undertaking building retrofit projects in the future.

Keywords: Building energy retrofit; Energy performance gap; Design; Simulation.

1* Alam, M.
Corresponding author, Faculty of Science, Engineering and Technology, Swinburne University of Technology, Australia
E-mail: mmalam@swin.edu.au

2 Wagle, D.
School of Engineering, Swinburne University of Technology, Australia

3 Zou, P.X.W.
School of Engineering, Swinburne University of Technology, Australia
1 Introduction

Buildings are one of the largest users of energy, accounting for 32% of total global final energy use and 19% of total energy-related greenhouse gas (GHG) emissions [1]. Reducing the energy consumption of buildings would contribute significantly to the reduction of overall energy requirement and emission [2]. New buildings constructed during this century use about 65% less energy for heating than the existing energy inefficient building [3]. This is ascribed to the improvements in construction technology and insulation attained after the oil crisis during the 1980s [3]. The existing older energy inefficient buildings are replaced by new energy-efficient buildings at a slow rate of 1-3% a year [4]. Given the low turnover rate of buildings and the high number of existing buildings, it is clear that the largest potential for improving energy performance is in the existing stock of buildings [5]. In the United States alone, existing building retrofit offers a substantial capital investment opportunity of more than $279 billion, which could yield more than $1 trillion of energy savings over 10 years [6]. It is estimated that the total feasible potential for energy savings by retrofitting existing buildings in most countries will be around 50% of the actual consumption [2]. In countries with a lower energy standard of the existing buildings, this potential will be even larger [2].

In Australia, emissions in 2030 are projected to be 592 Mt CO2-e, which is only 0.5% below 2005 levels (595 Mt CO2-e). However, Paris deal requires Australia to reduce emissions by 26-28% from 2005 levels by 2030 and reach net zero emissions nationally around 2050 [7]. Building sector in Australia accounts for approximately 23% of overall GHG emissions [8] and retrofitting of existing building stock can potentially deliver a 23% reduction in emissions and AUD$20 billion in financial savings by 2030 [7].

However, there often remains a significant difference between the predicted and designed performance of a building and how it performs in reality [9]. The predictions made during the design stage are not completely reliable, and actual savings deviate significantly from the expected savings [10]. This discrepancy is called the energy performance gap. The PROBE studies (Post-occupancy Review of Buildings and their Engineering) investigated the performance of 23 buildings previously featured as ‘exemplar designs’ in the Building Services Journal (BSJ) [11]. The research brought to light the so called ‘performance gap’, suggesting that actual energy consumption in buildings will usually be twice as much as predicted [11]. Menezes et al. describes a number of studies that show that the actual regulated consumption can be five times higher than predicted [12].

Inaccurate prediction of savings can result in significant financial loss to the client and investors. Moreover, in projects using energy performance contracting (EPC), ESCOs (Energy Service Companies) rely on design stage predictions to make critical decisions. They undertake energy retrofits of existing buildings through energy performance contracts that typically guarantee savings as part of their service. If those savings are not attained, they have to reimburse the client the shortfall amount [13]. Such contract conditions make ESCOs likely to stick to tried-and-tested retrofit measures. Hence, apart from being a potential source of a significant financial loss to clients and investors in all energy retrofitting projects, the energy performance gap also makes ESCOs reluctant to invest in high-impact, high-risk retrofitting technologies in EPC projects [13].

Therefore, it is crucial to enhance the reliability of design stage estimates and minimise the energy performance gap. The research aim is to find out the factors in the current building energy industry that lead to energy performance gap and to find out their solutions.
2 Research Method

A list of factors resulting in energy performance gap was gathered through literature review. Striving for a thorough investigation, the literature search covered energy performance gap, energy simulation, calibration, uncertainty, building energy in Australia, etc. Interviews of seven experienced building energy industry professionals (including designers, client energy managers, optimisation engineers, ESD engineers) were conducted to identify other factors that are not available in the literature. Another objective of the interview was to gain an understanding of the challenges experienced during building energy-retrofitting projects and to identify faults in current industry practices that lead to energy performance gap. Possible strategies of dealing with the problems were also gathered from literature study and the interviews.

3 Energy Performance Gap in Building Retrofit

From the study, several factors influencing energy performance gap were identified. The factors were categorised into seven groups. The factors and possible strategies to cope with them are summarised in Figure 1 and discussed below:

![Figure 1 Summary diagram of factors and strategies](image)

i. Poor communication

Poor interaction among various teams inhibits the development of innovative solutions that can be achieved from brainstorming. On the other hand, clients and designers often do not have a clear communication. According to [14], briefings are not clear, consistent or complete. On the other hand, the designer might fail to communicate the level of management, expenditure and vigilance that he expects from the occupant. This might lead to the occupants taking the building for granted or finding the building too demanding and dissatisfactory later down the road [15].

Similarly, the estimate might fail to take into account changes made during value engineering [16] that involve compromising the building services or replacing certain components with a cheaper alternative. If any changes are made after the estimation of energy consumption, this could cause a substantial performance gap because these alterations are rarely fed back into the energy model [12]. According to [17], variations, including changes to thermal mass, insulation, orientation, controls and operational hours, may not be reassessed in terms of energy performance.
Possible strategies:

Clients should be encouraged to provide clear and concise briefs to the designer so that the designer is fully aware of the client’s expectations. According to literature, there are two different approaches of briefing [14]. One approach is based on the idea that all briefing information should be complete before the design process starts while the other approach is based on the idea that briefing is a continuous process, which interacts with the design process [18, 19]. In an interview study conducted by [14], architects said that on-going briefing processes can result in new requirements and many changes along the way and can frustrate the efficiency of the design process. Hence, the former approach of briefing should be encouraged. Clear communication with the client about their usage patterns would also enable designers to design for them appropriately and estimate savings accurately.

An interviewee presented the idea of making a record of the entire process as it happens, referring to it as “Building passport”.

One of the things we are talking about at the moment is having what we are calling “building passport”. It is an electronic record of the building process. So all the plans will be stored there, and as the construction takes place, and the insulations are installed for example, whoever is doing that can photograph that, the photos get date stamped with a location and they can send them to a digital file so it gets stored in the building’s file.

Implementing this system would make it easier to ensure that everyone involved in the project is on the same page, without letting modifications go unnoticed. It would also make it easier to identify which process was done incorrectly and whom to hold accountable.

ii. Miscalculation of loads

The design phase usually only calculates the loads during hours when the building is in use, assuming the building is empty at night with most systems off [15], resulting in energy performance gap. According to [20] and [21], most of the energy waste in a building occurs during non-occupancy hours. Reviewed literature has shown that even during working hours, there are signs of wasted energy [20]. This can happen as a result of plug loads, server rooms, small power loads, elevator loads, catering, external lighting and other loads that are not attributed to major end uses. Such loads may not be included at the design stage, yet can account for more than 30 percent of the electricity demand in office buildings [9].

Possible strategies:

Virote et al. suggests predicting the utilization patterns of a building using data from buildings with the same activities, in the same geographic area and occupied by people that share the same cultural background [21]. Masoso et al. mentions the necessity of creating profiles of energy consumption of both the occupied and non-occupied times of buildings in all kinds of climates and incorporating them to develop elaborate input profiles for simulation accuracy [20].

Revising plug loads increased the estimated energy use by 15% median (32% mean) in an experiment conducted by [22]. The study recommends revising plug loads by using sub-metered data for improved accuracy. One interviewee presented a similar suggestion:

Energy modelling is conducted without the utilisation of detail data or only using gross energy meter data in a building. The only way to understand how a building really operates is to do detail sub-metering or data logging of each system and equipment.

iii. Poorly grounded assumptions

Poor and outdated design assumptions are yet another reason behind energy performance gap.
Construction techniques, building stock compositions, and occupant behaviours and usage schedules can vary significantly internationally, so basing parameter values on international studies might not yield accurate results. The simulation assumptions do not always have an evidential basis for use in Australia since the databases used in international studies to inform building simulation assumptions are not available in Australia [23]. The Commonwealth Scientific and Industrial Research Organization (CSIRO) made some efforts in that area with the launch of the Australian Building Energy Repository in 2013 but to date, the initiative has not received sufficient funding to achieve the goals [24].

Possible strategies:

A comprehensive Australian database should be created and funded adequately to address the lack of data on building attributes and occupant behaviours, which influence building energy consumption [24].

iv. Poor Design

Several problems arise from a lack of foresight during the design stage. For example, the designers might not think some aspects of the design and aesthetics through. For instance, not considering the aesthetics, fabric performance and building services at the same time can result in airtightness approaches being compromised and inadvertent thermal bridging [9]. Similarly, the design team may specify details that are difficult or impractical to build and have to be modified on site, which also results in a lower performance [9]. Since designers do not participate in the monitoring phase, but rather move on from designing one project to designing another one, they do not have the opportunity of studying the outcomes, receiving post occupancy feedbacks and verifying their prescriptions. Therefore, they might apply flawed practices to all their designs without being aware of it.

Possible strategies:

Powell et al. suggested that use of standard sizes of materials should be encouraged to avoid “cutting to fit” in order to avoid modification to the design on site [9]. Furthermore, interviewees suggested restructuring contracts in new ways so that occupant feedbacks are mandatory and duly reach designers.

v. Shunning accountability

Professionals are wary of Post Occupancy Evaluations because they think that the findings – which inevitably bring both good and bad news – may not enhance their reputations [25]. Shunning feedbacks from occupants about the building can lead to an inept and out-of-touch industry.

Some interviewees pointed out similar avoidance of accountability commonly exhibited by other members in the supply chain including contractors and facility managers.

Contractors implementing the retrofitting do not want accurate energy measurement and verification. They want things to be as cloudy as possible, and they will often suggest they will perform M&V themselves, which substantially reduces the ability to make them accountable of the outcomes at the end.

The main objective of facility manager is to make sure it is safe and operating and that he is not getting any complaint. So they often tend to tune the building so that it over-performs. They should be trained to make sure that they are tracking the system and know how to get the best out of it.
Possible strategies:
Interviewees suggested using incentives and punitive measures to foster greater accountability in the industry.

There has to be some sort of penalty if the performance is not as specified because if there is no consequence then designers are not going to be motivated to try to do their best.

An interviewee also suggested making NABERS rating public in order to make it easier for prospective clients to evaluate and select service providers. Another original suggestion was to adopt what other trust-based services such as Uber and TripAdvisor do by accepting feedback from clients online. It gives people a chance to voice dissatisfaction about performance gap, is a good way for businesses to be conscious of any room for improvement and can drive real change.

vi. Simulation uncertainties

Uncertainties related to simulation also affect the accuracy of saving predictions. Simulation software tend to over-simplify building and building systems, and are based on assumptions of thermal processes, and algorithmic differences [12, 26]. Moreover, errors in the input also get propagated to the output or the predicted energy consumption [27]. The accuracy of saving estimates relies on some parameters that are inherently uncertain. For example, weather and occupant density are two uncertain stochastic factors that fluctuate unpredictably over the course of time so it is difficult to ascertain their precise impact on the energy demand. Hence, estimations produced by simulation tools are only as accurate as the models and inputs they are based on [28].

Possible strategies:

Calibration techniques can enhance the accuracy of simulation models through iterative revisions of an initial model, correcting identified discrepancies based on evidence and expert’s knowledge [29].

Furthermore, Uncertainty Analysis can be applied to estimate the probability that the energy saving target for the selected building will be achieved after the retrofitting. Uncertainty Analysis is the process of determining the probability that the outcome will be different from the “best-guess” estimate [30]. It also allows accounting for the inconsistent nature of parameters such as temperature, flow and pressure set points, which change throughout the occupancy period.

vii. Lack of knowledge

Designers might lack the knowledge of certain limitations of various processes involved in building energy consumption, and they might base their prescriptions on a flawed perception [15]. Interviewees also pointed out a lack of expertise and a need for upscaling exercise to enhance the expertise of facilities staff.

The quality of education provided to facilities staff is certainly not adequate for the role that they are expected to carry out. They often lack the resources or the understanding of the systems that they are operating. The facilities staff most of the time are not paid very well. So, there is not much incentive for highly qualified and experienced people to go into facilities.

According to an interviewee, service people that designers rely on might also lack technical knowledge.

Often designers rely on service people for HVAC, ventilation and other installations. Especially in residential, people working in that field are not necessarily qualified and the technical knowledge is often lacking.

Possible strategies:

Interviewees suggested implementing automated systems to make decisions. An interviewee
suggested using QR code systems to aid installers.

_Sometimes there are materials that are substituted in the supply line somewhere that the person installing it does not necessarily realise that they are different. An improved system where we stamp the key products with some sort of QR code would be useful so that once it is installed on site, anyone can make sure that it is actually what was specified._

Interviewees also suggested providing better training to service and facilities people and making sure the people that are hired are qualified.

### 4 Conclusion

This study investigated the factors influencing energy performance gap in building retrofit through literature review and interview of relevant professionals. It was found that poor communication, miscalculation of loads, poorly grounded assumptions, poor design, shunning of accountability, simulation uncertainties and lack of knowledge lead to energy performance gap in a building energy retrofitting project. The identified factors will benefit energy efficiency professionals by making them aware of possible sources of errors in prediction. Several possible strategies to minimise the gap were also identified, which could also help the relevant authority to devise appropriate policies and regulations to minimise the gap. In a future study, the identified strategies will be analysed to determine their feasibility. PEST analysis would be used to determine the political, environmental, socioeconomic and technological feasibility of the strategies.

### 5 Acknowledgement

This research was conducted by the Australian Research Council Industrial Transformation Research Hub for nanoscience based construction material manufacturing (IH150100006) and funded by the Australian Government and Sustainable Built Environment National Research Centre (SBEnrc) in Australia.

### References


13. Heo, Y., Bayesian calibration of building energy models for energy retrofit decision-making under uncertainty. 2011.


Characteristic Towns in China under the Background of the Internet+ : Origins, Actions and Risks
Yidan Wang, Xiaomeng Wang and Yuzhe Wu

Abstract: Characteristic town in China is the product of gathered talent, technology, capital and information, as another tendency in urbanization compared to "megacities" and "small towns", the construction of characteristic towns is of great significance to push on China's new urbanization. Being first proposed and large-scale applied in Zhejiang, Characteristic town has a lot to do with Zhejiang's leading information technology. Consequently, this article aims at examining Characteristic towns’ development and performance after the emergence of the Internet+. This paper studies the origins and actions of characteristic towns through literature research and document study, and selects Dream Town and Cloud Town as typical cases to analyze their strengths in integrating Internet+ traditional industry. In the study, this paper puts forward three risks that have been studied rarely and the characteristic towns may face in the future: agglomeration risk, fair risk and excess capacity risk. According to the actual situation, this paper makes a discussion and puts forward specific countermeasures for the three risks.

Keywords: Internet +; Characteristic towns; Zhejiang Province

1 Land Resource Management, Zhejiang University, Hangzhou, China
1 Introduction

The urbanization process of global urban population is accelerating. In 1950, global urban population accounted for only 30% of the global population; while in 2009, the global urban population surpassed the rural population for the first time[1]. Cities have become new sources of technological innovation and new engines for economic growth.

China, as the largest developing country, has high-rising level of urbanization. According to official statistics, China's urban population accounted for more than 50% of the total population for the first time in 2011, indicating China's urban and rural population structure has changed tremendously[2] and the largest urbanization process in human history is happening.

In the patterns of urbanization development, whether prioritizing the development of megacities or giving priority to small towns has always been the focus of the debate. Yuzhe Wu(2013) pointed out that the academic community was divided into two factions—megacity faction and small town faction[3]. The characteristic town in China, as another tendency in urbanization compared to "megacities" and "small towns", is of great significance for the country under fast development of cities across its territory.

After the World Internet Conference was placed in Wuzhen and the Alibaba Group was developed in Hangzhou, Zhejiang Province has great strength in information technology. Characteristic towns in China, first proposed in Zhejiang Province, were closely linked with the Internet+. The Internet is used as a resource platform, while the Internet+ means applying the Internet interactively. The Internet+ industry model of characteristic towns integrates all industries and provides new opportunities for developing smart cities and achieving the new urbanization.

After characteristic towns in Zhejiang show their strong vitality, there is a general consensus throughout the country: construction of small towns can promote local economy development and traditional industry transformation. Subsequently, the state introduced a series of policies to support and encourage the development of characteristic towns. Characteristic towns set off a nationwide boom and have been the community's attention.

Although characteristic towns bring much experience to the modern urbanization, such as bringing about the development of agglomeration economy, encouraging the construction of the main diversification and grasping the characteristics of resources to maximize the effectiveness, we should also be concerned that characteristic towns may face with agglomeration risk, fair risk and excess capacity risk in the future.

2 Literature reviews
China's Internet has developed by leaps in the 21st century, making more and more scholars concerned about urban development issues related with the Internet. Huang Huang (2015) thought that the Internet+ integrated the physical world and the Internet world and brought new challenges to country development[4].

In the past, both Tuneng's Agricultural Location Theory and Weber's Industrial Location Theory pointed out that the advantages and disadvantages of the region would make different types of industries show the status of circle distribution. But it is different now. Tianyou Liao (2006) believed that with the Internet+, the virtual highway platform provided great convenience for the mutual connection. The equality of the Internet opportunity would make the direction of the industry gathering turn to the information center and data center[5].

Many scholars have shared the competitiveness and experience of the characteristic town. Jianrong Weng (2017) pointed out that the characteristic town was a new model to explore the economic development, winning in the particular industry, creative ideas and connotations[6]. As for Zhejiang's characteristic towns, Weiwen Zhang (2017) thought that the massive economy of Zhejiang Province provided high quality soil for cultivating characteristic towns[7]. Jin Chen (2016) thought that relying on Alibaba's industrial advantages and Hangzhou's business foundation, the characteristic towns in Hangzhou developed a broader market in a limited space[8].

In order to develop characteristic towns with better quality, Song Wang (2016) pointed out that the government should be more aware of its role so that the role of the market and government can be balanced[9]. Yingying Zhu (2016) held the view that the characteristic towns should firmly insist their characteristics, strengthening operations and management[10].

3 Methodology

3.1 Research methods
This article combines the method of literature research and the case study. After collecting a large quantity of literature and government's policy documents, we sort out and summarize literature, focusing on understanding characteristic towns' development process. Having displayed the historical backdrop of the issues, we make a further concrete analysis of two distinctive cases ——Dream Town and Cloud Town. They are typical examples of innovative and entrepreneurial industrial towns and are helpful in studying the opportunities offered by the Internet+. Based on the development status, we explore several potential problems the characteristic towns may face in the future, and then the strategies have been discussed.
3.2 Research route

4 Characteristic towns in China: Actions and Risks

4.1 Characteristic towns in China: Actions

In March 2015, Prime Minister Li introduced the Internet+ in the report on the work of the government for the first time, emphasizing that the Internet+ represented a new economic development model. In Zhejiang Province, the development of the Wuzhen Internet Conference and the Alibaba Group have brought technical strength to this region. The combination of Internet and traditional industries provides powerful impetus for the development of characteristic towns.

In April 2015, Zhejiang Provincial People's Government issued a document to speed up the planning and construction of the characteristic towns, aiming at building 100 provincial towns in
three years. In June the same year, the provincial government announced a list of the first batch of provincial characteristic towns. Both Dream Town and Cloud Town are on the list, totally 37 characteristic towns were the first batch of construction.

Zhejiang Province has also promulgated a series of documents to promote the planning and construction of the characteristic towns:

<table>
<thead>
<tr>
<th>Number</th>
<th>Published time</th>
<th>file name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2015.4.22</td>
<td>&lt;Guidance on Accelerating the Characteristic towns' planning and construction&gt;</td>
</tr>
<tr>
<td>2</td>
<td>2015.9.2</td>
<td>&lt;Opinions on Accelerating the Construction of Characteristic Towns&gt;</td>
</tr>
<tr>
<td>3</td>
<td>2015.9.17</td>
<td>&lt;Notice on Carrying out Statistical Monitoring Work of Characteristic Towns' Planning and Construction&gt;</td>
</tr>
<tr>
<td>4</td>
<td>2016.3.16</td>
<td>&lt;Notice on High-quality Accelerating the Construction of Characteristic Towns&gt;</td>
</tr>
</tbody>
</table>

Inspired by Zhejiang Province, there was a general consensus: characteristic towns' construction promotes urban development. In October 2016, the Ministry of Housing and Urban-Rural Development of the People's Republic of China released the list of the first batch of 127 national characteristic towns. In August 2017, the list of the second batch of 276 national characteristic towns was released.

With the introduction of national policy at the national level, the construction of characteristic towns in the country mushroomed. As of June 2017, there have been 26 provincial governments introduced the characteristic town policy. About 1000 distinctive characteristic towns are supposed to be cultivated before 2020, which accelerates the construction of new urbanization and industrial transformation and upgrading.

4.2 Typical Cases

Zhejiang Province took the lead in the development of technology and the completion of the economic transformation, then constructed a serious of characteristic towns, among them Dream Town and Cloud Town were typical cases as innovative and entrepreneurial industrial towns.

In fact, the process of constructing characteristic towns is a process of constructing new urbanization. The “people-oriented” and “access to the basic population of support” principle are the starting points and end-results of the Internet+. The rise of the Internet+ brings more tip-top professional people for the construction of towns, helping develop economy, culture and ecology.

Dream town in Hangzhou officially began construction in September 2014, being China's first industrial town with Internet+ characteristics. On the one hand, Dream Town is committed to
gathering high-quality talent in small areas. Each of the collaborators can be mobile and interchangeable at the lowest cost, which is also the essence of the Internet +. On the other hand, Dream Town provides a platform for entrepreneurs free of charge, with the flow, other business can promote the development of traditional industries, which is also an Internet model.

Cloud Town, developed from the initial agricultural town to the industrial park, and then to the characteristic town, is an example of the transformation and upgrading of traditional industry. In the construction process, Cloud Town encourages the diversification of the building subject. Jian Wang, the soul character of Cloud Town is also a chairman of the Alibaba Group Technical Committee. Welcoming all kinds of subjects involved is Cloud Town’s exploration and trial, which provides valuable experience to the new urbanization construction.

4.3 Characteristic Towns in China: Risks

Although characteristic towns have shown vitality and innovation, they also have to face some un-negligible problems, such as environmental problems, lack of innovation, excessive government power and so on. These issues have been studied many times and been proposed everywhere. However, through case studies and literature reviews, we find three typical and realistic risks that are closely related to the Internet+ and have been studied rarely.

"Agglomeration Risk"—some towns didn’t have valid agglomeration due to waste of resources; “Fair Risk”—some real estate agencies got or used land under the guise of philosophy, caused “unfair land policy”; “Excess Capacity Risk”—the evaluation of Internet+’s effect was exaggerated so that towns’ function wasn’t in accord with realities and even produce functional deformation.

4.3.1 Agglomeration Risk

“Small、Special、Colored” are the keywords of Characteristic Towns. They represent “small but exquisite”、“homogenization avoidance”、“diversified development” respectively. The former is the basis while the other two are extension.

The Internet+ Era urges de-centralization, non-authority, personality liberation, while some local authorities who flaunt their achievements ignore realities, may follow the trend blindly, cause a loss of long-term plan, make the towns deviate from “Small、Special、Colored” and then lead to “Population Concentration Risk” and “Industrial Agglomeration Risk” with wasteful resource. For example, if some towns get the cart before the horse, build a variety of large-scale scenic spots and industrial parks, regardless of the size of population, then this sort of behavior can easily lead to the contradiction named “big industry while small population”. What’s more, due to the convenience of the Internet platform, the imitation and the copy of towns’ construction seem quite easy, so as to bring a direct impact that characteristic towns may no longer be featured.
### 4.3.2 Fair Risk

Usually, a dozen square kilometers of land are needed in the process of characteristic towns’ construction, and enterprises can get land from the government in the name of the characteristic town at a lower cost. Under the Internet + Era, the increasing investment in characteristic towns may put impact on new industries and reinforce the impact by price rising in real estate market. To conclude, the real estate enterprises have bad impact on other emerging industries, reflects the inequality in market rules, land policies and so on.

That is to say, as a mixture of real economy and virtual economy, real estate economy will play a more and more significant role in the development of characteristic towns. Obviously, it’s far from being consistent with the motivation of the project which benefits the real economy.

### 4.3.3 Excess Capacity Risk

To some degree, if the role of the Internet+ is overestimated, the risk may be caused by deviation from actual development and nature of towns.

On the one hand, actual facilities and essential function may not be right for match. For example, if some towns provide lowly equipped recreational facilities and low quality service, it will probably lead to the waste of resources and undermining long-term development. On the other hand, actual measures may not be suitable for local connotation. If the original advantages are abandoned and new function can hardly have an appealing prospect, the development of the towns will certainly perform badly under the network resource sharing mechanism.

### 4.4 Discussion

First, Agglomeration Risk Avoidance. We should establish a good local performance evaluation system to strengthen ideology of local leadership, so as to plan effectively and lay a firm foundation for later development. Then, the key principle of avoiding scale effect is that the people should be the subject and goal of development, as it is important to consider the size of population and effectively complete industrial layout on this basis.

Secondly, Fair Risk Avoidance. Governments ought first to make the best of situation, encourage innovation in the management system and should take measures to minimize externalities caused by real estate companies against other emerging industries.

Thirdly, Excess Capacity Risk Avoidance. It is certainly worth optimizing the supply system of resources, promoting the upgrading of supporting facilities as well as establishing effective supervision and encouragement system to increase the utilization rate of resources.

### 5 Conclusions
The article displays that under the accelerated process of global rural population urbanization, China provides a new option for urbanization development. With the summarization of the analysis of theoretical connotation, practical experience from a number of scholars by literature review as well as case study of Dream Town and Cloud Town, this paper discusses the development of characteristic towns in China under Internet+ Era.

In summary, the development of characteristic towns is rapid with the advance of Internet+. However, we should pay attention to the potential risks that may accompany development and use right research methods, determinate valid research route, combine with historical experience, meditate on the current problems and learn the benefits of the combination of Internet+ with characteristic towns to promote greater development and innovation.

Acknowledgements

We would like to acknowledge those who helped us in the writing of the paper as well as the support offered by 2-2050205-17-182: Research on the Development Orientation of Characteristic Towns - From the Perspective of Agglomeration and Inclusion.

References

Occupant behaviour and its implications in energy use –

A literature review

Vivian W. Y. Tam 1*, Laura M. M. C. E. Almeida 2 and Khoa N. Le 3

Abstract: In a building life-cycle the operational stage is the most intensive in terms of energy use. This is due to the fact that buildings are complex open systems affected by multiple variables interconnected and correlated with each other, associated with the existence of technical systems, equipment, occupants, etc. Nevertheless, being occupants one most important factor impacting the use of energy in a building [1], the way occupants behave and their motivations are some of the main aspects that need to be considered in a building life-cycle. Therefore, it is crucial to understand why, how, when and how significantly their actions are impacting the energy performance of a building as a whole. Consequently, this paper reviews available resources that are related with occupant behaviour and how it affects the energy use in a building. As a main existing gap, researchers pointed the difference between real energy performance and the one predicted at the design stage of a building.

Keywords: Occupant behaviour, energy-related behaviour, energy efficiency, energy use, driving forces, green building.

1* Tam, Vivian W.Y.
Corresponding author, School of Computing, Engineering and Mathematics Western Sydney University, Australia
College of Civil Engineering, Shenzhen University, China
E-mail: V.Tam@westernsydney.edu.au

2 Almeida, Laura M. M. C. E.
School of Computing, Engineering and Mathematics Western Sydney University, Australia

3 Le, Khoa N.
School of Computing, Engineering and Mathematics Western Sydney University, Australia
1 Introduction

The building sector is responsible for 40% of the primary energy use in the majority of the countries [2]. One of the main contributions to high rates of energy intensity in buildings is the way occupants deal with energy. The impact occupants have in the energy performance of a building is extremely significant. Past studies showed that the difference between predicted energy and real energy use is mainly due to the way occupants behave when using energy [1, 3]. This behaviour has several direct and indirect factors that may have influence in the way occupants consume energy. These factors may be due to objective aspects such as climate, air velocity, temperature, noise, accessibility to control building features, time and activity type, as well as to other subjective factors such as the perception of comfort, expectations, gender, age, values, and social interaction. Furthermore, these factors may also be influenced by external features such as politics, economics and culture.

This paper reviews energy-related occupant behaviour, its direct or indirect impact in the way occupants use and perceive energy, and consequently their implications in energy use. The purpose of this paper is to assess relevant achievements or approaches in their conclusions and/or studies, and identify areas of future research.

2 First steps towards energy-related occupant behaviour

Due to the evident influence that occupants have in real building energy use, the interaction between occupants and energy use began to be a matter of interest since the early 50’s. The earliest research discussed the relationship among occupant window-opening habits and heat loss through air-change rates [4] and it was identified a strong seasonal pattern in the habits that families have when opening windows [5]. The way occupants interact with artificial lighting and what drive them to switch on and off the lights, led to find a direct relationship with minimum real and perceived illuminance, as well as with daylight levels [6]. Accounting also the occupant’s interaction with solar shading is crucial due to the fact that by ignoring this fact it lead to an overestimation of energy savings [7].

3 Occupant behaviour in residential and office buildings

3.1 Occupant energy-related behaviour

After a series of projects [8] and studies [9] in the residential sector and by matching correctly occupant behavior, in 40%-70% of the time when using energy, it was concluded that the use of energy varies from one household to another, appearing irrational or unexpected from an energy conservation perspective but coherent in the context of family schedules, occupancy patterns and comfort preferences. Therefore, in the social and behavioural context aspects such as life-style, demography, economy, interaction with building features, systems and equipment will impact the energy use [10]. Similarly, cultural and economic contrast patterns between two whole different cities, in different countries, will impact differently the energy use in terms of space heating, lighting and hot water uses [11].

Annual energy use in residential buildings is directly related to occupant’s location and life-style. Reducing 2°C in the air-conditioning thermostat and matching light schedules to occupancy
patterns it is possible to decrease 39% in electricity uses. Besides, if occupants switch off the lights when there is no occupancy in the rooms it would lead to a 29% decrease in energy use\textsuperscript{[12]}.

3.2 Predicted vs real energy uses

Occupant behaviour is ignored in most energy simulations\textsuperscript{[13]}. One of the major factors impacting energy use is the unexpected occupant behaviour, which alone represented 64% of the difference between real and predicted energy. Heating, ventilation and air-conditioning (HVAC) operation over the expected schedule represented 24% of the discrepancies and equipment inefficiencies, conductive heat losses and divergences in the minimum outdoor-air rates were related to the remain 12%. Therefore, the actual energy use in a building is over twice as the predicted one during the design stage\textsuperscript{[1]}.

Using the conventional calculation procedure related with occupants’ behaviour in energy use and compare and validate an existent schedule data algorithm related to demands of hot water, lighting and power for electric appliances, it led to an overestimation of energy use\textsuperscript{[14, 15]}. There is a gap between the way designers predict occupant behaviour and how they really operate, because predictions were based in unrealistic schedules that cannot translate human behaviour in a plausible way\textsuperscript{[16]}. Therefore, when analysing the predicted energy use, if occupant behaviour is accounted in energy modeling simulations, it appears expected to verify a difference of more than 150% between the established lower and higher values used as reference\textsuperscript{[17]}.

3.3 Control systems and thermal comfort

After the mid 90’s, thermal comfort and its implications in energy use, as well as occupants’ wellbeing and questions such as indoor air quality (IAQ) and how occupants perceived comfort in a building was gaining additional relevance. It appeared the first computer model FENESTRA that allowed to account with occupants mobility and their relationship concerning thermal comfort\textsuperscript{[18]}; and a relevant study in the context of IAQ audits of 56 office buildings in Europe, that accounted with the inputs from occupants in relation with their perceptions of thermal comfort, IAQ, light and noise levels by means of a survey\textsuperscript{[19]}. One aspect that increased occupant satisfaction and thermal comfort, as well as reduced lighting energy in private offices was the fact that occupants would have manual dimming control\textsuperscript{[20]}. Therefore, using intelligent lighting occupancy sensors it was possible to save up to 30% of electricity for lighting\textsuperscript{[21]}. Another aspect that needs control is shading devices. As an example, reducing solar gain and glare, due to the activation of Venetian blinds, will lead to an increase of the electric uses associated with lighting\textsuperscript{[22]}. Occupants influence the performance of a building; passively, just by their presence and depending on the type of activity occupants are performing, they could impact the hygro-thermal conditions of a building and its acoustics; and actively, by having control of elements in a building, such as lighting, shades, windows and radiators. Therefore, occupants have a huge influence in energy use\textsuperscript{[23]}.

4 Behavioural algorithms and model tools

4.1 Developed algorithms

With an adaptive control algorithm (ACA) where indoor environment quality (IEQ) parameters (such as air temperature, air velocity, CO\textsubscript{2} concentration, illuminance at working plane) were
measured and a survey based on the seven-point ASHRAE scale to assess subjective thermal comfort sensations and predict the mean vote (PMV) was carried out; it is possible to save up to 30% of the cooling load without compromising the perceived thermal comfort [24]. Another algorithm used was the genetic algorithms (GA), that allowed the study of an automatic shading-device controller that learned the preferences of occupants regarding blind position and take into account the complex and unpredictable occupant behaviour on a long-term basis [25].

Aiming to account with all phenomena related to occupancy and allowing the possibility of accessing empirically-derived behavioural models in a dynamic mode, it was used the simulation software ESP-r coupled with the sub-hourly occupancy control (SHOCC) simulation module [26]. Later on, the SHOCC tool was applied to the simulation tools DAYSIM and Lightswitch Wizard, which alone allows an average of 20% energy savings [27], in order to obtain a more realistic estimation in lighting uses [28].

4.2 Sustainability tools and energy-related occupant behaviour

It was compared the actual energy use intensity to the baseline model of several buildings certified by the green building certification tool, LEED (Leadership in Energy and Environmental Design). Almost all buildings had savings over 40%, when compared to the design model projections, but there was no clear relationship between occupant satisfaction in comfort temperature and the building energy intensity [29]. Moreover, through the analysis of surveys from 177 buildings in the United Kingdom, it was concluded that occupants were more tolerant to green buildings and even more in small buildings than in larger ones [30].

The influence a sustainability certification program brand, such as LEED, had in the behaviour of occupants was analysed [31]. The authors referred that just by having a “green building” brand does not mean that the building is a “green building”. The concepts of sustainable design will only have real time effects when properly used by occupants. Nevertheless, LEED branding influences the environmental awareness of occupants and how they use light, by preferring natural to artificial light, as well as promotes waste reduction. Once again, the relevance of making occupants active participants in saving energy strategies, by making them aware of their contribution and responsibility in the way energy is used in buildings, and promoting communication between them, was referred in another researcher [32]. The significance of “green” tools and brands was also mentioned as a positive catalyst to reduce energy use and increase occupants’ awareness.

4.3 Other factors affecting energy use

A strong correlation between average annual electricity use and floor area was found in a study where 27 households were selected by focusing the research on the energy uses by varying the location, type of household, age, number of occupants, income, energy resources, lighting systems and appliances [33]. Therefore, according to some authors, energy performance in households is affected by several factors such as the strong relationship between energy use and the number of occupant, income and age besides climate, building and equipment; while economic and demographic factor did not seem to affect a significantly energy uses [34].

Another important factor that needs to be deeply researched is the importance of a formal connection between behavioural patterns and building energy management systems. Researchers developed and implemented algorithms for sensor-based modelling (collecting data related to lighting, acoustics, CO₂, temperature and relative humidity) and prediction of user behaviour in
smart buildings, connecting the behavioural patterns to building energy and comfort management systems through simulation tools, such as EnergyPlus. The results indicated a 30% potential on energy savings without scarifying the IAQ [35]. Energy waste is generally related with lack of information and misbehaviour in energy use [36].

5 Real energy use

5.1 Driving forces in energy-related occupant behaviour

Understanding the importance of knowing how the behaviour of occupants affects energy use in a building led [37] to elaborate the final report Annex 53 for the Programme on Energy in Buildings and Communities (EBC), related with occupant behaviour and modeling, for the International Energy Agency (IEA), in November 2013. In this report driving forces were defined as energy-related occupant behaviour. These driving forces referred to parameters that have influence on the way occupants interact with buildings and its control systems; and may be from an external or internal source, where the first were connected to the building and building equipment properties, time and physical environment; and the second one related to biological, psychological and social aspects.

Table 1. Energy-related occupant behaviour, according to IEA

<table>
<thead>
<tr>
<th></th>
<th>Internal driving forces</th>
<th>External driving forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupant related</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychological</td>
<td>Expectations and needs of comfort</td>
<td>Light and solar radiation</td>
</tr>
<tr>
<td></td>
<td>lifestyle and habits</td>
<td>temperature and humidity</td>
</tr>
<tr>
<td></td>
<td>environmental awareness, ...</td>
<td>air rates and wind speed, ...</td>
</tr>
<tr>
<td>Social</td>
<td>Interaction with other individuals</td>
<td>Type of control</td>
</tr>
<tr>
<td></td>
<td>family composition</td>
<td>availability and accessibility</td>
</tr>
<tr>
<td>Biological</td>
<td>Clothing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>age, gender and health activity, ...</td>
<td>Duration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>temperature and humidity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>air rates, ...</td>
</tr>
<tr>
<td>Location related</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Error! Reference source not found. represent the driving forces that influence occupant behaviour when using energy in cooling, heating, ventilation (including window operation), lighting, domestic hot water (DHW), appliances and cooking.

5.2 Energy performance in buildings

A pilot study was developed in order to identify the gap on energy performance of a building between design and operational stages. There were three different aspects that may contribute to the previous differences. The first was related to incongruences among energy modelings in the design stage and the energy measurements during the operational period; discrepancies concerning equipment learning approaches and real measurements; and finally the third divergence was linked to the energy rating systems where the design compliance was always different from the one
displayed in the energy certificate. As conclusion, the author focused on the fact that the differences in the energy performance of a building vary with external conditions and time steps of the energy measurements. Moreover, it was suggested a change in the way building engineering is performed nowadays in order to address the existing energy performance gap.[38]

With the intention to present a reliable answer that might address the most relevant gaps found in literature, such as: differences between predicted and real energy uses; real and modelled occupant behaviour; systems performances; it was developed a DNAs (Drivers, Needs, Actions and Systems) framework that intends to become a standardized tool for building information modelling (BIM) allowing building designers to account with occupant behaviour from early stages of the construction process [39, 40].

5.3 Interactive and social-media

Interactive and social-media technologies may influence the way occupants use energy, taking advantage of the fact that occupant’s values affect the way individuals and communities decide and behave. Therefore, in order to communicate information that motivates a change in behaviour, their values have to be taken into account [41]. A research project called eViz, that aimed to reduce energy use for heating purpose by using visualization on mobile devices to drive occupants as energy efficiently aware was created in the United Kingdom[42].

6 Discussion and conclusion

This paper intended to review the main key points in energy-related occupant behaviour research, the main conclusions and the most relevant gaps. One of the most relevant gaps identified by researchers was the difference between real energy performance in a building and the one predicted at the design stage. This gap is due to the fact that real occupant behaviour is not being taken into account at the design stage and the schedules used in energy simulation programs are based on theoretical values that do not reflect the real ones. Furthermore, occupants should be well informed of the best practices when dealing with building systems, such as lighting, HVAC, equipment, DHW, etc. Further studies point to the need of understanding more in depth the relationship between occupant energy-related behaviour and its implications to the energy management system in a building. Another aspect that needs further development is the quality of the measurements and data [43] as well as the need of additional reliable models to simulate occupant behaviour and actions, and a standard framework to be able to integrate building simulation programs [44]. There is also the need of supplementary methods to relate socio-economic trends and new technology developments.

References

rating actual inhabitants' behavior schedules for accurate prediction of maximum ACEEE summer study on energy consumption and the effect of occupant behavior on homes in the Pacific Northwest constructed according to improved thermal standards. Energy, 31(5): p. 677-693.


An Overview of Building Lifecycle Embodied Carbon Emissions Research

Trinh, T.M.K.H.1*, Doh, J.H.2 and Hou, L.3

Abstract: The building and construction industry is a sector that is heavily tied to natural resources and contributes to a large discharge of greenhouse gas emissions. It is therewith critical for the entire industry to work towards sustainable design and construction with which environmental impacts could be utmost reduced. An overview of research reveals that the primary emission type, throughout a building lifecycle, constitutes emissions at the construction stage (a.k.a. upstream embodied carbon), as well as emissions at the operational stage. While there has been a significant research interest on mitigation strategies for curbing operational emissions, embodied emissions are generally overlooked. However, recent studies have revealed that reducing operating carbon is accompanied with a little increase in embodied carbon. Therefore, this study posits that both aspects, when tackling the global carbon emissions challenge, are equally important and need to be collectively examined, and a potential resolution would be identifying the interplay between embodied and operational carbon. According to the comprehensive review on the state-of-the-art literature pertaining to lifecycle carbon issues, this study reiterates the increasing significance of embodied carbon, urges that accurate assessment approaches for embodied carbon should be formulated, and recommends that the future research focus should be placed on holistic carbon assessment standard that could calibrate both embodied and operational carbon impacts.

Keywords: Buildings; Embodied and operational carbon emissions; Environmental impacts; Climate change.

1* Trinh, T.M.K.H.
Corresponding author, School of Engineering, Griffith University, Gold Coast, Queensland 4222, Australia
E-mail: kim.trinh@griffithuni.edu.au

2 Doh, J.H.
School of Engineering, Griffith University, Gold Coast, Queensland 4222, Australia

3 Hou, L.
School of Engineering, Griffith University, Gold Coast, Queensland 4222, Australia
1 Introduction

The building and construction sector is crucial as it contributes greatly in the economic growth of a nation. Such a sector, which is heavily tied to natural resources, has been long plagued as one of the major contributors of climate change\[1\]. According to Chau et al. (2015), the building sector accounted for 40% of the world’s energy consumption, 30% of raw materials use, 25% of solid waste, 12% of land utilisation, and 33% of greenhouse gas emissions\[2\]. Moreover, the annual usage of concrete in the construction industry continues to increase by 23 billion tons\[3\], and the cement industry solely contributes 5% to the global manmade CO2 emissions\[4\]. It is therefore urgent for the construction sector to formulate effective solutions and techniques to accommodate sustainable development strategies.

Basically, the building’s lifecycle carbon emissions consist of two main components: embodied and operational emissions. Due to the largest share of energy-related in-use emissions\[5\], embodied carbon is presently not a consideration when the building is designed, specified and constructed. However, recently, there have been solid evidences that embodied impacts of buildings also serve as the main contributor to the global emissions. Based on the types and functions of buildings, geographic and climatic conditions, applied construction methods, etc., they can occupy for more than 50%\[6\] and up to 74%-100%\[7\] of the building’s lifecycle carbon emissions. Moreover, Ibn-Mohammed et al. (2013) claimed that the increasing proportion of embodied emissions was actually one consequence of efforts to reduce the operating emissions\[8\], thereby shifting the environmental pressures from one life cycle stage to the others. This implies that there is a certain limit for the overall emission savings through reduction in operating energy; hence, sustainable design now should target towards the impacts embodied in the remaining phases of the building’s life cycle.

In response, this paper aims to provide a comprehensive overview of the building’s lifecycle embodied carbon emissions and the current trend concerning embodied versus operational carbon in the building’s lifetime. Additionally, the paper emphasises the importance of embodied carbon along with the need for an internationally-accepted assessment framework to calibrate both embodied and operational carbon in the building performance analysis.

2 Building’s Life Cycle Carbon Emissions

The whole-life carbon emissions can be categorized as Embodied Carbon (EC) and Operational Carbon (OC). While embodied carbon is defined as the carbon emitted from the extraction, manufacturing, transportation of the final material to onsite assembly, OC is the carbon expended to maintain the desired indoor environment of a building, encompassing all activities relevant to the function of the building, including HVAC system, domestic hot water, lighting and appliances\[9\]. However, in practice, there are various definitions of embodied carbon, relying on the boundary of the studies and EC’s different forms. Based on the chosen system boundary, there are three common definitions: cradle-to-gate; cradle-to-site; and cradle-to-grave EC (see Figure 1).
Figure 1. Building’s lifecycle embodied carbon emissions (cradle-to-gate; cradle-to-site, and cradle-to-grave)

According to Li et al. (2014), embodied carbon comprises of two forms: direct emissions from the assembly activities and indirect emissions, incurred in the extraction of feedstock, and the production and transportation of final building materials to the construction site. Further, embodied carbon can be defined as the summation of fuel-related carbon emissions, discharged from the production plants and equipment, and process-related carbon emissions, for example, the calcination of limestone occurring in the cement manufacture. Moreover, in the same manner of Embodied Energy (EE), embodied emissions can also be classified into: Initial Embodied Emissions, ranging from the materials production to the jobsite erection phase, and Recurring Embodied Emissions, referring to repair and replacement when the material’s lifespan is shorter than the building operation years. Besides, the sequestration of carbon within constructive materials, such as timber and wood components and the lifetime use of materials, namely the carbonation of concrete, should be taken into consideration as well to obtain the most accurate value of the overall embodied carbon emissions.

2.1 Embodied carbon versus operational carbon in buildings

In the past, many researchers believed that embodied impacts of a building are insignificant compared with the operational ones. For instance, Suzuki and Oka (1998) estimated that the embodied energy and carbon emissions of all office buildings in Japan accounted for 18% and 21%, respectively. Recently, Ramesh et al. (2010) have conducted a critical overview of the lifecycle energy assessment of 73 case studies across 13 countries. Results revealed that operating and embodied phases, amounting to 80-90% and 10-20%, respectively, were the main contributors of the building’s lifecycle energy demand. In like manner, many other studies also found a smaller share of embodied carbon (less than 20%) in comparison with operating carbon. Consequently, reducing the operation energy consumption and carbon emissions has been long believed as being utmost importance and far more effective than tackling the embodied impacts.

However, lately, several studies have indicated that embodied carbon percentage can be higher. Based upon the type and the function of a building, along with other factors including geographic and climatic conditions, building’s orientation and structural system, building’s lifespan, etc. embodied carbon can vary from less than 20% for conventional buildings to as high
as 80% for low-energy buildings and almost 100% for zero-energy buildings. For example, Islam et al. (2015) asserted that emissions embodied in the construction and maintenance phases respectively amounted to 47% and 42% of the total energy demand and Greenhouse Gas (GHG) emissions. From a post-occupancy lifecycle analysis of a newly-built residential house, Crawford (2014) affirmed the significance of embodied energy and GHG emissions in the building’s lifecycle. Specifically, the author figured out that EE and EC (including initial and recurrent) could respectively account for 59% and 54%, exceeding those of the operation stage.

In addition, with respect to the moderate and cooling regions, embodied energy could represent from 25% to 35% of the total lifecycle energy, due to the lower operation energy demand. On the contrary, in heating dominated regions, embodied emissions only accounted for 10% of the whole building’s carbon emissions. This observation indicates a sensitive manner of embodied impacts in terms of geographic and climatic conditions. Furthermore, the relative share of embodied carbon and operating carbon are dependent on the building’s lifespan. To illustrate, Rauf and Crawford (2015) investigated the building’s functional life and its effects on the lifecycle embodied energy of buildings. For a building’s service life of 100 and 150 years, EE respectively amounted to 54% and 52% of the entire lifecycle energy. A small decline in the latter embodied energy percentage was attributed to an increase demand for maintenance and replacement during the extended time.

In case of low energy buildings, Thormark (2007) affirmed that embodied energy ranged 40%-60% of the total energy consumption. Chastas et al. (2016) undertook a literature review of embodied energy in 90 residential buildings. The results disclosed an increasing share of embodied energy in the trend towards passive, low-energy, and nearly zero-energy buildings, which were 11%-33%, 26%-57%, and 74%-100%, respectively. The gradual increase proportion from 33% to 100% of the lifecycle energy stems from the fact that reduction in operating energy could be accompanied with a little increase in embodied energy due to the application of energy efficient instruments. These findings put a question on the actual relative relationship between embodied and operational impacts and challenges the common belief of the trivial contribution of embodied carbon in a building’s performance. In summary, Figure 2 illustrates a wide range of embodied impacts (EE and EC) reported in some frequently cited studies.

![Figure 2. Embodied vs. operational impacts in the building life cycle](image)

### 2.2 Embodied carbon and its variation

Despite the increasing awareness and development of computation models, there is currently no
internationally-accepted analysis framework and design standard covering the embodied environmental impacts in the building performance assessment. Thus, there is a great amount of quantification analysis studies derived for estimating embodied emissions of different building types, leading to a wide range of findings in the body knowledge. According to Eaton and Amato (1998), depending on different kinds of structures, which were steel, composite, reinforced and precast concrete, the embodied carbon of office buildings was 600-850 kgCO$_2$-eq/m$^2$. On the other hand, Clark (2013) reported that the embodied carbon of office buildings varied from 300 to 1650 kgCO$_2$-eq/m$^2$, depending on different methodologies applied in academic and industry assessments. Likewise, Ding (2004) reviewed embodied energy obtained from previous researches for residential and commercial buildings with a wide range of 3.6-19 GJ/m$^2$. Recently, Dixit et al. (2012) reported several parameters causing the variability of EE values, which were system boundaries, EE measurement methods, the building’s geographic location, data resources’ ages and completeness, technology of manufacturing processes, and so forth. Therefore, the authors emphasised the urgent need of a holistic and globally-accepted measurement protocol to evaluate the embodied environmental impacts of the building’s lifecycle.

3 The significance of embodied carbon

Since the use phase is generally believed as the biggest contributor in the building’s lifecycle environmental impacts, recent decades have witnessed the rapid advancement in the field of green technologies, such as energy-saving HVAC systems and the employment of advanced constructive materials and renewable energy, along with the world-wide stringent regulations of sustainable policies. As a result, OC is substantially decreasing and no longer the driving force in the building sustainable performance. The massive decline of in-use emissions has consequentially led to the growing relative proportion of embodied carbon. Certainly, the application of energy-efficient measures requires sophisticated installation techniques, thereby resulting in higher material consumption and embodied emissions. Moreover, a passive design with improper material selection as well as inappropriate construction methods and waste management could further intensify the severe issue. For illustration, Wang et al. (2016) investigated the lifetime GHG emissions of two state-of-the-art commercial green buildings to disclose the relationship between low GHG buildings and green buildings. The authors recognised that the employment of exterior shadings could reduce the energy consumption of air-conditioning in the use phase, but may induce more embodied carbon emissions. Furthermore, depending on the material used for the shading system, namely, lower carbon-intensive steel versus aluminum, the growing EC of two green buildings were different. On the other hand, Sartori and Hestnes (2007) acknowledged that some self-sufficient buildings possessed extremely high embodied energy, surpassing the lifecycle energy of several low-energy versions. This indicates that there is a limitation for energy-saving in the occupancy phase and the sustainable analysis now should focus on the embodied impacts incurred in the rest of the building’s lifecycle.

Besides, some recent studies highlighted the critical influence of the construction carbon emissions, when the carbon footprint accounting is scrutinised from the temporal point of view. In fact, ‘the carbon spike’ occurred in the early short-term lifecycle phases is more detrimental than the decades-long operation emissions, owing to the cumulative volume of GHGs trapped in the atmosphere. Furthermore, from macro-level analysis, the construction phase actually
constituted more than 60% of the lifecycle carbon and energy of the whole building sector, due to numerous construction projects being erected every year\textsuperscript{[28]}. Additionally, the annual carbon footprint per working area of the pre-occupancy stages are far higher than those of the use phase. According to Crawford and Treloar (2003), the annual operational energy of most of Australian buildings was only equal to 2-5% of their corresponding embodied energy\textsuperscript{[29]}. Hence, as the world population and the immense demand for newly-built buildings are growing, the relevant embodied environmental impacts cannot be overlooked.

4 Conclusion

While a great amount of efforts has been put into tackling the operational emissions, little attention is paid to embodied emissions occurred in the upstream processes. This prompted an overview of the lifecycle embodied carbon emission to disclose the interplay between embodied and operating carbon and verify the significance of embodied impacts in the sustainable performance of a building. Owing to the advent of energy efficiency technologies and the regulation of stringent sustainable policies, the potential for curbing operational carbon has increased. As the operating carbon is continuously reduced to approach zero energy or zero carbon buildings, the contribution of embodied carbon is on the increase. Since the increasing percentage of embodied carbon is one outcome of efforts to reduce in-use emissions, excluding the embodied impacts of the building’s construction in sustainable design and assessment may cause bias in decision-making and lead to counterproductive reduction schemes. As there are several definitions and quantification analysis studies of embodied carbon, the contemporary state of research is plagued by a wide variation of EC values. Due to the increasing significance of embodied carbon and the current trend towards low-carbon buildings, it is important to develop a robust inventory data and a comprehensive methodology to streamline the EC computation framework. Moreover, the development of a lifetime carbon accounting benchmark in terms of both EC and OC is essential to provide the trade-offs amongst different design options and a better understanding of potentials of GHGs mitigation strategies.

References


Risk factors for alliance infrastructure construction projects: A study in New Zealand

Chang-Richards, A.Y.\textsuperscript{1*}, Taumate, P.\textsuperscript{2} and Wang, C.\textsuperscript{3}

Abstract: The Alliance Organizational Model is increasingly becoming a world-wide used method to manage large infrastructure projects. However there is little empirical research on the effectiveness of such a model in managing risks to ensure project success. To fill this gap, this research aims to investigate the risk factors that are inherent in a large infrastructure construction project and how the alliance organizational model plays a role in risk management. A case study of the Waterview Connection Project in Auckland was undertaken along with a series of interviews with professionals that were involved with its project management organization, the Well-Connected Alliance. The critical risk factors identified are primarily operationally-related and relationally-related. A highly specified software called Activated Risk Manager, the execution of a ‘High Performance Plan’ and Construction Execution Plan were the most cited mechanisms used to managing those risks. The learnings from the Waterview Connection Project, one of the most important infrastructure developments to take place in New Zealand contribute to an improved understanding of risks that exist in complex large infrastructure construction projects. The ways those risks are managed can be transferable to inform risk management practice for future alliance projects both nationwide and internationally.

Keywords: risk management; construction sector; infrastructure projects; alliance; New Zealand

\textsuperscript{1*} Chang-Richards, A.Y.
Corresponding author, Department of Civil and Environmental Engineering, University of Auckland, New Zealand; E-mail: yan.chang@auckland.ac.nz

\textsuperscript{2} Taumate, P.
Department of Civil and Environmental Engineering, University of Auckland, New Zealand

\textsuperscript{3} Wang, C.
Department of Civil and Environmental Engineering, University of Auckland, New Zealand
1 Introduction

The construction of large infrastructure projects can be challenging to manage when there are unknown complexities and uncertainties beyond the best knowledge of project managers. Under those circumstances, efficient implementation of a risk management approach requires the practitioners to have the risk situational awareness, capabilities and knowledge and proper tools and techniques. Good practice of project risk management also shows how the project management team overcame the traditional construction culture by using a cooperative procurement approach and creating a collaborative environment that supports a joint risk management effort among different parties. Having an effective and responsive risk management mechanism is extremely important for construction project success, especially when initial risks change and new risks emerge during the projects’ lifecycles.

Various strategies exist to address problems caused by adversarial relationships in construction projects. Amongst those most commonly used, relational contracting has been extensively applied in the forms of partnering, alliancing, joint venture and integrated project delivery. Other collaborative tools for risk management included such as inviting project parties to attend joint workshops and team building activities, all proved to be beneficial. Previous research suggested that for the risk management strategies to be useful and effective, it is critical to know about the risk profile in relation to a group of projects of similar kind. However, according to Guo et al., despite the importance of a joint risk management approach, there is a lack of empirical studies, including studies of processes and studies of real-time projects, that can increase the understanding about risk management in large infrastructure projects.

The research reported in this paper seeks to bridge this gap by empirically investigating the risk factors for a large infrastructure construction project and the mechanisms used for management of those risks. To achieve this goal, two research questions were formulated.

1) What risk factors are critical in affecting the project outcomes? and
2) What mechanisms have been put in place in addressing those critical risk factors?

The reminder of the paper starts with an overview of the risk management approach in infrastructure projects, followed by a review of critical risk factors relevant to large alliance infrastructure projects. A case study method will be presented in the Research Method section. The Waterview Connection Project, one of the most important infrastructure developments to take place in New Zealand, will be presented as a case study of how risk management mechanisms were adopted and influencing the management of project risks. A discussion reveals the implications of profiling risks and risk management practice for future complex infrastructure projects. The paper ends with a conclusion and suggests future research directions.

2 Risk management in infrastructure projects

2.1 Risk factors in infrastructure projects

Drawing on the literature, the risks in relation to infrastructure construction projects can be categorized into five groups: project management risks, operational risks, engineering risks, external risks and financial risks. Rezakhani also categorized risk factors based on three general phases of a project life cycle, namely, initiation, design and construction.

- *Project Management Risks* are the risks that affect the management of the project. For
example, Boadi et al. identified organizational risks such as the shortage of resources, agency reputation and the legal liability of planning for a large infrastructure project [17]. Cost over-runs as a result of failure to follow schedule or price estimation errors, communication failure and scheduling errors are also common in the process of managing a construction project [1, 18, 19].

- **Operational Risks** are risks that affect all operational works in a project which includes, design inadequacy, inadequate control plans, labor’s capabilities and resources availability [20]. Such risks can directly lead to poor workmanship and affecting the quality of construction work [11, 21].

- **Engineering Risks** are risks that directly affect the engineering aspects of a project, namely, project design and construction methodology. In most cases, those are the technical risks such as the design flaws or failure of certain techniques and technology in construction [22].

- **External Risks** define the outside influences on projects that prevent a project from achieving success. These risks are often outside of the project management’s control and they are hard or impossible to eliminate [23]. For example, those include the weather conditions and natural hazards [16]. Culture shocks and local regulatory requirements were also identified by Liu et al. [24] as external risk factors that may cause ripple effects on the project result.

- **Financial Risks** are risks that affect the financing of projects, including inflation, foreign exchange fluctuations, fund availability and contractors financial conditions [23, 25]. Financial risks are always critical in any project as they can affect the overall cost, the available budget and hence the success of the project [20].

**2.2 Risk management strategies for alliance infrastructure projects**

The most common risk management mechanisms used in managing project risks is the Risk Management Approach (RMA) as identified by studies reviewed. However, little literature has provided a full analysis on the use of RMA in alliance-type of projects. Most studies only talked about risk management for projects in general [13, 15]. Wilkinson and Scofield [26] defined that an alliance is a procurement and contracting system to manage large infrastructure projects. The participants in the alliance can be designers, suppliers, contractors and clients - all working collaboratively under an alliance contract to share risks and rewards [1, 25, 27, 28]. Research on project alliancing has revealed a number of benefits including the reduction of project costs and increase of profits for both the client and the contractors [29, 30]. In particular, scholars found that project alliancing is “a risk and reward mechanism developed to share project risks and rewards between allied parties.” The alliance governing structure of ‘risk sharing’ allows for risk management in projects to be effective [26, 28].

The RMA method was introduced into risk management of engineering projects due to its good applicability for risk assessment [31, 32]. In New Zealand, the RMA method is applied by drawing on the AS/NZS ISO 31000:2009 Risk management standard and the means of managing the risks include *Eliminated, Transferred, Controlled or Accepted* [33]. These four risk management strategies or a combination of them have been used in different situations. Table 1 below summarises these strategies in responding to varied risk categories.
### Table 1. Risk factors & risk management strategies

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Risks</th>
<th>Strategies</th>
<th>Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Management Risks</strong></td>
<td>Initiation, Planning &amp; Design Phase: Team Selection, Legal Liability, Decision Making &amp; Objective Variation, Relational &amp; Performance, Communication Issues, Resources Availability, Insufficient Quality Control Plans</td>
<td>Control</td>
<td>Form Risk Management Committee: Key-Risk Agenda, Constant Risk Monitoring</td>
</tr>
<tr>
<td></td>
<td>Maintenance Phase: Fund approval, communication issues</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operational Risks</strong></td>
<td>Initiation, Planning &amp; Design Phase: resources unavailability, inadequate design, consent delays, lack of site control plans</td>
<td>Transfer/share</td>
<td>Acquire Insurance for: accident &amp; injury, equipment &amp; plant</td>
</tr>
<tr>
<td></td>
<td>Construction Phase: Health &amp; Safety, Site access/ restrictions, unpredictable site conditions, material availability &amp; delivery, equipment failure &amp; theft, labour availability &amp; capabilities, poor construction productivity, environmental risks</td>
<td>Mitigate</td>
<td>Provide contingency for bid and time buffers, Conduct Site Inductions for safety and environmental, Ensure adequate supervision is provided &amp; qualified workers are hired</td>
</tr>
<tr>
<td></td>
<td>Maintenance Phase: Deterioration of Facility,</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engineering Risks</strong></td>
<td>Initial Phase: inadequate design</td>
<td>Transfer</td>
<td>Ensure Contractor participates in Design</td>
</tr>
<tr>
<td></td>
<td>Construction Phase: new/ revised quality standards, construction methodology variation, productivity, design &amp; construction errors</td>
<td>Eliminate</td>
<td>Change original design to prevent design inadequacy</td>
</tr>
<tr>
<td></td>
<td>Maintenance Phase: ineffective maintenance practices used, incompetent inspection personnel</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>External Risks</strong></td>
<td>Initial Phase: societal risks, stakeholders</td>
<td>Transfer</td>
<td>Acquire insurance, Contractual Clauses for delay and payments for damages, Contingency plan</td>
</tr>
<tr>
<td></td>
<td>Construction Phase: weather &amp; natural hazards, vandalism &amp; theft, fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Maintenance Phase: weather &amp; natural hazards, vandalism &amp; theft, fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Financial Risks</strong></td>
<td>Initial Phase: project cost approval, under pricing</td>
<td>Transfer &amp; Sharing</td>
<td>Price Contingency, Reliable Project Financier</td>
</tr>
<tr>
<td></td>
<td>Construction Phase: cost overrun, interest rate fluctuation, contractor financial conditions, delayed payments, foreign exchange fluctuations</td>
<td>Eliminate</td>
<td>Providing Performance Bond &amp; pre-qualifications conditions for suppliers, Owner purchase of, Equipment &amp; Materials, Contract to evade changes in exchange rates</td>
</tr>
<tr>
<td></td>
<td>Maintenance Phase: funding, cost overruns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3 Research methodology

The case study method was chosen for this research paper due to its theory-based nature\(^{[34, 35]}\). This is important as it allows for a detailed investigation into the risk management practices of large infrastructure projects. The Waterview Connection Project was chosen as the case study. It is one of the most important infrastructure developments in New Zealand. The Waterview Connection Project is being constructed for NZ Transport Agency by the newly established Well-Connected Alliance. By the time of undertaking this research, the project was in its final stages of construction. The project was intended to provide Auckland, New Zealand’s largest city, with a reliable motorway network in the region. The alliance team comprises one client organization, namely, the New Zealand Transport Agency (NZTA) and six delivery organizations, including Fletcher Construction, McConnell Dowell Constructors, Parsons Brinkerhoff, BECA
The qualitative methods including semi-structured interviews and a focus group were used to collect the case study data. The data collection was approved by the University of Auckland Human Participants Ethics Committee on 25\textsuperscript{th} May 2015 with reference number 014583. The sample of interviews includes all the experts involved in risk management practice for the Waterview Connection Project. Invitation to participate in interviews was sent by the General Manager of the alliance project management team. In total, 12 people were interviewed between June and August 2015 followed by a focus group with all these interviewees in September 2015. The details of these interviewees are shown in Table 2.

<table>
<thead>
<tr>
<th>Code</th>
<th>Role in Well-Connected Alliance</th>
<th>Number of years working in the industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>QM</td>
<td>Quality Manager</td>
<td>≥10 years</td>
</tr>
<tr>
<td>SM</td>
<td>Systems Manager</td>
<td>≥5 years</td>
</tr>
<tr>
<td>RM</td>
<td>Risk Manager</td>
<td>≥20 years</td>
</tr>
<tr>
<td>DE</td>
<td>Design Engineer</td>
<td>≥10 years</td>
</tr>
<tr>
<td>PE</td>
<td>Project Engineer</td>
<td>≥5 years</td>
</tr>
<tr>
<td>SE1</td>
<td>Site Engineer</td>
<td>≤5 years</td>
</tr>
<tr>
<td>SE2</td>
<td>Site Engineer</td>
<td>≥10 years</td>
</tr>
<tr>
<td>SE3</td>
<td>Site Engineer</td>
<td>≥5 years</td>
</tr>
<tr>
<td>PCCM</td>
<td>People, Communications, Culture Manager</td>
<td>≥10 years</td>
</tr>
<tr>
<td>PRM</td>
<td>Public Relations Manager</td>
<td>≥10 years</td>
</tr>
<tr>
<td>CSM</td>
<td>Communications, Stakeholder Manager</td>
<td>≥20 years</td>
</tr>
<tr>
<td>TWM</td>
<td>Temporary Works Manager</td>
<td>≥5 years</td>
</tr>
</tbody>
</table>

Each interview session took one hour on average. The participants of the interviews were asked a series of questions, which are focused on the risk profiles of the Waterview Connection Project and how those risks have been managed. Interviewees were also asked about their perception on the difference in risk profiles between non-alliance and alliance infrastructure projects. In the focus group, participants were encouraged to share their stories of success and failures and summarise the lessons they have learned from working on this project. The qualitative data collected through interviews and focus group were analyzed by using content analysis method\textsuperscript{[37]}. In November 2015, the data analysis result in the format of a research report was sent back to the interviewees for validation. A consensus of data validity was received from these interviewees.

4 Results and discussion

4.1 Waterview Connection Project risk profile
The risk factors that were identified as most relevant to the Waterview Connection Project are tabulated in Table 3 below. The interviewee who identified a particular risk was also shown in Table 3 by using the code.
<table>
<thead>
<tr>
<th>Risk category</th>
<th>Risk factors</th>
<th>Identifier (interviewees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Risks</td>
<td>Under designing risks, construction errors, safety of temporary works, incorrect programming</td>
<td>QM, DE, SE2, TWM, SE3</td>
</tr>
<tr>
<td>Personal Risks</td>
<td>Intellectual property loss, individual shortcomings, heavy workloads</td>
<td>QM, SM, RM, PE, SE3</td>
</tr>
<tr>
<td>Operational risks</td>
<td>Environ, health &amp; safety hazards, deaths &amp; accidents, budget, inadequate resources, inadequate quality plans</td>
<td>QM, TWM, SE1, PCCM, SE3</td>
</tr>
<tr>
<td>Unknown Risks</td>
<td>Natural disasters, bad weather, fires, economic cycle</td>
<td>QM</td>
</tr>
<tr>
<td>Relational Risks</td>
<td>Client &amp; Project reputation, losing public trust, cultural risks, effective communications, social risks</td>
<td>QM, SM, PCCM, PRM, CSM, SE3</td>
</tr>
</tbody>
</table>

Nearly all interview participants pointed out that operational risks pose the greatest challenges to the Waterview Connection Project. Interviewees all emphasized that the quality of all project-related activities are a critical factor contributing to project success. As interviewee RM suggested “If we make sure we deliver at different levels and for all kinds of purpose, no matter the job is small or big, the final quality of the project will be ensured”. This view, however, is in line with the findings from Al-Bahar and Crandall [20] that lack of quality of doing on the operational side can be a major risk that may have ripple effects in the project if the project is considered as a system. Other operational risks such as health and safety, cost overruns, lack of resources and planning, together with environmental risks also echoed what concerned Imbeah and Guikema [6], and Chapman and Ward [18] as critical risk factors the project team should manage holistically.

The equally highly ranked risk factors are Relational Risks, which encompass the relationships between the project and the public, the Waterview Connection Project and the client (NZTA) as well as the relationships within the alliance team itself. Several interviewees such as QM, SM and RM noted that the complexities of this project mean that each party bears the risk of financial loss or cost overruns if the duties allocated to that party are not well carried out or any party in a collaborative relationship does not communicate or cannot performance well. As a result, the entire project will suffer from poor performance, like cost overruns and delays. One of the reasons for establishing an alliance team, according to the interviewee SM is to manage those relational risks.

Construction risks are a big concern for any infrastructure project as the construction process involves complex relationships and complicated factors [13, 15]. Under designing risks, construction errors, safety of temporary works and incorrect programming were the four major risk factors that were considered by the interviewees under this category. As noted by Site engineers SE1-3 and Systems Manager SM that the Waterview Connection Project is a large infrastructure project that involves extensive construction and building activities and the major part of the construction is a three kilometers waterview tunnel. There were a large number of unforeseen technical problems arose as the construction proceeded. This has highlighted the importance of early detection of flaws in the design and construction methodologies when managing a complex project [1, 12, 17].

Personal Risks as mentioned in the interviews include the ‘loss of intellectual property (IP)’ and the risk of large workloads due to unnecessary requirements on workers by the alliance team to achieve its goal. However, the loss of IP was not considered as a ‘big deal’. According to the interviewee CSM, the workers are ‘paid to share their knowledge and skills’ rather than ‘keeping them in their pockets’. Furthermore the interviewee SM stressed that the alliance itself is a ‘constant learning curve’ and everyone in the alliance team has contributed to an overall
understanding of systems. The large workload, noted by interviewees SE 1-3, was related to the
very nature of their job as being a site engineer and having to work overtime where needed.
Fatigue as a result of this, however, was taking a toll of their productivity. This finding somehow
confirms what Guo et al. [1] mentioned that lack of attention to individual staff wellbeing can be a
major risk that affect the quality and performance of construction projects.

The majority of interviewees also highlighted some unknown risks which were considered as
those out of their control, such as bad weather, storms, fires due to lightening and inflation. The
project manager PE suggested that the alliance team, especially those work on site had to cancel
their schedule more frequent than they have planned for due to the unexpected weather patterns.
There were also several fire incidents caused by lightening. As there are some construction
products imported from overseas, the fluctuated economic cycle has caused escalated pricing issue
due to inflation and changes interest rate. As one interviewee RM suggested ‘all these things are
unknown and they really affected the way we had to work around those things – we don’t know
what we don’t know when building this tunnel as our first project of national significance’. In
some literature, those external risks were called ‘Acts of God’ and only better planning can reduce
the impact of those risks on project outcomes [9, 21].

4.2 Risk management mechanisms for the Waterview Connection Project

The interviews and focus group identified a total of eleven methods that were used by the alliance
team (Table 4). Among those eleven mechanisms, three were regarded as most useful in managing
existing and emerging risks during the lifecycle of Waterview Connection Project, namely, use of
the Construction Execution Plan (CEP), the specified software named ARM and the use of a High
Performance Plan (HPP).

Table 1. Risk management methods adopted for the Waterview Connection Project

<table>
<thead>
<tr>
<th>Risk management mechanisms</th>
<th>Description</th>
<th>Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEP, JSEA, ITP, TWP</td>
<td>Main Documents</td>
<td>QM, DE, PE, SE2, TWM, SE3</td>
</tr>
<tr>
<td>Finance Solutions</td>
<td>Hedging, Forecast Money</td>
<td>QM, RM</td>
</tr>
<tr>
<td>Plan of Action</td>
<td>Response to Unknown Risks</td>
<td>QM</td>
</tr>
<tr>
<td>Peer &amp; External Reviews, Risk Management Systems Audit</td>
<td>Daily reviews by Managers &amp; Engineers of Site Specific Plans, External Reviews by third parties, Insurance Company Audits the systems regularly</td>
<td>QM, DE, SE2, TWM, SE3</td>
</tr>
<tr>
<td>Software: ARM</td>
<td>Active Risk Manager, a risk register program</td>
<td>SM, RM, PE,</td>
</tr>
<tr>
<td>Culture Theme: One Team</td>
<td>Alliance culture promoted throughout offices, no identification with home companies, integrated Teams</td>
<td>QM, SM, RM, PE, SE2, PCCM, PRM</td>
</tr>
<tr>
<td>Reward System</td>
<td>Incentive reward money, Site Awards</td>
<td>SM, RM, SE2, SE3</td>
</tr>
<tr>
<td>Toolbox &amp; Pre-start talks</td>
<td>Talks conducted on site to stress H&amp;S Protocols, construction methodology</td>
<td>QM, SE1, SE2, SE3</td>
</tr>
<tr>
<td>Protocols: Enviro, H&amp;S, Media</td>
<td>Protocols to ensure the safety of the workers, protocols to ensure the safety of project’s reputation</td>
<td>QM, DE, PE, SE1, PRM, SE3</td>
</tr>
<tr>
<td>Construction Review Team</td>
<td>Team checks construction activities &amp; check of materials used are correct, review the construction for correctness of design</td>
<td>SE2</td>
</tr>
<tr>
<td>High Performance Plan</td>
<td>Plan includes: Think One Team Model, Above The Line, Community Works, Workshops, Meetings, 24/7 hotline, monthly gatherings</td>
<td>RM, PCCM, CSM</td>
</tr>
</tbody>
</table>

Several tools were used together with CEP to help with managing project risks. They are Job
Safety and Environmental Assessment (JSEA), Inspection Test Plans (ITP) and Temporary Works Plans (TWP). The CEP forms and templates were used to document all the risks and risk management methods within the project and its activities. The JSEA mainly deals with health & safety risks as well as environmental risks. The ITP document was used to monitor the risks that are concerned with the project quality. It details the criteria that materials used for construction and the end product of construction activities that were required.

The software used by the alliance risk management team is the Activated Risk Manager (ARM). This software was extremely useful as a risk register which records and monitors all the project’s critical risks and their management methods. ARM itself incorporates the risk management principles and guidelines into its system and takes advantage of computer technology. Several interviewees including SM, RM and CSM, spoke highly of this tool and emphasized that by using ARM, risk management can be undertaken on the real time horizon. Interviewee PE also commented that all the risk profiles are shared with all alliance team members by logging in ARM, so any new or emerging risks that concern a particular team member can raise an immediate alert and get address on a timely basis.

High Performance Plan (HPP) is an annual plan the alliance team sets to manage all its communication issues or relational issues. The plan includes scheduled workshops, meetings, social events and community work to help develop the relationship between the project and the public as well as the relationship within the project itself. The HPP also includes the strategies that the alliance project team employs to ensure the alliance culture of ‘one team’ is realized. With all the parties participating as an alliance, working together and teamwork is inherent in the HPP. The alliance team also promotes the ‘one team’ culture through the models and policies set in HPP. The models include the ‘Think One Team’ model and the ‘Above the line’ model. The former model aids in getting all the workers to work together and encourage good collaboration, whereas the later model sets the performance expectations that the alliance project team has for all its workers.

5 Conclusion

The study of the Waterview Connection Project in this paper confirmed most of the risk factors commonly inherent in large infrastructure projects. The risk management mechanisms, however, were innovative and designed for the particularities of alliance culture and context. It is therefore not surprising to learn that relational risks were considered as equally important as operational risks. By providing an empirical study on the risk management practices within large infrastructure projects, this research hopes to encourage an improved understanding of risks in relation to complexities of those projects.

Further empirical studies of the risk factors existing in large infrastructure projects are needed and a comparative analysis across different projects and different regions can help project practitioners to build the knowledge of good practice for risk management. Finally, quantification of the risks identified and the benefits of managing those risks in terms of project outcomes such as cost, quality and schedule can be undertaken for future research.
Acknowledgement

The authors express their thanks to the Department of Civil and Environmental Engineering, the University of Auckland for their financial support of the research; and to the interviewed experts in Well-Connected Alliance who shared their views and perspectives. Especially the authors would like acknowledge the generous assistance provided by Stan Schwalger of Well-Connected Alliance with data collection.

References


Managing Construction Risks with Equitable Contractual Exclusions

Terence Y M Lam

Abstract: Under the traditional procurement method, the building owner tends to pass on most of the risks to the contractor by contract documents. Equitable allocation of risk between building owners and contractors is paramount because allocation can influence the behaviour of the project participants and hence affect project performance and outcomes. This study examines how contractual exclusions should be executed through contract documents in order to develop an equitable risk allocation framework for the building owner to fairly transfer risks to the contractor in Hong Kong, where improper risk allocation is currently a major issue in the construction industry.

Equitable contractual exclusions were identified by exploratory qualitative study of a group of experts, using document research. These experts comprised construction clients, architects, engineers, quantity surveyors and contractors selected from the construction industry and professional bodies in Hong Kong, forming a task force to examine how procurement practices should be improved.

The qualitative study identified a number of equitable contractual exclusions including uncertainly of work conditions, delaying events, indemnifications, liquidated damages and sufficiency of contract documents. These can be used to fairly transfer capability, contractual and legal, economic, physical, and political and societal risks to the contractor.

A preliminary ‘equitable risk allocation framework’ is established by aligning the contractual exclusions and a range of risks involved. Such risk allocation should be made absolutely clear to the contractor in the contract documents by means of contractual exclusions and in the pre-tender briefing, and can be fairly applied for contract management by the building owner and his project manager to avoid disputes and claims. Further research should be conducted by an industry-wide survey to generalize the framework.

Keywords: Construction risks; Contractual exclusions; Equitable risk allocation framework; Hong Kong

1 Terence Y M Lam
Corresponding author, Faculty of Science & Technology, Technological & Higher Education Institute of Hong Kong, Hong Kong, China
E-mail: terencelam@vtc.edu.hk
1 Introduction

Makombo (2012) defines risks in construction as the existence of possible or actual events which may have a negative or positive outcome on the aim and objectives of the project during any phase of the projects lifecycle. From the contractor’s perspective, construction risk is regarded as unforeseen events that could adversely influence successful completion of the project in terms of cost, time and quality, and from the client’s perspective, the negative effects also cover any other performance criteria such as loss of business, reputation, failure to meet housing production targets and the like.

According to Ahiaga-Dagbui and Smith (2005), construction projects are particularly prone to risks and uncertain events. Akintoye and MacLeod (1997) explain that construction industry and its clients are associated with high risks due to the nature of construction business, processes, environment and organization, especially the fact that construction is a people’s business. For example, tender or on-site performance errors can lead to time and cost overruns as well as poor quality performance in projects.

According to a research into the risk management for construction projects conducted by Akintoye and MacLeod (1997), the contractors showed most emphasis on risks associated with cost which in turn influences profitability. Almost all types of risk, including scope changes, inclement weather, unknown ground conditions, disputes, etc., particularly present potential financial ramifications. Risk is therefore considered to be one of the main causes leading to cost overruns in construction projects. Flanagan and Norman (1993) further spell out that risks are poorly managed in most cases and that the risk retained results in cost overruns during project delivery. It is essential to understand and control risks in the project during the design and construction phases.

Making sure that as many risks as possible are recognized and that equitable allocation of risk between building owners (construction clients) and contractors is paramount because allocation can influence the behaviour of the project participants and hence affect project performance and outcomes, in particular the final cost and time (Zaghloul and Hartman, 2003). Contract documents are commonly used to definite and allocate risks between the contracting parties: the building owner and the contactor. Under the traditional procurement method, the contract documents are prepared by the building owner who tends to pass on most of the risks to the contractor. Consequently, the contractor may add a high contingency to the bid price or deliver poor quality work and make all sorts of claims. The implications of this contractual risk are that the building owner has to spend much more resources to accept a higher tender price, to manage the increased work disputes, and to bear extra legal costs for litigation of claims (Lam et al., 2007). Nonetheless, Rahman and Kumaraswamy (2002) and Dey, et al. (1994) spell out that risk is manageable and that an effective risk management can primarily alleviate risks by proper planning, thus minimising financial losses and raising profit margins.

This study will therefore examine how contractual exclusions should be executed through contract documents of both building and infrastructure projects in order to develop an equitable risk allocation.
framework for the building owner to fairly transfer risks to the contractor, as part of the risk-response control measures for managing construction contracts in Hong Kong, where improper risk allocation is a major issue in the construction industry (Lam et al., 2007; CIC, 2010).

2 Building Owner’s Risks

When the risks are identified, building owners and their professional advisors can take appropriate measures to control the effects of three types of risk: design, construction and client’s risks.

Design risk occurs at the various stages of design fulfilment. This type of risk causes increases in cost due to unforeseen activities during the pre-construction phase of the project where a problem develops as a result of imbalance between the scope and the initial budget, so designers should eliminate scope creep during the development of design, as spelled out by Günhan and Arditi (2007) and Lam and Siwingw (2016).

Building owner’s risk may arise due to the addition of previously undefined project scope. The cost increase is not confined to change in scope but may also cover a request for use of alternative materials that are costly and changes in circumstances that may happen when actual work on a project is very different from what was envisaged in the contract documents, for example, project acceleration by the owner.

Construction risk and the associated increments in costs may occur during the construction phase, for example, cost increase brought about by a shortage of materials or when geotechnical conditions encountered are different from those budgeted for.

3 Risk Transfer and Allocation Framework

There are four methods of risk allocation between building owners and contractors, which in practice may take one or combination of the following (Akintoye and MacLeod, 1997; Flanagan and Norman, 1993; Birch and McEvoy, 1992): risk retention, risk avoidance, risk reduction and risk transfer. Whilst the design risk and the building owner’s risk can be controlled by risk retention and avoidance approaches, this study focuses on how ‘risk transfer’ should be executed by contract documents in order to achieve equitable risk allocation between the contractual parties.

Virtually all construction contracts allocate risk. The building owner aims to reduce risk and improve project performance at the same time. Equitable risk allocation can achieve lower transaction cost and hence project success. When a risk is shifted to the contractor unfairly, they would either insure against it or add a contingency to the bid, thus resulting in an increased project cost. Alternatively, when the risk becomes a problem, the contractor defends the increase in cost by making claims, disputes or even litigation, which are undesirable general outcomes arising from inequitable risk allocation in the construction industry (Zaghloul and Hartman, 2003; Latham, 1994).
Building owners and contractors tend to transfer risks associated with construction projects. Most often the construction risk is transferred to the contractor using contractual exclusions, usually by disclaimer clauses. All construction projects involve risks and it is important that risks should be equitably allocated between the contracting parties so as not to jeopardise the project performance, in particular the final cost. Construction contracts are often used as a framework to set out which party should assume which risk. Disclaimer clauses can be used to transfer one party’s risk to another by contractual terms. Using disclaimer clauses is still generally a traditional practice adopted by the building owner to ‘transfer risk’ to the contractor. The building owner tends to allocate as many risks as possible to the contractor, thus resulting in a confrontational relationship.

Through a research into the perception of building owners, contractors and consultants, Zaghloul and Hartman (2003) identifies the most common five disclaimer clauses in the contract that the building owner can use to transfer the liability to the contractor, as listed below in the order of frequency of use and elaborated by CIC (2010):

- **Uncertainty of work conditions.** The building owner may exclude the contractor’s right to claim for loss and expense due to uncertain work conditions, for example, extra works due to unforeseen geotechnical conditions disrupting piling works.
- **Delaying events.** The building owner restricts and sets out the grounds for extension of time (EOT) to the contractor.
- **Indemnification.** The building owner sets out the indemnities and the limits of liabilities, which will have to be borne by the contractor.
- **Liquidated damages.** The building owner imposes financial penalty to the contractor if the work is delayed due to reasons not listed in the EOT grounds.
- **Sufficiency of contract documents.** The building owner transfer the risk of uncertain works to the contractor when the design is not yet mature, quite often by means of lump sum contract.

Lam *et al.* (2007) suggest that the allocation of risk between the building owner and the contractor is an important decision leading to the project success. An expert team was set up to formulate the decision model, comprising a deputy director, a cost and quantity manager, a contract manager, a senior manager, two quantity surveyors and a cost control administrator from a range of owners, consultants and contractors, all having extensive practical experience and working at managerial positions in Hong Kong. Through a comparison of the decision outcomes from a fuzzy logic model developed from their practical experience and the actual risk allocation stipulated in the ‘Railway General Conditions of Contract for Civil Engineering and Building Works’, 16 risk criteria are identified, which should be equitably allocated between both contractual parties according to the model in Table 1, as concluded by the expert team for construction contracts in Hong Kong.
However, the decision model has two limitations. First, the model is developed by a small team of practitioners so cannot be regarded as a generalized and robust one. Second, the model does not spell out how the risk can be shared between the parties through the contract documents. This study identifies how the risks within the model can be equitably transferred to the contractor by means of fair contractual exclusions so that a preliminary allocation framework can be established for further study and empirical testing.

Table 1 Allocation of risk between the building owner and the contractor

<table>
<thead>
<tr>
<th>Risk</th>
<th>Party sharing the risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability</td>
<td></td>
</tr>
<tr>
<td>- Contractor design</td>
<td>- Contractor</td>
</tr>
<tr>
<td>- Subcontractor failure</td>
<td>- Contractor</td>
</tr>
<tr>
<td>- Quality of work</td>
<td>- Contractor</td>
</tr>
<tr>
<td>- Safety on site</td>
<td>- Contractor</td>
</tr>
<tr>
<td>- Obtaining approval or consent from the relevant authority</td>
<td>- Contractor</td>
</tr>
<tr>
<td>Contractual and legal</td>
<td></td>
</tr>
<tr>
<td>- Conflicts in documents</td>
<td>- Owner</td>
</tr>
<tr>
<td>- Third party delay</td>
<td>- Owner</td>
</tr>
<tr>
<td>Economic</td>
<td></td>
</tr>
<tr>
<td>- Inflation</td>
<td>- Share</td>
</tr>
<tr>
<td>- Availability of labour and equipment</td>
<td>- Contractor</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
</tr>
<tr>
<td>- Ground conditions</td>
<td>- Owner</td>
</tr>
<tr>
<td>- Rights of access to site</td>
<td>- Owner</td>
</tr>
<tr>
<td>- Quantity variations</td>
<td>- Contractor</td>
</tr>
<tr>
<td>- Inclement weather</td>
<td>- Share</td>
</tr>
<tr>
<td>Political and societal</td>
<td></td>
</tr>
<tr>
<td>- Changes in laws and regulations</td>
<td>- Share</td>
</tr>
<tr>
<td>- Public disorder</td>
<td>- Owner</td>
</tr>
<tr>
<td>- Labour disputes and strikes</td>
<td>- Contractor</td>
</tr>
</tbody>
</table>

Source: adapted from Lam et al. (2007)

4 Research Method

This research identifies five contractual exclusions in the contract commonly used by the building owner to transfer risks to the contractor, and an allocation model established by an expert team in Hong Kong. The research aligns the fair contractual exclusions with the model in order to develop an allocation framework with which risks can be fairly transferred to the contractor by equitable contractual exclusions. The fair contractual exclusions were identified by exploratory qualitative study of a group of experts, using document research. These experts comprised construction clients, architects, engineers, quantity surveyors and contractors selected from the construction industry and professional bodies in Hong Kong forming a task force to examine how procurement practices should be improved. Their practical views and opinions on how risks should be equitably shared through contract documents were captured in the notes of a meeting for examining this issue. The document research of this study involved a thorough review of the notes of the task force meeting.

Seymour et al. (1997) advocate that qualitative methods can bring the respective experience and views of practitioners and hence the realities in social and construction management studies. Fellows and Liu
(2008) add that the scrutiny of qualitative data can draw and confirm themes on causal relationships found in the theory and literature review.

Although the task force represents the construction industry to certain extent, the results of this study can only lead to a preliminary risk allocation framework. An industry-wide survey will be conducted, as a separate research, so that the framework can be further tested and become more robust to benefit the whole construction industry.

5 Findings and Discussion

The document research confirmed that risk allocation between the building owner and the contractor is currently a major issue in the construction industry in Hong Kong, and it identified the five equitable contractual exclusions for transfer of risks as follows:

5.1 Uncertainty of work conditions
Equitable share of risk should be encouraged in practice. At a public works department in Hong Kong, for highly uncertain works such as civil engineering projects where unforeseen geotechnical conditions disrupting piling works could come up, bills of quantities (BQ) with provisional quantities is used so that the contractor is paid based on the actual work done and the rates in the BQ. Also, the contract may include a provision allowing any disputes to be settled by alternative dispute resolution mechanisms such as mediation, adjudication, arbitration and/or litigation.

5.2 Delaying events
In relation to the grounds for extension of time (EOT) to the contractor, the contract may impose a condition that a timely notice should be given precedent to the contractor’s entitlement to an EOT and additional payment. However, the contractor’s failure to give timely notice should be considered by the contract manager when assessing a claim.

5.3 Indemnification
The contractor should be required to take out suitable Contractor’s All Risk (CAR) policy with sufficient cover at a ‘fair level’ for the third party liabilities. This is to ensure reasonable amount of insurance premium and hence profit margin to the contractor, which in turn encourages good performance.

5.4 Liquidated damages
Any uncertain work conditions coming up during the course of works should be carefully considered by the contract manager as an acceptable ground for the delay and hence the grant of EOT to waive the financial penalty.
5.5 Sufficiency of contract documents

To control the risk of cost overruns, the public works department adopts two equitable approaches for risk allocation. First, lump sum contracts based on drawings and specification with BQ for most of the building projects: provisional quantities are used for uncertain items (not yet mature) at the tender stage. Actual work done will be re-measured for payment. This approach is considered to be more equitable as compared with the private-sector practice, in particular in residential projects, where lump sum contracts without BQ are often used to control the cost. Second, lump sum contracts based on drawings and specification without BQ for minor building projects and repairs, where the measurements are simple. Tenderers are required to provide a priced schedule of rates themselves, showing approximate quantities which have been used to build up the tender. Again, provisional quantities can be used for uncertain items such as repairs of concrete and defective wall tiles.

As suggested by an architect in the task force, to control the price of provisional items, guaranteed maximum price (GMP) approach can be adopted where the design is not yet mature, for example, due to delay of government approvals. This contractual arrangement allows equitable share of risk between the building client and the contractor, hence protecting both parties’ commercial interests whilst achieving early completion of tender documents for the tendering process. However, the contractor has to take on the risk for design development to supplement the outline specification and schematic drawings. However, they are allowed to make price adjustment if there is a change on the scope of work. The GMP can provide estimated quantities on certain provisional items which have yet to be finalised, and this form the basis for valuation of variations. Through an industry-wide questionnaire survey on risk mitigation measures for GMP contracts in Hong Kong, Chan et al. (2012) identify seven groups of factors in which development of standard contract clauses is one of them. The results in turn support this research to identify equitable contract exclusions.

Cost fluctuations of labour and materials are usually not allowed in tender bids by tenderers for building projects which normally last for a relatively short duration. For projects expected to run for more than two years, it is fair to include price fluctuation clauses into the contract. This is a normal practice for the government contracts in Hong Kong. Hwang et al. (2017) confirm that cost fluctuation of labour, materials and equipment due to market changes and high interest rate at market and country levels is one of the top 10 risks in international joint-ventured building and infrastructure major projects.

In addition to these, CIC (2010) identifies from experienced practitioners other essential contract terms which should be fairly determined by the building owner when allocating risks to the contractor:

- The level of retention monies in the payment terms;
- Collaborative process for the review of variations;
- Provision for paying the contractor’s development of value engineering initiatives which save time and cost.
5.7 Equitable risk allocation framework

Based on the exploratory qualitative findings, an equitable risk allocation framework can be established as shown in Table 2. It is clear that the equitable contractual exclusions drawn from this study can align the range of risks as shown in Lam et al.’s (2007) findings on risk allocation in construction contracts in Hong Kong. The results demonstrate that the building owner can make use of the contractual exclusions identified to fairly transfer capability, contractual, economic, physical as well as political and societal risks to the contractor.

Table 2 Equitable risk allocation framework

<table>
<thead>
<tr>
<th>Risk</th>
<th>Party sharing the risk</th>
<th>Equitable contractual exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability</td>
<td>- Contractor design</td>
<td>- Provision for paying the contractor’s development of value engineering initiatives</td>
</tr>
<tr>
<td></td>
<td>- Subcontractor failure</td>
<td>- EOT is granted for uncertain work conditions</td>
</tr>
<tr>
<td></td>
<td>- Quality of work</td>
<td>- Appropriate level of retention monies in the payment term</td>
</tr>
<tr>
<td></td>
<td>- Safety on site</td>
<td>- Cover for the Contractor’s All Risk (CAR) policy should be sufficient but set at a ‘fair level’</td>
</tr>
<tr>
<td></td>
<td>- Obtaining approval or consent from the relevant authority</td>
<td>- EOT is not granted for this delay</td>
</tr>
<tr>
<td>Contractual and legal</td>
<td>- Conflicts in documents</td>
<td>- EOT is granted for this delay; Collaborative process for the review of variations</td>
</tr>
<tr>
<td></td>
<td>- Third party delay</td>
<td>- ditto</td>
</tr>
<tr>
<td>Economic</td>
<td>- Inflation</td>
<td>- Price fluctuation clauses for contracts &gt; 2 years</td>
</tr>
<tr>
<td></td>
<td>- Availability of labour and equipment</td>
<td>- Price fluctuation clauses not applicable</td>
</tr>
<tr>
<td>Physical</td>
<td>- Ground conditions</td>
<td>- BQ with provisional quantities</td>
</tr>
<tr>
<td></td>
<td>- Rights of access to site</td>
<td>- EOT is granted for uncertain work conditions</td>
</tr>
<tr>
<td></td>
<td>- Quantity variations</td>
<td>- Drawings and specification without BQ for minor works; Collaborative process for review of variations</td>
</tr>
<tr>
<td></td>
<td>- Inclement weather</td>
<td>- Contractor’s failure to give timely notice for claiming EOT will be assessed.</td>
</tr>
<tr>
<td>Political and societal</td>
<td>- Changes in laws and regulations</td>
<td>- Collaborative process for the review of variations; EOT is granted for this delay</td>
</tr>
<tr>
<td></td>
<td>- Public disorder</td>
<td>- Ditto</td>
</tr>
<tr>
<td></td>
<td>- Labor disputes and strikes</td>
<td>- EOT and variations are not granted</td>
</tr>
</tbody>
</table>
6 Conclusions

Risk allocation between the building owner and the contractor is currently a major issue in the construction industry in Hong Kong. The qualitative study of this research identifies the following equitable contractual exclusions that the building owner can apply to fairly transfer capability, contractual, economic, physical as well as political and societal risks to the contractor.

- Lump sum contracts based on BQ with provisional quantities for highly uncertain works.
- Lump sum contracts based on drawings and specification without BQ for minor building projects and repairs.
- In addition, GMP approach can be adopted where the design is not yet mature to control the price of provisional items.
- EOT should be granted for uncertain work conditions coming up during the course of work.
- Contractor’s failure to give timely notice for claiming EOT should be carefully assessed by the contract manager.
- Cover for the Contractor’s All Risk (CAR) policy should be sufficient but set at a ‘fair level’ for the third party liabilities.
- For projects expected to run for more than two years, it is fair to include price fluctuation clauses into the contract.
- The level of retention monies in the payment terms.
- Collaborative process for the review of variations.
- Provision for paying the contractor’s development of value engineering initiatives which save time and cost.

Risk allocation has implications on the project cost and success. When the risk transferred to the contractor is perceived to be high but they cannot control its occurrence and outcome, premium would be added as a contingency to the bid. This means that the contract could bear a significant high premium, along with the potential increase in cost due to claims, disputes and adversarial owner-contractor relationship. It is vital that there is a clear understanding of the nature of risks, which should be equitably allocated to the party who is best able to manage and own them, in accordance with the allocations between the building owner and the contractor shown in Table 2. Such risk allocation should be made absolutely clear to each party in the contractual exclusions and the pre-tender briefing, in particular the contractor, by the project manager. The framework can also be fairly applied for contract management to avoid disputes and claims.

The ‘equitable risk allocation framework’ established by this research should only be regarded as ‘preliminary’. Further research should be conducted to test its external validity by an industry-wide survey in order develop a generalised framework for the benefit of construction industry.

Even with the powerful control through contractual exclusions, the success of any project is
questionable if there is no trust between the contracting parties. Other research should also be conducted to find out possible relational procurements for improving the risk allocation processes through creating a stronger and longer relationship, in particular partnering which is commonly used in Hong Kong.

References


CIC (2010), *Guidelines on Partnering*, Construction Industry Council (CIC), Hong Kong.


Research on the long-term effect mechanism of urban housing market development in China

Changchun Feng\textsuperscript{1*}, Sizhu Wang\textsuperscript{2}, Yongpei Guo\textsuperscript{3}

Abstract: First of all, this paper analyzes the demand and development of the real estate in terms of transmission mechanism; Then dissects the effect of market regulation policies in the real estate market since 1986. On that basis, it discusses the long-term mechanism of establishing sustainable development of urban housing market. The writer takes the coordinated development of urban and rural areas and the security of the right to development as the starting point to establish a construction land policy of region-city in which people, industry, land, house and property are linked. The paper takes city or urban agglomeration as its core to establish a policy in which the linkage policy of industry, people, land and house is according to the difference between the land and cities and the difference of land, finance, tax and investment. And to establish townhouses’ graded supplement and consumption system and a multi-layered housing guarantee system in step-by-step filtration, we should make resources clear, manage a good plan and develop the rental housing market and build low-cost houses in many ways. Besides, regulate the run of finance and agency market at the same time, to conduct de-leverage and curb speculation. Besides, make regulations and standards, and develop green energy saving real estate products and build livable community and put up with a framework of building a long-term mechanism for urban housing development.

Keywords: Housing Market, Regulation Policies, ”Industry - people - land - Housing” Linkage, Long-term effect Mechanism

1 The demand and development of real estate from transmission mechanism

1.1 Demand for real estate is derived demand

Real estate demand and development should be understood from the transmission mechanism. Real estate demand is usually a derived demand. For example, following the development of the third industry, there is need to build more commercial service facilities, so that the demand market for shops, office buildings and other property would increase. Since the development of urbanization, a large number of people would enter into the cities and towns thus causing great demand for housing. Therefore, understanding the transmission mechanism of urbanization
development on the demand for real estate, is important to make housing development policies. Urbanization of China should be promoted in four aspects, industrialization urbanization, population urbanization, social urbanization, and resource urbanization. The core is, as long as the economy grows, jobs and population would increase, thus attracting people to move in, thus forming the human capital, material capital and resources capital agglomeration, promote urban development, thereby causing the demand for real estate, and to promote the real development of the real estate industry.

2.2 Real estate development and economic development are interactive relations

Promoting the economic development is not the only role of real estate market. Only then the economic development and urbanization of an area or city happens, the real estate market would develop, which is the transmission mechanism of social economy and urbanization of real estate development. Since the reform and opening up policy, real estate has become the main pillar of economic growth, and the economic development mode is not healthy.

Of course, in the social and economic development and in the process of urbanization, the real estate plays an important role to increase employment, promote consumption, and solve the urban residents housing. The real estate economy has a long industrial chain, the market fluctuation will quickly transfer to the development of other industries, related to the social and economic development and people's livelihood. For example, the real estate economy including building materials, machinery, decoration, furniture, real estate fluctuation will affect the development of these industries, even to the city space layout, city renovation, and community services.

Investment in real estate development has close relationship with GDP, according to data from 2000 to 2015, real estate investment accounted an increasing proportion of GDP, and the real estate “five tax revenues” accounted for a remained high proportion of local fiscal revenue. Therefore, we must have a correct understanding of the relationship between real estate development and economic development. The optimization adjustment of the real estate should be carefully adjusted, according to the regional economic development and the urbanization level, and should aim at different groups of people, establish and improve the housing system, and ensure the sustainable and healthy development of real estate.

Table 1-1 The ratio of Real estate development investment/ GDP

<table>
<thead>
<tr>
<th>Year</th>
<th>① GDP</th>
<th>② Fixed-asset investment</th>
<th>③ Real estate development investment</th>
<th>④ Investment of residential development</th>
<th>③/①</th>
<th>③/②</th>
<th>④/③</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>99776</td>
<td>32918</td>
<td>4984</td>
<td>3312</td>
<td>5%</td>
<td>15%</td>
<td>66%</td>
</tr>
</tbody>
</table>
The five tax revenues of Real estate accounted for the proportion of local fiscal revenue

<table>
<thead>
<tr>
<th>Year</th>
<th>Revenue</th>
<th>Revenue</th>
<th>Revenue</th>
<th>Revenue</th>
<th>Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>110270</td>
<td>37213</td>
<td>6344</td>
<td>4217</td>
<td>6%</td>
</tr>
<tr>
<td>2002</td>
<td>121002</td>
<td>43500</td>
<td>7791</td>
<td>5228</td>
<td>6%</td>
</tr>
<tr>
<td>2003</td>
<td>136565</td>
<td>55567</td>
<td>10154</td>
<td>6777</td>
<td>7%</td>
</tr>
<tr>
<td>2004</td>
<td>160714</td>
<td>70477</td>
<td>13158</td>
<td>8837</td>
<td>8%</td>
</tr>
<tr>
<td>2005</td>
<td>185896</td>
<td>88774</td>
<td>15909</td>
<td>10861</td>
<td>9%</td>
</tr>
<tr>
<td>2006</td>
<td>217657</td>
<td>109998</td>
<td>19423</td>
<td>13638</td>
<td>9%</td>
</tr>
<tr>
<td>2007</td>
<td>268019</td>
<td>137324</td>
<td>25289</td>
<td>18005</td>
<td>9%</td>
</tr>
<tr>
<td>2008</td>
<td>316752</td>
<td>172828</td>
<td>31203</td>
<td>22441</td>
<td>10%</td>
</tr>
<tr>
<td>2009</td>
<td>345629</td>
<td>224599</td>
<td>36242</td>
<td>25614</td>
<td>10%</td>
</tr>
<tr>
<td>2010</td>
<td>408903</td>
<td>251684</td>
<td>48259</td>
<td>34026</td>
<td>12%</td>
</tr>
<tr>
<td>2011</td>
<td>484124</td>
<td>311485</td>
<td>61797</td>
<td>44320</td>
<td>13%</td>
</tr>
<tr>
<td>2012</td>
<td>534123</td>
<td>374695</td>
<td>71804</td>
<td>49374</td>
<td>13%</td>
</tr>
<tr>
<td>2013</td>
<td>588019</td>
<td>446294</td>
<td>86013</td>
<td>58951</td>
<td>15%</td>
</tr>
<tr>
<td>2014</td>
<td>636139</td>
<td>512021</td>
<td>95036</td>
<td>64352</td>
<td>15%</td>
</tr>
<tr>
<td>2015</td>
<td>676708</td>
<td>551590</td>
<td>95979</td>
<td>64595</td>
<td>14%</td>
</tr>
</tbody>
</table>

Figure 1-1 The five tax revenues of Real estate accounted for the proportion of local fiscal revenue

Table 1-2 Per capita housing area of Chinese households since the opening reform policy

<table>
<thead>
<tr>
<th>Year</th>
<th>Per capita housing area (㎡)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>3.6</td>
</tr>
<tr>
<td>1991</td>
<td>7</td>
</tr>
<tr>
<td>2005</td>
<td>26</td>
</tr>
<tr>
<td>2009</td>
<td>30</td>
</tr>
<tr>
<td>2015</td>
<td>33</td>
</tr>
</tbody>
</table>
2. The market regulation policy should avoid the big fluctuation of real estate market

Before 2014, the real estate regulation policy focused on the immediate and short-term effects. The main objectives of the induction period are: 1998-2003, which mainly promotes the comprehensive development of the real estate industry; 2003-2005, which focused on curbing overheated real estate investment; 2005 to September 2008, which focused on stabilizing housing prices; December 2008 to 2009, which played a role in driving economic growth; December 2009 to August 2014, which suppressed the price of housing prices rose sharply; September 2014 up to now, in which the policy of differentiated regulation has been implemented to establish a long-term mechanism for the regulation of real estate.

Before 2014, the real estate market adopted a unified macro-control policy, which basically reached the expected target and achieved the short-term effect. But since the differences between regions and cities in China's real estate market are very big, the pertinence is not strong, unified regulation policy has positive effect to the market, while also decreased robustness and increased volatility. Our analysis of the periodic fluctuation of the real estate market in Beijing shows that the regulation policy is an important factor that causes the fluctuation of the real estate market cycle. Before 2006, the Beijing real estate market experienced five great cycle. Fluctuation I (1986-1990): encouraged by the the 13th National Congress of the Communist Party of China and the Compensation for the use of land reform, the real estate market began to develop, after the peak in 1987 in the first wave, the real estate market began to shrink, down to the bottom in 1990. Fluctuation II (1991-1993) : influenced by the "14th National Congress of the Communist Party of China" and "Deng Xiaoping’s south patrol", the real estate market peaked in 1992, and then the "investment boom", "real estate boom" and other forms of "overheated economy" happened, and the government began to adopt the macro-control control policy, then the real estate market cooled in 1993. Fluctuation III (1994-1996): in 1995, the state council housing system reform leading group put forward "national comfortable housing project implementation plan" to start building economically affordable housing, and stimulated the real estate market, which peaked in 1995. Then the "Asian financial crisis" brought down the housing market. Fluctuation IV (1997-1999): in 1998 the state council issued "the notice on further deepening the reform of urban housing system, accelerating the construction of the housing”, and stopped the housing material distribution, implemented the monetization of housing policy. In 1995, "15th National Congress of the Communist Party of China” caused the real estate market to a peak in 1998, and a slight drop in 1999. Fluctuation V (2000-2004): influenced by the policy of "8.31", "ripen land" transfer...
and macro-control, the peak appeared in 2001 and in 2002, the regulation was introduced, and the real estate market cooled down and experienced a long trough.

Figure 2-1 The change of Residential selling price and area 1998-2015

According to the general rules of the market, the fluctuation of the real estate market is correlated with the cyclical fluctuation of the economy. If it is mainly caused by the regulation policies to cause large cyclical fluctuations, it needs to be considered. The real estate development cycles are there, and is closely related to economic development, thus we should make the real estate market regulation policy volatility smaller, and avoid ups and downs, which is the key to establish a long-term mechanism. Therefore, we consider and explore the long-term mechanism of housing market development from the following aspects.

Figure 2-2 Fluctuations of the real estate market 1986-2006
3 Establish a robust long-term development mechanism from the linkage of "industry-people-land-housing"

In 2016, the central economic work conference proposed: 1. Classified and different regulations policies regards of different city, and ease the inventory of tier-three and tier-four cities. 2. Focus on preventing asset bubbles and ensuring that no systemic financial risks occur. 3. Return to the residential property of houses, and use the microcredit support for the reasonable demand of housing purchase. 4. Curb speculative demand for investment. Have strict limits on the flow of credit to speculative demand and deleveraging. 5. Accelerate research to establish a basic system and long-term mechanism that meets the national conditions. 6. Restrain the housing bubble and prevent the ups and downs. According to the spirit of these six aspects, we believe that we should establish a long-term mechanism and a stable development mechanism in the future, and we should start from the linkage of "man-industry and property" in both region and city level.

3.1 From the overall development of the urban and rural areas and the development right, establish the construction land policy linked to the "man-industry - land - wealth (money)" in the regional-urban areas.

In the government report 2016 in NPC and CPPCC, the pothook policy of "people – land-money" was brought up, which is based on "people-oriented" concept, and using "social justice" as the direction, and also is the adjustment of the real estate market policy in the past. The purpose of this policy is to speed up the speed of fulfilling "to 2020, one hundred million migrant workers and other permanent population would become citizen" target, and make people moved to the town from the countryside entitled to basic public services such as education, employment and health care. From urban and rural development as a whole and guarantee for farmers and urban residents’ right of development, we consider to drive population flow by jobs, and build a city area in which "people - industry - land- wealth (money)" linked together in construction land policy. Industry development bring jobs, then employment population flow, then increase land supply in consideration of population employment, and stimulate further land reclamation for land demand, and give full consideration to the rational allocation of land resources in the area - city, and establish a unified urban and rural land market, supply land resources effectively and allocate land income distribution rationally.

Specifically, the "people, industry, and of money" core elements, correspond to the industrial development, population flow, index and index trading in total four hook link of “people, industry land and money”. Through the city industrial development and rural agricultural modernization, promote the flow of population from rural area to urban area, and protect the employment of transferred population in city and the new rural community to promote urbanization. Through
population flow, implement the new rural community construction and land consolidation, resulting in land saving construction quota. Through market transactions, meet the needs of urban land, provide space for urban and industrial transfer population, and return the income in rural areas for land comprehensive renovation and development of agricultural modernization, which in turn promote urban and rural area industrial development. Finally form the benign cycle development of the pothook policy of "people – industry- land- money" policy to realize the optimization of urban and rural land allocation, industry sustainable development, population reasonable transfer, long-term operated capital chain.

To solve the problem from the angle of the development right, it will not only solve the rural land protection and ensure the development of city land, but also protect the rights and benefits of rural areas and farmers, and reach a fairer and more reasonable way to solve the problem of income.

*Figure 3-1 The pothook policy of “Industry-People-Land-Money”*

*Figure 3-2 The key element of the pothook policy of “Industry-People-Land-Money”*
3.2 Based on the city or urban agglomeration, establish "industry + people + land + housing" linkage, and different "land, finance, taxation and investment" policy according to different cities.

The gap between China's regions and cities is large, and the space and time development is unbalanced, thus the development and guiding strategy should be differentiated. Different land supply policies are adopted for different regions and cities, according to scale and level of economic development. According to different people, the housing system should be established, the different types of housing should be provided, the financial and fiscal policies should be formulated, and different investment construction modes should be implemented for different types of housing.

Specifically, where the industry develops, where people should go, where the money should go, where the land should be supplied, and where the house should be built.

-- Major cities (tier one or two cities), with developed industries, large population and strong demand, should increase supply (land, housing). In terms of space, the central area is inefficient and should be increased, the urban transportation infrastructure and the residential area should be developed, and the urban sprawl (urban agglomeration) should be specially supported.

-- Small and medium-sized cities (tier three, four cities and even tier five cities), with a focus on developing the real economy, attracting populations, increasing demand and digesting inventories. At present, in the process of new-type urbanization, despite the fact that they are welcome and even hukou (registered permanent residence) system is open, young people are unwilling to go, mainly because of lack of employment, poor public service facilities and inconvenient lifestyle. Therefore, the development of the real economy should be given priority in formulating policies, and the development of the industry will attract the people to absorb the inventory and promote the development of the real estate industry.

-- Small towns should develop a characteristic economy, attract neighboring populations to the nearest urbanization, make balanced allocation of public service facilities, and build a new type of community.

3.3 To establish a long-term and stable development mechanism, we should further deepen reform and improve the housing system

At present, some cities have abolished affordable housing, housing price ceilings. Instead, they construct public rental housing, commercial housing, and shared property ownership. Overall, the housing security system has not yet been fully established. In order to establish a long-term mechanism, we need to further improve the housing system according to the situation of different cities, and improve the housing system and the market supply system from the top level.

(1) Establish the housing gradient supply and consumption system for urban residents.
Only by establishing a gradient supply and consumption system can sustainable housing development be realized.

(2) Improve public housing policies and establish a multi-level housing security system.

![Multi-level supply system of affordable housing](image)

(3) Develop the housing rental market and multi-channel newly-built economic leasing housing.

Local government plans for the construction of economy's annual rental room, mainly from real estate development enterprises’ parking requirement in the ordinary commodity housing or affordable housing projects. After construction, local government housing administration buys the housing at the cost price and is responsible for leasing management, it can also be determined directly by economic rental housing management implementing agencies determined by the municipal or county people's government organization.

Set the area standard. The single-set construction area of economic rental housing is strictly controlled within 90 square meters, with a two-bedroom of 75 square meters as the main form. A one-bedroom house cannot exceed 40 square meters, and three bedrooms cannot exceed 90 square meters. Improve access conditions and exit mechanisms. The applicant should have a local household registration or a local employer. The applicant and the spouse have no room in the local area, and the family income and assets must meet the prescribed standards. The standards are determined by local governments, according to local residents’ income, living standards and housing prices and other factors. Rent criteria. Based on the government's pricing and comprehensive consideration of the management fee, maintenance fee and loan interest of the house, the standard rent should be determined according to the market rent level, and the rent shall be adjusted every three years. Exit mechanism. In order to ensure the maximum benefit of economic rental housing and benefit more mezzanine groups, it is recommended that the lease housing contract should be signed for no more than 3 years. After the expiration of the application,
the renewal of the approval shall be in conformity with the requirements of entry; if not, the lessee shall move out of the house. Formulate supporting policies. ① The land for economic lease housing construction should be given priority in the annual land use plan and land supply plan. ② It is proposed to give preferential land to property development enterprises in the way of protocol. ③ Economic leasing housing construction projects can enjoy the exemption of various administrative fees and government funds and other policies in the same way of affordable housing construction projects. ④ Economic leasing housing development units may apply for development loans to commercial Banks under construction projects. ⑤ Real estate development enterprises lease economic rental housing free of sales tax and property tax.

(4) Revitalize the level-two market in the way of acquisition of small and medium-sized stock of housing, and a system of both renting and selling (sale: common property housing, rental: public rental housing).

First of all, use a variety of channels to raise funds to reach the acquisition of small and medium-sized stock of housing and digest inventory. Sources of funds: ① Special funds of acquisition in annual fiscal budget. ② The government funded housing purchase management company ask loans to banks using property held by the company as collateral. ③ The part of the housing provident fund. ④ The other way to raise funds to purchase: like advance payment to the applicant for the purchase. In addition, the government's economic rental housing rental income can also be added to the purchase of funds. House type. The utility model has the advantages of reasonable location, convenient lifestyle, good quality, small and medium-sized dwelling types, etc. Rental objects. Middle and low-income groups, residents with no room or having a small set of home occupied housing. Price standard. Implement government pricing. On the basis of taking into account the purchase price of housing, management fees, maintenance fees and loan interest, and reach reasonable determination. Withdrawal mechanism. Shall not be transferred within 5 years after the purchase of housing, if transfer, the government may have priority to repurchase, and closing up a certain proportion and lots of ordinary commodity housing and the government repurchase price difference between the price of land revenue to purchase, and pay the business tax, city maintenance and construction tax, education surcharges, stamp tax, land value-added tax and personal income tax, and the housing should continue to be used for economic rental housing.

Supporting policy. ① Through waiving business tax and personal income tax, encourage families with more than two sets of property to provide secondary housing for the "sandwich" group. ② Through lowering down payment ratio and loan interest rate for second improved housing units, residents who have need to improve living conditions should be encouraged to provide secondary housing for the "sandwich" groups. ③ We suggest that local finance should provide loans for low-income families who buy government housing. ④ Housing provident fund
should gradually cover all low-income groups, housing provident fund loans should be properly
tilt for "sandwich layer" in terms of interest rates, loan lines and repayment years. Develop
flexible commercial housing loans to meet the needs of residents with different income levels.

3.4 Find out the real situation and plan well

How many housing stock the city has, how many houses should be constructed, how to plan,
where to put the construction, many cities are not very clear, thus lacking overall planning and
orderly development. Thus we must understand the situation well, plan well, so that we can
develop and supply due to different cities’ situation, otherwise will form new housing stock.

3.5 Regulate the operation of financial and intermediary markets, deleverage and curb speculation

Deleveraging real estate is to regulate the operation of financial and intermediary market. Some places often confuse investment with speculation. Reasonable investment should be released, but we still need to curb speculation. In the case of deleveraging, illegal financial services such as “down payment loan” should be severely restricted, and the development of loans and mortgages should be tightened for the overheated market and the larger bubble areas and cities. We will strengthen the supervision the financing of development enterprises. At the central level, macro-financial policies are formulated, and the local level puts forward detailed rules for the implementation of the city itself. In the case of a city, the practice of advanced cities from abroad can be learned, and different financial regulation and support policies are applied to the different population group.

3.6 Draw up standard, develop green and energy-saving real estate products, build livable community.

Establish long-term effective mechanism of urban housing development, we should not only
start from the policies and regulations, but also should consider technology, quality, specifications
and standards, in order to vigorously develop the green energy-saving real estate products and
build livable communities. Developing green energy-saving real estate products in high speed in
the cities is the development goal. According to the urban space planning, develop and construct
the easy living community and a good living environment need to study the development and
construction standards and norms of green energy conservation. Real estate development should
follow the principle of sustainable development from construction, living environment and safety.
Real estate products should be regulated and improve on technology and quality. We should
encourage the development of real estate project in accordance with the green building standards,
make full use of the natural environment and resources, maximize the energy-saving, land-saving,
water saving, and material saving goal and protect the environment and reduce pollution.
References


Properties of improved magnesium phosphate cement and its Carbon Fiber Composites

Zhu Ding\(^1\), Yu-Yu Li\(^1\), Ji-Xiang Zhu\(^2\), Yuan Fang\(^1\)

Abstract: Magnesium phosphate cement (MPC) has been proved an excellent repair material for deteriorated concrete structures. It has high adhesive performance that leading to high bonding strength with old concrete substrate. But the setting time of it is very short, difficult to use as a binder of fibre composite. In this paper, the properties of the improved magnesium phosphate cement, the properties of the carbon fibre MPC matrix composite were studied. These properties include physical and mechanical of the fresh mixed and the hardened MPC binder paste, the bond strength of fibre in matrix. Also, the microstructure of the matrix was investigated. The results show the improved MPC binder is potential to develop a fibre reinforced inorganic polymer, as an alternate to externally bonded FRP composites for strengthening of concrete structures. The present study may provide a deep understanding the behaviour of MPC bonded fibre composite.

Keywords: Inorganic adhesive and matrix, magnesium phosphate cement, concrete, concrete strengthening, fibre reinforced polymer, mechanical property.

---

\(^1\)Zhu Ding.
Corresponding author, School of Civil Engineering; Guangdong Province Key Laboratory of Durability for Marine Civil Engineering, Shenzhen University, Shenzhen, 518060, China
E-mail: zding@szu.edu.cn

\(^2\)Ji-Xiang Zhu.
School of Architecture and Environment, University of Shanghai for Science and Technology, Shanghai, 200082
1 Introduction

Concrete structures may deteriorate during service by loading and environmental effect. To those deteriorated concrete structures, fibre reinforced polymer (FRP) composites were major material in the strengthening in the current time. FRP strengthening technology has many advantages, high strength-to-weight ratio, excellent corrosion resistance and the fast-curing etc. However, FRP composites has some weakness, they have poor fire/high temperature resistance because the organic polymers matrix (commonly an epoxy resin) [1,2]. In addition, the epoxy forms a sealed coating on concrete surface which prevents the exchange of moisture, leading to the incompatibility of concrete and FRP composites. To overcome these problems, we attempt to develop cement-based FRP material. Magnesium phosphate cement (MPC) is a high early strength, green and sustainable cement. MPC is receiving greater attention because of its many advantages, include quick strength development, good durability and dimensional stability, good water absorption resistance, and excellent adhesion properties with old concrete substrate [4-6]. These properties make MPC a very attractive material for the rapid repair of concrete structures, for sealing boreholes, and the solidification of hazardous wastes.

However, MPC develop strength by a violent acid-based reaction between magnesia and phosphates solution, resulting in a very fast setting of the paste. The setting of fresh mixed MPC paste is less than 10 minutes usually. Retarders such as borax and boric acid need to be added to prolong the setting time of MPC paste [7]. Therefore, in the past many years, it was only used for the rapid repair of concrete structures [8]. However, in the recent days, we successfully improved MPC to be as a potential matrix for fiber reinforced composites [9,10]. The MPC based fiber composite had been tested the performance in concrete reinforcement, and the preliminary evidence had proved it is promising in the field of structure reinforcement. In this study, the improved MPC was used for preparing fiber reinforced composites for concrete strengthening. The properties and microstructure of MPC fiber reinforced composites were determined.

2 Experiments

2.1 Materials

MPC binder was prepared by dead burnt magnesia (M), mono potassium phosphate (MPP), a class F fly ash (FA) and boric acid (BA) with water (W). The dead burnt magnesia used in the study was bought from Jinan city, Shandong Province, China. The MgO content in magnesia is 83.18 wt. % and the average particle size is 46.65 micro meter. MPP and BA are chemical reagents, which were manufactured by Guangzhou reagent factory (China). The MPC binder mix proportions are summarized in Table 1. The dry powder blended by magnesia, phosphate and fly ash called binder (B). The addition of BA to magnesia was 0.1. Tap water was used as the mixing water. For making mortars, quartz sand passed through a sieve with a size of 600 μm was used as the fine aggregate. The raw material mix of MPC binder was showed in Table 1. The carbon fiber sheets were used for producing composites, which has a nominal thickness of 0.11 mm and a weight of 200 g/m². The fibre has a tensile strength of 3400 MPa and elastic modulus of 240 GPa.
### 2.2 Test Methods

To determine the fluidity of fresh mixed MPC paste, a mini-cone slump flow test was used, with an upper diameter of 36 mm, a lower diameter of 60 mm and a height of 60 mm. The diameter of the circle of cement paste which then flowed over the horizontal glass plate was measured, Figure 1. The setting time of the paste was determined using Vicat Needle tests following ASTM C-191.

The compressive strength of MPC paste and mortar was determined based on tests of 30mm×30mm×30mm cube specimens. For each combination of testing parameters, three identical specimens were prepared and the average strength of the three specimens was presented as the compressive strength of the pastes. The compressive strengths were obtained after 1, 3, 7 and 28 days of curing. The flexural strength of each inorganic paste was determined using prisms with the dimensions of 40mm×40mm×160mm and following ASTM C-348.

Pullout test was performed to evaluate the bond performance of fiber sheets in different MPC paste matrix. The specimen were prepared in the form of a 70.7mm×70.7mm×70.7mm cubes in which one layer of dry carbon fiber sheet was embedded at the center. For the purpose of exerting uniform stresses in the fiber sheets during the pullout tests, the fiber sheets out of the cubes were impregnated with a two-part epoxy matrix, of which the ratio of the resin to hardener was 2:1 by weight. Test specimen of pullout test is presented in Figure 2.

![Figure 1. Fluidity test of fresh mixed MPC paste](image1)

![Figure 2. Pullout test specimen](image2)

All the above MPC test specimens were demolded after 24 hours and cured in an environment with a temperature of 25±2°C and relative humidity of 65±5%. All the mix proportions in Table 1 were tested for the flow, initial setting time and compressive strength. While the samples No.
1\textsuperscript{st} to 5\textsuperscript{th} in Table 1 represent the mixing proportions used to prepare test samples for flexural and bonding strength. The sample No. 3\textsuperscript{rd}, 4\textsuperscript{th} and 5\textsuperscript{th} were also used to prepare mortar specimens for compressive strength test.

3. Results and Discussions

3.1 Physical Properties of MPC binder

In fibre composites, it will become the matrix when the inorganic binder hardened. Therefore, the workability plays a very important role on the performance of fiber composites. Because MPC binder has poor workability, especially the setting time of the fresh paste is too short to use as a composite matrix. The setting time has to be prolonged enough for installation. In this study, boric acid (H\textsubscript{3}BO\textsubscript{3}) was used to increase the setting time of MPC, the sample 1\textsuperscript{st} to 5\textsuperscript{th}, which were used as the W/B 0.22 had the similar initial setting time, around 25 minutes.

At the same time, with the higher flow, higher impregnation of the fibers can be achieved, which may result in higher bonding and ultimately in higher strength. Flow of the inorganic matrix should also be consistent to be applied on vertical surfaces and soffit of beams or slab for strengthening existing RC structures. The fluidity results of fresh MPC paste are showed in Figure 3. Flowability of is mainly depending on water content of paste. It is already proved that with the increases in water content, flow was increased but there are some adverse effects on other properties. In the test, a fixed W/B was use as 0.22, for the sample 1\textsuperscript{st} to 5\textsuperscript{th}. To get higher flow with suitable strength properties, FA as filler also to add to the MPC paste.

According to Figure 3, the flow of fresh mixed MPC paste increases with increase in FA up to certain limit. Increase in FA content results in increase the flow of MPC up to 80\% by weight of magnesia then a decrease in the flow was observed. This behavior might be attributed to small and spherical grains of FA, which help in flow of the paste at smaller water contents. It is because of FA small spherical grain help in flow of the paste at smaller water content. But beyond 0.8 of FA to M, it seemed like the same water content is not enough to lubricate the binder, which resulted in lower flow.

3.2 Mechanical Properties of MPC

Different strength of MPC paste had been evaluated in this research to check the best performance of the inorganic paste in Mechanical properties. Compressive strength, flexure strength, and pullout strength of fibers in the MPC matrix of composites are experimentally studied.

3.2.1 Compressive strength

Compressive strength of MPC depends on many factors like fineness of magnesia, M/P ratio (Magnesia/Phosphate), water to binder ratio, and FA content [11]. M/P ratio has also effect on setting time of MPC pastes. In this study M/P ratio was selected as 1 to ensure an adequate strength with reasonable setting time. A lower W/B ratio results in higher strength and vice versa. Figure 4 showed the compressive strength of MPC paste sample 5\textsuperscript{th}, 6\textsuperscript{th} and 7\textsuperscript{th}, which has the water content from 22\%, 24\%, and 26\% respectively. The strength drops evidently with the water content increases, from 22\% to 26\%, but increases the flow. A higher change in water content results in high variation of compressive strength of MPC paste or MPC mortar.
Effect of FA content on compressive strength of MPC paste is also studied. Compressive strength of MPC paste increases with increase in FA/M 0.8, and then a decrease was observed (Figure 5). This behavior might be attributed to better compaction of MPC by FA micro sized particles [12].

In case of MPC mortar, sand and FA acts as filler, so addition of FA to the MPC mortar will increase the amount of filler in the mix, which results in decrease in compressive strength (Figure 6). Strength development also decreases with increase in filler content by reducing reaction rate between magnesia and phosphate solution in MPC mortar.

3.2.2 Flexural Strength

Flexural strength is indirect measure of tensile strength of the pastes. According to the present test, the mortar of the inorganic binder has shown higher flexural strength than respective paste (Figure 7). This higher strength of mortars might be because of high density of sand particles which increases the toughness of the pastes and resulted in higher flexure strength. Flexural strength for different mix proportions of MPC pastes were tested on 7d. An increase in flexural strength of MPC pastes were observed with increase in FA content up to 80% by weight of dead burnt magnesia, then a decrease is observed (Figure 7). This was similar behavior to the compressive strength of MPC paste. Flexural
strength of MPC mortar was higher than that of MPC paste and it keeps on increasing by increasing FA content. This higher flexure strength of MPC mortar may be attributed to the high density sand particles filler.

![Graph showing flexural strength (7d) of MPC paste and MPC mortar](image1)

![Graph showing pullout strength of carbon fiber composites with different FA addition](image2)

### 3.2.3 Pullout bond strength

To determine the bond strength between carbon fiber sheets and MPC matrix, pullout test was conducted. It shows the effectiveness of the fibers in particular inorganic matrix. In this test fibers are embedded in 70.7mm×70.7mm×70.7mm cube MPC paste and after 7 days of curing, fiber sheets were pulled out of matrix using a universal testing machine. Pullout bonding strength is then calculated by dividing the ultimate force to the surface area of the fibers embedded in the matrix. Effect of FA content and water content is studied on pull out strength of MPC. FA has shown an insignificant effect on pullout strength of fibers in the inorganic matrix (Figure 8).

### 3.3 Micro Analysis of Matrices

Microstructure of the hardened MPC paste has been conducted to study matrix-fiber interaction in the composite. These micro studies can help to relate the mechanical properties of the inorganic pastes to the micro structures and elements of the inorganic materials. XRD and SEM analysis were employed to study the micro level compounds in the pastes as well as observe the micro structure of the pastes.

#### 3.3.1 XRD Analysis

XRD analysis of the MPC paste was conducted at 28d. In the XRD analysis of MPC, various peaks showed a high level of crystalline phase of MPC paste (Figure 9). These peaks referred to two types of crystalline compounds, one compound is identified as unreacted magnesia (MgO), while the other peaks formed from MKP (MgKPO$_4$·6H$_2$O) which is the reaction product of MPC. Some other phases of defused peaks can also be found in the XRD pattern, which represent the amorphous phases of same compounds. So both crystalline as well as amorphous phases of dead burnt magnesia (MgO) and MKP were present in the MPC cement, which is a highly favourable combination and resulted in more compacted and dense microstructure.
3.3.2 SEM Analysis

Figure 10 show micrographs of MPC hardened paste. It shows a dense and acicular structure of MPC hydration product i.e. MKP (MgKPO$_4$.6H$_2$O). There are also FA particles in the diagrams. MKP is main component for developing high mechanical properties, while residual magnesia and FA act as filler in the MPC paste. So in this micrograph well compacted pastes resulted in a high mechanical strength. Micrograph of MPC composites also shows a good impregnation and interlocking of fibers with inorganic MPC pastes. The SEM photos in Figure 11 show a good fastening effect of fibers with pastes can be observed. The SEM analysis was performed at 28day, so relatively higher hydration product can be observed. This might be the reasons for good bonding and pullout strength of fibers in MPC matrix.

4 Conclusions

The workability of fresh mixed MPC paste was improved. The flow of MPC paste reaches to 145mm when addition of FA was 80% by weight of magnesia. The improved workability of MPC paste can allow it is used in-site installation.

The strength is inverse proportional to the W/B ratio. The more water content, the lower is the strength. The results of FA content on compressive strength of MPC paste showed that, compressive strength of MPC paste reaches its highest when FA/M is 0.8. But, in MPC mortar, the
sample with FA/M 0.6 has the highest strength.

The mortar of the inorganic paste has shown higher flexural strength than respective paste. This higher strength of mortars might be because of high density of sand particles which increases the toughness of the pastes and resulted in higher flexure strength. An increase in flexural strength of MPC pastes were observed with increase in FA content up to 80% by weight of dead burnt magnesia.

FA has shown an insignificant effect on pullout strength of fiber in the MPC matrix. With the dosage of FA to M from 0.4 to 0.8 by weight, the pull out strength increases in sequence, but drops a little in FA/M is 1.0.

Acknowledgement

The authors are grateful for the financial support received from the National Natural Science Foundation of China (Project No: 51472163 and 51172146).

References

Real Time Locating System for Construction Safety Management: An explanatory investigation in the Australia construction industry

Patrick X.W. Zou, Nini Xia

Abstract: Real Time Locating System (RTLS) has been viewed as a promising technology for tracking and analysing the location of workers or other objects to diagnose danger and then prevent accidents. Despite the advocacy of RTLS, few investigations exist on its current application in the practice. We thus aims to address this gap by identifying the current practice of RTLS for on-site safety management in the Australian construction industry. The research results reported here were explanatory and mainly based on semi-structured interviews with numerous project engineers and managers. Three aspects were explored, including usefulness and favour of different real-time locating technologies, implementation barriers and areas for improvement, and relevance of RTLS with project characteristics. The results show that the majority of the interviewers considered RTLS useful and various technologies were adopted with GPS as the most frequently used; the main barrier are lack of skills and knowledge; and the prime area for enhancing its application was to improve practitioners’, especially, front-line workers’ recognition of the benefits of RTLS. Future considerations for our subsequent questionnaire design were also discussed, and our main focuses should include, but not limited to the following: factors that will influence the selection of a specific technology and the relative importance of the identified barriers and strategies to overcome these barriers.

Keywords: Construction safety management; Real-time locating system; Australia

1 Patrick X.W. Zou
   Corresponding author, Department of Civil and Construction Engineering & Centre for Sustainable Infrastructure, Swinburne University of Technology, Hawthorn, Victoria 3122, Australia
   E-mail: pwzou@swin.edu.au
2 Nini Xia
   College of Management and Economics, Tianjin University, No. 92 Nankai District, Tianjin 300072, PR China
   E-mail: ninixa@tju.edu.cn
1 Introduction

Safety continues to be a critical issue in the construction industry globally where injuries and accidents frequently occur. According to the United States (U.S.) Bureau of Labor Statistics (BLS, 2013)\(^1\), over 3,200 workers were fatally injured at work in the construction industry alone. In 2016, the injury rate in Australian construction industry was 3.3 per 100,000 workers, occupying the fourth highest among all the sectors\(^2\). These statistics demonstrate a priority and more efforts are needed to safety management in construction.

It has long been acknowledged that one direct factor for workplace injuries and accidents is human unsafe acts and lack of hazard recognition\(^3\)\(^-\)\(^5\). One traditional way to warn and prevent unsafe acts directly is manual inspection, that is, inspectors observe workers’ acts on site\(^6\). Manual inspection has distinct advantages such as providing prompt corrective actions; however, it may be deficient because it is impractical, if possible, for inspectors to monitor workers’ behaviors all the time; in practice, they mainly inspect at a randomly scheduled and limited time\(^7\). In addition, manual inspection remains error prone as they are very labor intensive, time-consuming, and potentially subjective\(^6\). The construction environments are considerably dynamic and human errors and accidents can be hardly predicted, thus, it requires real-time and continuous monitoring\(^8\),\(^9\).

To enhance safety monitoring and prevention, Real Time Locating System technologies (RTLSs) emerge as one effective complement to the traditional human inspection\(^10\). RTLS refers to an automated real-time locating and tracking system, which is the integration of the hardware and software system, to track the real-time location and conditions of field project entities (e.g., workers, equipment, materials) based on their geometry information\(^7\),\(^11\). With an analysis of localization data gathered, potential danger such as excessive speed of equipment and close proximity and possible collisions between a worker and a crane can be detected, and then drivers and workers will be warned timely\(^12\),\(^13\). The importance of real-time location awareness may be highlighted by the fact that 25% of all construction fatalities have to do with the close proximity of workers to equipment\(^13\). RTLSs have been applied in real situations and demonstrated to increase tracking efficiency and reduce errors against human supervision and monitoring\(^6\),\(^11\). In addition to real-time safety monitoring and warning, with RTLSs, real-time re-planning of equipment that may produce danger can be made, thereby improving work processes\(^15\). Furthermore, safety information gathered by RTLSs can be used for information communication between on-site managers and workers and among diverse project stakeholders\(^9\),\(^10\), and for further analysis facilitating decision-making for subsequent safety practices\(^6\).

Different RTLSs and their combinations have been developed. For example, Zou et al (2015)\(^10\) presented the results of a RTLS development and application in a real construction site. However, little is known concerning the current states of RTLSs applications in realistic construction sites. An examination on the practice will provide a better understanding of how industrial professionals view RTLSs concerning safety management, whereby measures can be formulated for boosting the adoption of the RTLS techniques by practitioners, which can be considerably promising for field safety monitoring and management. Such practical investigations can also direct academic research for addressing practical concerns, and bridge the research-practice gap. Regarding this, the present research aims to conduct an explanatory investigation based on qualitative data from semi-interviews with practitioners in the Australian construction industry. In order to collect a wide range of opinions\(^16\), our next study will be to design and implement a questionnaire survey based on these interview results.

2 Real Time Locating System Technologies

In addition to site safety management, RTLSs can be used in a variety of activities of construction projects, such as construction process management, and property management and maintenance\(^11\). Current RTLSs can be categorized as sensor and non-sensor (vision-based) networked localizing and tracking technologies. Sensor-based technologies comprise tags to be connected with sensors through signals, while tags were not contained in non-sensor technologies. As non-sensor technologies (e.g., Robotic Total Station (RTS) are difficult for being used to track multiple entities, most of RTLSs fall within (wireless) sensor networks\(^6\). Given this, individual or combined sensor networked RTLSs are frequently used for safety
monitoring and warning in construction sites. Below, we introduce several prevailing technologies, including their advantages and limitations.

One early and prevailing technology is Global Positioning Systems (GPS) and, recently, the location-based service (LBS), which is mostly used in outdoor environments. Relying on communication with Earth orbiting satellites for triangulation, GPS uses a triangulation method to get the location, namely, the coordinates \((x, y, z)\) of project entities. The position is computed by measuring the distance from a set of satellites to the GPS receiver, the duration of travel of the GPS signal from the satellites to the receiver, and the speed of light \[^{17}\]. GPS can also be used for tracking and regulating the speed and route of vehicles. GPS has a great potential for use because it is commercially available, low-cost (e.g., purchase or maintenance), time-saving for installation, and stand-alone without pre-installed infrastructure \[^{18}\]. But use of GPS and LBS may be constrained in congested or indoor environments \[^{19, 20}\].

An alternative is Radio-Frequency Identification (RFID), which has benefits such as data storage in a tag, data transfer capability with a reader, and relatively inexpensive installation cost \[^{21}\]. With assistant tags, RFID can overcome the problem of multipath and signal attenuation in congested environments which are often the case for construction sites. Another technology related to the family of RFID is ultra-wideband (UWB) technology \[^{6}\]. UWB consists of tags and sensors: a tag is attached to an object that requires tracking, where every tag emits UWB signals that will be calculated using time difference between the multiple sensors and its angle at every sensor. UWB enables signal reflection filtered from the original signal that helps in overcoming multipath distortion in the indoor environments, thereby providing accurate results \[^{22}\]. UWB accuracy has been justified in various situations related to construction safety improvement, including the collisions between workers and equipment and among equipment \[^{9, 23}\]. UWB’s accurate results provide opportunities for posture data of the construction workers for analysis of monitoring ergonomic and physiological status \[^{24}\]. As the systems that are radio frequency based, RFID and UWB both require a local area network (LAN). Without LAN, their locating accuracy will be decreased dramatically; however, it can be expensive and impractical in large open areas \[^{25}\].

Other technologies include ultrasound which can provide the most accurate results in in line-of-sight LOS conditions, Bluetooth and wireless LAN which are economical, optical localization, and so on. for more information, please see a detailed description of these technologies in a review paper by Li et al (2016)\[^{11}\].

3 Research Methods

Our semi-structured interviews were deployed in May 2017, which include a total of 25 project engineers and managers in Australian construction industry. They were all selected based on their familiarity with the use of RTLSs for safety management in construction sites. At the time when we conducted the interviews, all participants had been participating in one construction project where at least one RTLS technology was adopted for safety monitoring and management.

Semi-structured interviews are always conducted in a formal way with “a list of questions and topics that need to be covered during the conversation.” \[^{26}\] Thus, before our interviews, a total of nine questions were designed for extracting the opinions of those interviewees on the current practice of RTLSs in the Australian construction industry. Specifically, four questions are concerned with the generic usefulness of RTLTs and favor of a specific technology: (Q1) “On a scale of 1-10 scale (1 being least useful and 10 most useful), how useful you think RTLS is?” (Q2) “What kind of RTLS technology is used by the project you are currently involved in?” (Q3) “Which technology you feel not at all useful in site?” and (Q4) “Which technology you accept the most?” three questions are concerned with the usefulness, barriers, and areas for improvement concerning the application of RTLSs: (Q5) “Does the work force have the IT skills/proper knowledge to use it or not? If No, How you manage?” (Q6) “On what are the barriers of using RTLS technology?” and (Q7) “Please mention few lines for improving construction safety using RTLS.” The last two questions are designed for inquiring the relevance of RTLSs with project characteristics: (Q8) “In what structures you mostly use
RTLSs (commercial or residential structures)?” and (Q9) “What is the approximate timeframe when you use RTLSs in the project you are currently involved in?” Each interview lasted about 30 min and the interviewer recorded the interview by asking for the permission of the interviewees. Results of these nine questions were presented around the above three topics.

4 Results and Discussions

4.1 Usefulness and favor of different real-time locating technologies

The majority of the participants scaled the usefulness of the implementation of RTLSs at the level of 7 and 9 in a particular organization. This evidenced the pressing demand and acknowledgment of RTLSs from the practice, and also highlighted the implications of efforts from the academia to improve related technologies. Regarding this wide acknowledgement of RTLS, our next study investigate the main areas that these technologies are applied to, such as providing timely corrective actions, redesigning work processes, facilitating decision-making for latter safety practices, and gathering information for safety communication among multiple project stakeholders.

As to the kinds of RTLSs used in construction sites, the responses were mixed with different responses like GPS and RFID. This is reasonable as different technologies have advantages and limitations. Furthermore, selection of one particular technology should consider a variety of factors, such as the construction environments (e.g., numbers of obstacles), maintenance cost of the technology, and the required signal strength [6]. The subsequent questionnaire survey should explore what factors matter the most when selecting a specific technology. It seemed that most mentioned RTLSs are sensor-based, given the argued benefits of vision-based technologies [27], we may provide vision-based technologies in the questionnaire and explore their application status in real cases.

For the relative usefulness of each technology, the majority of the participants responded that it was not practical to compare among different technologies as every technology had its advantages. They also expressed that they would like to apply new technologies as long as they were demonstrated efficient and effective. But several participants also mentioned that it was not necessary and useful to adopt such technologies for paint or simple interior work. Finally, according to the interviews, GPS was used at the highest rate. This may be because GPS can be used for various purpose in addition to safety monitoring, such as surveying. Furthermore, perhaps the wide range that GPS can cover makes it favorable for observing large number of workers and materials in a construction site.

4.2 Barriers and areas for improvement

For the projects where RTLSs were adopted, the respondents said that the staff were equipped with good skills and knowledge for using the technologies in the project. In contrast, for the projects where RTLSs were relatively less employed, the main reason was the lack of relevant skills and knowledge of those technologies. Thus, lacking skills and knowledge and inadequate training of how to use a particular technology acted as one barrier for using RTLSs. Other frequently commented barriers included cost, lack of technical staff, and the inaccuracy of technologies under bad climatic conditions. Certainly, proposing practical measures for addressing the barriers identified should be one of our main tasks in the next study.

Regarding the areas for improving the application of RTLSs in the field of construction safety, the most mentioned aspect was awareness of the benefits of these technologies of the staff, especially, the front-line workers. Several participants suggested that seminars of the RTLSs may be helpful for improving workers’ awareness and recognition. The participants also said that more efforts should be made to enhance the robust and accuracy of certain RTLSs, and inaccurate location may serve as a major barrier for the application (e.g., a localization error can lead to a fatality). In fact, the issue of robust and accurate localization performance has been one of the research focus [6, 7, 21]. Our next questionnaire survey should further explore the relative importance of these identified barriers and areas for improvement.

4.3 Relevance of RTLSs with project characteristics
It seems that there was no clear relationship between structures and RTLSs. Instead, many participants said they adopted RTLSs in both commercial and residential structures because safety should be a high priority in either kind of buildings. Several participants also mentioned that technologies were mostly used in large-scale projects where human observations were impractical and lacked efficiency. Similarly, the participants reflected that there was no particular time frame concerning the use of RTLSs in projects; technologies would be used whenever it was necessary. Subsequent questionnaire surveys can include other project characteristics, such as project cost, client sector, by which the relationships between these different project characteristics and the use of RTLSs can be explored.

In addition, as a questionnaire for obtaining a wide range of opinions, we aim to include different main project stakeholders in our sample, such as clients, contractors, consultants, and designers. With regard to the diversity of stakeholders in construction projects who are likely to possess divergent opinions [27, 28], it is meaningful to explore whether there is a disagreement among the project stakeholders concerning the usefulness, the favor of different RTLSs, and barriers and areas for improvement.

5 Conclusion

An understanding of the current status concerning the application of RTLSs in realistic construction projects can shed lights on areas for both academic research and practice. However, such an investigation seems to be lacking in the current literature. Our study addressed this gap by conducting an explanatory interviewing with project engineers and managers in the Australia construction industry. It was found that the majority of the participants assessed RTLSs useful for safety management, and different technologies were adopted with GPS as the prevailing one. Frequently mentioned barriers for the application of RTLSs included the lack of required skills and knowledge, the lack of technical staff, inadequate training, cost, and the inaccuracy of technologies under bad climatic conditions. In order to enhance the use of RTLSs in construction sites, awareness of front-line workers about these technologies and improvement in the robust and accuracy of them should be paid attention to. According to the results of the interviews, no obvious relationships were observed between the type of structures and time frame and the use of RTLSs.

This study acts as part of our comprehensive research program. Our next step is to develop a questionnaire for collecting a wide range of practitioners’ opinions on the current application of RTLSs. Given this, a large eligible sample should be obtained. In addition, we would pay attention to the following extra issues: (1) factors that will influence the selection of a specific technology would be explored as various technologies were adopted, (2) the relatively importance of the identified barriers and areas for improvement would be investigated, (3) more project characteristics and different project stakeholders will be considered.

References


Title of Invited Keynote Presentation:

**System Dialectics of Low or Zero Carbon Building**

Pan, W.1*

**Abstract:**

Anthropogenic climate change is grounded on abundant alleged evidence and is taken as a proposition for this keynote. Buildings worldwide contribute to at least one third of all carbon emissions. However, despite the burgeoning body of knowledge of low or zero carbon building, there is little research into it in a systems manner. The aim of this keynote is to introduce a novel approach of adopting dialectical systems theory for research into low or zero carbon building, and provoke a scholarly debate on their future development. The keynote explains the need for systematizing the research into low or zero carbon building and for adopting dialectical systems theory. The keynote reviews the relevant concept, theory and evidence. The statistics of analyses reveal six clusters of practice and identify a significant gap in the knowledge. The keynote finally recommends several strategies for furthering the knowledge of low or zero carbon building by exploring system dialectics.

**Keywords:** System dialectics; low or zero carbon building; dialectical systems theory.

---

1* Pan, W.
Corresponding author, Department of Civil Engineering, The University of Hong Kong, Hong Kong
E-mail: wpan@hku.hk
1 Introduction

According to the Intergovernmental Panel on Climate Change (IPCC 2007), anthropogenic climate change is grounded on abundant alleged evidence. Climate change represents a serious global risk (Stern 2007). The Paris Agreement that came into force in November 2016 calls for global actions to achieve ‘peak’ greenhouse gas (GHG) emissions as soon as possible, to reach ‘carbon neutrality’ in the second half of this century, to keep the global average temperature increase well below 2°C relative to pre-industrial levels, and to pursue efforts to limit it to 1.5°C (UNFCCC 2015). Anthropogenic climate change is thus taken as a proposition for this keynote.

Buildings worldwide account for over one third of all carbon emissions (UNEP 2010), and offer the greatest opportunity for carbon reductions (IPCC 2007). The low or zero carbon building (L/ZCB) approach has emerged as an innovative model of sustainable development of the built environment. The L/ZCB model has accordingly been adopted in many countries and regions as an important government strategy for addressing climate change, achieving a low carbon economy and uplifting quality of people’s life (Pan and Garmston 2012; Wilford and Ramos 2009). In addressing anthropogenic climate change many countries have tightened up their building energy regulations and even formulated L/ZCB policies (Pan and Ning 2015). Examples include the Energy Performance in Buildings Directive recast for all new buildings in EU countries to be ‘nearly zero-energy’ by 2020 (EU 2010) and US government’s goals of ‘net zero energy’ for all new commercial buildings by 2030 (Crawley et al. 2009).

However, despite the burgeoning body of knowledge of L/ZCB, there is little research into it in a systems manner. Limited previous studies held inconsistent approaches. Successful delivery of L/ZCBs requires far more than a technological solution per se, but well addressed socio-political contexts, whilst systematizing research into L/ZCB challenges traditional approaches but requires innovative theories and techniques.

The aim of this keynote is to introduce a novel approach of adopting dialectical systems theory for research into low or zero carbon building, and provoke a scholarly debate on their future development.

2 A need for dialectical systems theory for L/ZCB research

This keynote explains the need for systematizing the research into L/ZCB and elaborates the innovative theories and techniques drawing on the past five years of research into L/ZCB at the Low Carbon Construction Taskforce of the Centre for Innovation in Construction and Infrastructure Development of The University of Hong Kong.

Analyzing L/ZCB as complex socio-technical systems (Pan 2014), dialectical systems theory is proposed. This theory applies the law of requisite holism (Mulej 2007), as a realistic ground between the scientifically impossible total system that is full and real holism and the practically often dangerous one-viewpoint system that is fictitious holism (Mulej et al. 2003; Pan and Ning 2013). This theory explains the interdependence among the elements of the systems. Adopting the requisite holism, the stakeholders of L/ZCB form their decisions drawing on their perceptions, attitudes and practices within the environments of the socio-technical systems. The ‘socio’ system in this context is understood to cover the broad spectrum of socio-cultural, political, regulatory and economic systems. The ‘technical’ system covers the technological system and its development and diffusion within the ‘socio’ contexts.

3 The concept, theory and evidence of L/ZCB

The keynote, having elaborated the dialectical systems theory, reviews the concept and theory of L/ZCB (Pan 2014) and examines evidence of over 600 empirical building cases of L/ZCB collated over the world. The statistics of analyses reveal six clusters of the buildings towards zero carbon: (1) private residential low-rise rural ‘zero carbon buildings’ in cold zone; (2) private commercial low-rise ‘zero carbon buildings’ in temperate zone; (3) public low-rise ‘zero carbon buildings’ in temperate zone; (4) private urban ‘zero carbon buildings’ in temperate zone; and (5) private residential low-rise suburban ‘zero carbon buildings’ in temperate zone (Pan and Li 2016). The identified significant gap in the knowledge and practice is high-rise buildings in hot-and-humid climates.
With construction moving towards more adoption of automation and robotic technologies, research into carbon emissions of L/ZCB also faces challenges in its theory and methodology. There is no recognition of prefabrication in the life cycle of a building, and inconsistent methods and models for carbon estimation contribute to discrepancy in published results. Different socio-technical contexts render benchmarking of L/ZCB ineffective and learning difficult.

4 Recommended strategies for L/ZCB research

The keynote finally recommends several strategies for furthering the knowledge of L/ZCB. First and foremost, system boundaries of L/ZCB should be made explicit in future studies and benchmarking exercises. Initial modelling is shared drawing on the works by Pan (2014). A systems understanding of L/ZCB must consider the scope of the carbon reduction or (net) zero target, the parameters covered and the value-based context-specific nature of L/ZCB. L/ZCBs should be regarded as complex socio-technical systems, but should not be exaggerated as surrogates for sustainable buildings, which have a broader scope than simply achieving carbon reductions. The system boundaries of L/ZCBs developed by Pan (2014) cover eight types of boundaries, the policy timeframe, building lifecycle, geographical, climatic, stakeholder, sector, density and institutional boundaries. The boundaries are dynamic, and some interact with each other. The boundaries must be explicitly specified to achieve an effective understanding of L/ZCBs in a systems-integrated manner.

Second, partnership should be established in specific socio contexts to facilitate knowledge sharing and transfer among the demand, supply, regulation and institution sides of stakeholders. Internationally, alliances can be developed for maximized synergies. The Paris Agreement (UNFCCC 2015), pledging to reach ‘carbon neutrality’ in the second half of this century, calls upon the Parties to cooperate with the private sector, civil society, financial institutions, cities and regions. In Hong Kong, the recently published Energy Saving Plan 2015-2015+ advocates a partnership among government and public sector development agencies, private sector to collaborate with energy and built environment stakeholders to enable the ‘Energy Wise’ transformation (ENVB, DEVB and THB 2015). The Hong Kong’s Climate Action Plan 2030+ sets a voluntary ‘4T’ (‘Together, Target, Timeline and Transparency’) partnership framework between government and building sector to reduce electricity consumption and carbon emissions (ENVB 2017).

Third, advanced research should be conducted for a better understanding of high-rise L/ZCB. Challenges exist in various socio-technical aspects (Pan et al. 2017). Smart technologies can support that, such as BIM-aided decision making in selecting low-carbon building measures (Chen and Pan 2016) and virtual reality integrated design for improving information integrity (Niu et al. 2016).

All in all, system dialectics lays a solid basis for future L/ZCB research and thus offers a huge potential for exploration. The future L/ZCB research in return will provide a modern context within which the dialectical systems theory can be further developed.

Acknowledgments

Acknowledged is HKU Conference Support for Teaching Staff for delivering this keynote presentation. The works described in this presentation was supported by a number of grants from the General Research Fund of the Hong Kong Research Grants Council (17207115), the Construction Industry Council (CICR/01/13 and 200007451), the HKSAR Government’s Central Policy Unit’s Public Policy Research Funding Scheme (2014.A8.020.14E) and the SFC/RGC Joint Research Scheme (X-HKU711/14).

References

ENVB, DEVB and THB (2015). Energy Saving Plan for Hong Kong’s Built Environment 2015-2025+, Environment Bureau in collaboration with Development Bureau and Transport and Housing Bureau, HKSAR, HK.


UNFCCC (2015). Adoption of the Paris Agreement. Paris: UNFCCC.