Procuring OSM: Base-line Models of Off-site Manufacture Business Processes in Australia

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Abstract

A pressing cost issue facing construction is the procurement of off-site pre-manufactured assemblies. In order to encourage Australian adoption of off-site manufacture (OSM), a new approach to the underlying processes is required. The advent of object-oriented digital models for construction design assumes intelligent use of data. However, the construction production system relies on traditional methods and data sources, and is expected to benefit from the application of well-established business process management techniques. The integration of the old and new data sources allows for the development of business process models which, by capturing typical construction processes involving OSM, provide insights into such processes. This integrative approach is the foundation of research into the use of OSM to increase construction productivity in Australia. The purpose of this study is to develop business process models capturing the procurement, resources and information flow of construction projects. For each stage of the construction value chain, a number of sub-processes are identified. Business Process Modelling Notation (BPMN), a mainstream business process modelling standard, is used to create base-line generic construction process models. These models identify OSM decision-making points that could provide cost reductions in procurement workflow and management systems. This paper reports on phase one of an ongoing research project which is intended to develop a prototype workflow application that can provide semi-automated support to construction processes involving OSM and assist with OSM adoption decision-making, thus contributing to a sustainable built environment.

Keywords: Australia, BPMN, process models, procurement, OSM.
INTRODUCTION

Off-site manufacture (OSM) has been recognized as an effective vehicle for the reduction of cost at the procurement stage of construction in many countries, including the UK (Gibb and Isack, 2003), Australia (Blismas and Wakefield, 2009), and Hong Kong (Baldwin et al., 2008).

Off-site manufacturing, off-site assembly, off-site fabrication and prefabrication are modern methods of construction. For the sake of simplicity, in this paper the term OSM is used to indicate many different production processes distant from the construction site. Although OSM in Australia has been identified as a key vision for a changing construction industry (Hampson and Brandon, 2004), adoption of OSM in Australia remains low due to the reticence of stakeholders. Studies show that OSM adoption is not considered because knowledge of both financial and industry process benefits are lacking in decision-makers.

The purpose of this paper is to provide some of the preliminary results of an ongoing research project. The larger project aims to develop a prototype workflow application that can provide semi-automated support to construction processes involving OSM. This IT-based tool aims to assist construction industry stakeholders increase confidence in the adoption of OSM. The base-line process models developed during the study provide a method of visualising opportunities for OSM adoption for a generic construction project.

The balance of this paper reports on stage one of the larger project. The report begins with a short review of OSM followed by a discussion of some reasons for the lack of OSM adoption. A brief description of the stage one research methodology is followed by a section that provides examples of generic construction project base-line process models developed to date. The process models are presented as cases showing opportunities for OSM adoption along with workflow analysis. This paper concludes with a description of the remaining stages of the ongoing research project.

OFF-SITE MANUFACTURE

Various terms are used interchangeably referring to the off-site production of components that are procured for all types of construction projects. Four common terms found in the literature are: off-site production, off-site fabrication, off-site construction (preassembly and prefabrication) and off-site manufacture (OSM). OSM is used as a collective term in this paper for ease of understanding the general issues.

OSM is consistently used to describe off-site construction activities that include manufacture and assembly of buildings or parts of buildings. It also includes their subsequent on-site installation. Gibb and Isack (2003) differentiate four categories of production at an off-site location.

1) Individual Component: traditionally manufactured in a factory because the quantities required are obtained more efficiently through mass-production, for example doors or light fittings.

2) Assembly component, non-volumetric: these can be effectively mass-produced for large projects because of the degree of standardisation, and include skeletal structural frames, wall panels, claddings, bridge units, and building services.
3) Assembly component, volumetric: many of these components such as shower rooms and toilet pods for large residential buildings, can be standardised. However, manufacture and assembly of unique components that enclose a usable space, such as plant rooms, may not be as cost effective.

4) Modular building: the standardised design of office blocks, tourist accommodation, and multi-story residential blocks provides the widest scope for use of mass-production distant from the construction site. This type of manufacture and volumetric assembly produces modular units that form the actual structure and fabric of a building.

Taking into account the purposes of these different component types, it is clear that quantity and standardisation would be the main drivers for utilisation of OSM for any residential project. OSM process maturity is evident for non-volumetric components such as precast concrete floors, timber wall panels and metal framing. However, utilisation of these types of components remains limited.

**OSM ADOPTION ISSUES**

The argument against the use of manufacturing processes for construction projects focuses on two issues: cost and the unsuitability of the routine standardised processes of manufacturing for construction projects (Gann, 1996). Each of these issues has been researched from a number of perspectives.

This paper focuses on three topics specific to the lack of domestic OSM capacity in Australia. Some of the arguments against the adoption of OSM for construction are outlined below. Procurement, resource and information-flow have been selected for consideration because they provide the core of arguments identified (Blismas and Wakefield, 2009) against the adoption of OSM. At the same time, these processes are mandatory for reliable business process models that take into account both digital and traditional data sources.

**Procurement**

Procuring OSM has been identified as a barrier to adoption. For example, Gibb and Isack (2003) report that the expectations of clients with regard to the adoption of OSM are not always met. A major disappointment is the poor quality of OSM components. A number of researchers have identified the limited number of OSM suppliers as contributing to poor quality. The limited number of suppliers has two seemingly insurmountable problems: a lack of skills and a lack of work. This vicious circle (Park et al., 2012) creates a downward spiral. Insufficient work leads to insufficient experience to adapt to unique requirements, which leads to poor quality products because development of more efficient manufacturing facilities is stalled because of the lack of work.

The residential building sector appears to overcome quality problems based on the lack of OSM skills and capacity. Both estate and high-rise projects provide the quantities of standardisation necessary to ensure that OSM adoption is the most financially favourable option. Thus, OSM is becoming the industry norm for residential building, providing global support for the effort to create a sustainable built environment (Luther, 2009). However, the uptake of OSM processes has not progressed at the same pace in the non-residential sectors of the construction industry.
Researchers have identified four resources issues that can be identified as contributing to stakeholder reluctance to adopt the OSM option (Goodier and Gibb, 2007). Stakeholders perceive that OSM has higher costs for design, production, craneage and transportation of quantities to the project site. Focusing on these individual cost items, rather than the benefits accruing to a total project, appears to influence the lack of industry capacity. Indeed few OSM providers probably means high capital cost in early stages of a project.

At the same time, reduced cost is identified as being a benefit obtained through the adoption of OSM for unique construction projects, with little actual research to support this view. One exception is a study carried out in Hong Kong (Pan et al., 2007). The research compared traditional and precast production for some building elements using labour and materials as variables. They found that the costs of traditional labour (80%) and materials (20%) differed from those of OSM labour (50%) and materials (50%). Though the comparison is simplistic, it does suggest that using traditional construction on-site production methods means higher labour costs for larger percentage of materials so that OSM production will be more cost-effective. This will be true in a high-cost labour market such as Hong Kong or an environment with a shortage of on-site construction skills such as Australia. If cost-based evaluation methods show that OSM is an expensive alternative to traditional on-site construction method, then consideration of other criteria may provide a different perspective.

Information-flow

Examples of differences between and similarities of, off-site and on-site production have been considered a major factor in the OSM debates. A case of difference is communication systems. They are based on formalisation and standards within factories and, therefore, are able to be controlled and monitored. The traditional ‘factory’ is geared towards the production of specified products which means that repetitive and routinised production processes require little technical communication (Gann, 1996). On the other hand, dealing with uncertainty such as is found on most construction sites, supports active and ad hoc communication channels. Thus, the two different communication purposes and styles are suggested as reasons for higher costs, due to poor quality work for OSM products in Australia (Blismas and Wakefield, 2009).

In addition, the difficulty of communication between on-site construction and off-site manufacture is attributed to different types of knowledge based on specialist jargon (Wikforss and Löfgren, 2007). However, the growth of ICT tools and systems means that a number of informal construction project communications channels have become standardised through technology. For example, all building sites in Australia have adopted mobile telephones as standard equipment. Integration of construction communication can also be facilitated through the use Building Information Modelling software (such as AutoDesk Revit, Tekla and Cadsoft) and document management software (such as ACCUBuild, ACONEX and Prolog).

It could be argued that standardised knowledge transfer, based on a variety of IT languages and products, provides an opportunity to overcome the previously perceived communication differences. Information systems/information technology—could be a driver for an increase in the rate of OSM adoption. Although the issues of procurement, resources and information-flow have been presented as separate items in this discussion, in reality these problems are not
independent of one another. However, in an attempt to overcome perceived barriers to OSM adoption, this ongoing research suggests focusing on information-flow as the key to a suitable solution. It is assumed that procurement and resource allocation are business processes that can utilize information systems for managing, controlling, and monitoring construction projects (Kenley and Seppänen, 2010).

RESEARCH METHODOLOGY

The focus of this study is the Australian construction sector. The purpose of this study is to assist stakeholder OSM adoption through the use of construction industry business processes prototype automation systems. This support is also expected to increase demand through identification of OSM opportunities and thus domestic OSM capacity.

Because procurement of OSM, even in the residential sector in Australia, is constrained due to limited capacity to supply OSM products domestically, identification of generic construction processes is considered a first step towards reducing total construction costs (Blismas and Wakefield, 2009). An important feature of generic construction processes is that they can be expanded to take into account unique construction features.

Model Development

Stage One of this ongoing research consisted of the development of base-line process models using Business Process Modelling Notation, a mainstream business process modelling standard (Russell and ter Hofstede, 2009). The purpose of the base-line models is to identify probable OSM processes within a generic construction project. The OSM processes are modelled as OSM tasks presented in a visualised form to reflect procurement workflow management aspects.

Step one for the base-line model development was to define a generic construction value chain including appropriate for OSM adoption opportunities. Three limitations had to be taken into account. First, how to create a practical model suited to the limitations of the resources of the research project. Second, how to create a generic construction model that all stakeholders could utilise. Third, how to consolidate existing research knowledge, including researcher domain knowledge, into a generic construction process model as the foundation for a practical IT-based tool such as a prototype workflow application.

Figure 1: Generic Construction Project Value Chain for study into Australian OSM adoption

A generic six-phase value chain representing a generic construction process, as shown in Figure 1, was the outcome of step one. These value chain phases were chosen because OSM could be included or excluded at the beginning or end of each of these construction project
phases. Thus, all along the chain, cost reduction through the adoption of OSM remains a possibility.

These six phases as noted in Figure 1 are: Arrange Project Team, Develop Detail Design, Prepare Tenders, Tendering Award Contract, Build, Hand Over and Operation. These phase distinctions were made with the understanding that any generic model is only able to provide a representation of very complex sets of inter-acting processes taking into account a wide variety of stakeholder perspectives.

Step two in the model development was to create generic base-line business process models for each of the six phases of the construction project value chain. These generic models provide a visualisation of OSM adoption decision-points within each indicative construction project phase. Each of the phases has increasing levels of detail to illustrate the complex inter-relationships for OSM adoption linking procurement tasks, required resources and necessary information flows found in the literatures (Kenley et al., 2011; Baldwin et al., 2008; Walker and Rowlinson, 2008).

EXAMPLES OF BASE-LINE BUSINESS PROCESS MODELS

Due to limited space, only partial views of the complexity of the levels of two phases of the value chain are presented in this report. The Prepare Tender base-line business process model indicates that OSM adoption could be located within a specific bid. However, details of an individual bid are not included in this report, because the next level of complexity for the Prepare Tender phase cannot be adequately illustrated. At the same time, case two of this report is able to provide a description of a second level of detail, including OSM adoption points for the Build phase.

Case One: Business Processes for Tendering (Contractor Viewpoint)

Construction stakeholders have specific purposes, roles and points of view (Aguilar-Savén, 2004). Thus, the base-line models need to indicate these limitations inherent in a generic model. The example of a tendering process base-line model in this report is presented only from the Contractor viewpoint.

The processes outlined in Figure 2 from start to finish:
1. receipt of a tender package
2. review of tender documents
3. contractor notifies client: accept or decline tendering (if declined end of tendering process)
4. accept: tender time frame prepared
5. tender queries sent to Project Manager for clarifications and/or Project Manager receives tender queries from other contractors
6. Project Manager makes tender clarifications and distributes to all contractors
7. contractors receive tender clarifications
8. bid prepared incorporating all tender clarifications (including three sub-processes: prepare project plan, prepare cost estimation, prepare methodology report)
9. examine draft bid
10. change and finalise bid
11. submit bid to Project Manager
12. bid reviewed and assessed by Project Manager
13. notification received by contractor from Project Manager: contract awarded or not awarded.

The base-line model in Figure 2 provides a visual representation of one level of the **Prepare Tender** phase for a generic construction project. It illustrates a specific point within the business processes, preparation of cost estimations, when the contractor (one of many different construction project stakeholders) could adopt OSM.

**Figure 2: Prepare Tender phase (contractor viewpoint) business process base-line model**

However, some studies consider adoption of OSM at the tender stage of a project not to be cost-effective. At the same time, all contractors must be able to meet the project outcomes in their bid, and cost is the major criterion for the acceptance or rejection of a bid. Therefore, cost reduction by the inclusion of OSM procurement at the tender stage could provide a competitive advantage (Goodier and Gibb, 2007).

**Case Two: OSM Intervention Points for Build Phase**

Identification of a second level of detail was the second step in the development of the base-line business process models for a generic construction project. This second case provides some insights for procurement, resource and information-flow relating to OSM in the **Build** phase.

During the **Build** phase contractors engage in common processes, especially concerning the flow of information contained in construction and shop drawings (Phelps and Horman, 2008). The usual practice is for contractors to receive construction drawings that have been produced by the design engineers currently in 4D format. Contractors then produce shop drawings, traditionally in 2D format, for their use on-site, and send these to the design engineers for review (Kenley et al., 2010). No procurement proceeds until the shop drawings have been
approved by design engineers. For most projects this information transfer process is based on many iterations and is thus a significant drain on project resources.

Once the shop drawings have been approved by the design engineers, different types of products may be procured and produced using different processes. Figure 3 shows the generic construction process during the Build phase, as an example of multiple OSM products being used in a project. For example, two different OSM products indicated in Figure 3 could be steel and mechanical services. The steel structure contractor could begin manufacturing OSM elements in their factory at the same time as the mechanical OSM elements are ordered. However, in this level of the construction project model only generic processes are shown; a more detailed level of processes illustrates unique project processes.

**Figure 3:** Base-line process model of the Build phase of a generic construction project

**YAWL (Yet Another Workflow Language)**

Another level of process complexity, i.e. a workflow specification of the generic base-line models, has been created using YAWL <http://www.yawlfoundation.org>. YAWL is a well-defined process modelling and execution language. It is based on a well-established conceptual foundation derived from extensive workflow patterns research. The term workflow pattern refers to components within business processes that have generic applicability and are recurrent in form (Russell and ter Hofstede, 2009). YAWL has a fully-supporting system, the YAWL system, which is a state-of-the-art open source workflow management system.

Figure 4 is a graphical representation of a YAWL model of workflow (the work that needs to be done) representing typical tasks for the Build phase. The workflow visualisation includes actions such as the information exchange between design engineers and contractors, OSM prefabrication process at the factories and on-site task/action sequences management. Figure 4 specifies information flows (envelope/document), time sequence (clock), human resource allocation (human figure) and work action (the magnifying glass/document).

Although the Build phase is not considered an early phase of a construction project, it can provide opportunities for OSM adoption. The literature suggests that changes to original plans
providing additional cost savings could be still be made in the Build phase by incorporating OSM as indicated in Figure 4 (Pektasx and Pultar, 2006).

**Figure 4:** YAWL model of the Build phase of a generic construction project

The generic base-line business process models presented provide insights into procurement, resources and information-flow in relation to OSM adoption in construction projects (Phelps and Horman, 2008; Pektasx and Pultar, 2006). The development of these generic base-line models is the first stage of an ongoing study concerned with OSM adoption in Australia.

Stage two of the research will centre on construction industry stakeholder feedback on these base-line models, in order to develop reference models (Ouyang et al., 2010). Identification of actions, responses and sequences becomes the foundation for the development of a complete YAWL model for each phase in the generic construction project.

Stage three of the ongoing project aims to produce a prototype workflow application using YAWL for semi-automated support for OSM processes (e.g. procurement, information management and allocation of resources). It is expected that the workflow application will enable time and cost savings. All users of such a system will be able to see the positive relationship between OSM adoption and their current workflow processes. This understanding will reinforce the positive implications regarding the financial benefits to be obtained through reductions in procurement costs. In addition, the identification of OSM adoption points in all construction project phases is expected to assist OSM adoption leading to an increase domestic OSM capacity in Australia.
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