Influences of risk tolerance, perception and safety climate on unsafe behaviour in construction: workers and managers

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Abstract

Despite improvements made in construction safety over the last few decades, injuries and fatalities still occur on a regular basis, and construction safety appears to have reached a plateau. In such an environment, an understanding of how construction practitioners process safety risk information plays an important role in leading accident prevention. A comprehensive literature review found that safety risk tolerance plays a prominent role in risk behaviours. However, no explicit understanding of safety risk tolerance exists, and little is known about the mechanisms of how safety risk tolerance affects construction practitioners' safety behaviours. Therefore, the aim of this research is to investigate the effects of risk tolerance together with risk perception and perceived safety climate on the safety behaviours of two parties: frontline workers and first-line management (FLM).

To achieve this aim, a mixed methods research design was applied. A total of 192 valid responses from workers and 164 valid responses from FLMs were collected from a questionnaire survey and were analysed by using descriptive statistical, mediating effect analysis, moderating effect analysis, information entropy and canonical discriminant analyses. Thereafter, qualitative data were collected through semi-structured interviews with 10 experienced construction practitioners. Qualitative data were analysed using thematic analysis to validate and obtain in-depth explanations regarding the quantitative findings.

On the basis of the quantitative analysis, firstly, the workers' and FLMs' tolerance level for the different safety risks were revealed. Findings indicate that the workers' risk tolerance is significantly higher than that of the FLMs and both parties show significantly different tolerance levels between common injury and fatal risks. Secondly, on the basis of these findings, the risk behaviour patterns (which refer to how risk tolerance and risk perception influence workers' safety behaviours and the involvement of FLMs' safety management) were investigated under two risk scenarios: common injury risk scenarios and fatal risk scenarios. Quantitative results show that workers and FLMs exhibit different risk behaviour patterns in these two scenarios. Thirdly, the moderating effects of perceived safety climate on the identified risk behaviour pattern were explored. As expected, if FLMs perceived more positive safety climate, they tend to give more efforts to safety management; however, if workers perceived more positive safety climate, they tend to underestimate safety risks, especially those who have a higher risk tolerance. Fourthly, the critical influential factors of risk tolerance were identified according to mean-value analysis and information entropy analysis. Thematic analysis of the interview transcripts identified four main recurring themes, namely, confirmation and explanation of the risk tolerance differences between workers and FLMs, discussion of risk behaviour patterns, discussion of influential factors of risk tolerance and suggestions for construction safety management. Then, a comprehensive comparison regarding risk tolerance between workers and FLMs was summarized and a framework for safety risk tolerance management for construction projects was developed.

The research findings expand the knowledge of safety management by offering a deep and comprehensive insight into safety risk tolerance and by providing relevant comparisons between construction workers and FLM. Within these findings, valuable practical insights were obtained, including (1) improve current safety training and education by adding the critical risk tolerance influential factors, (2) improve risk perception and awareness for the risks with high tolerance, (3) build and emphasize tailored safety climate for workers and managers, (4) show real solicitude for workers and (5) encourage workers' active involvement in safety management.

Keywords: Construction safety; risk tolerance; risk perception; safety behaviours; safety climate; construction workers; first-line management

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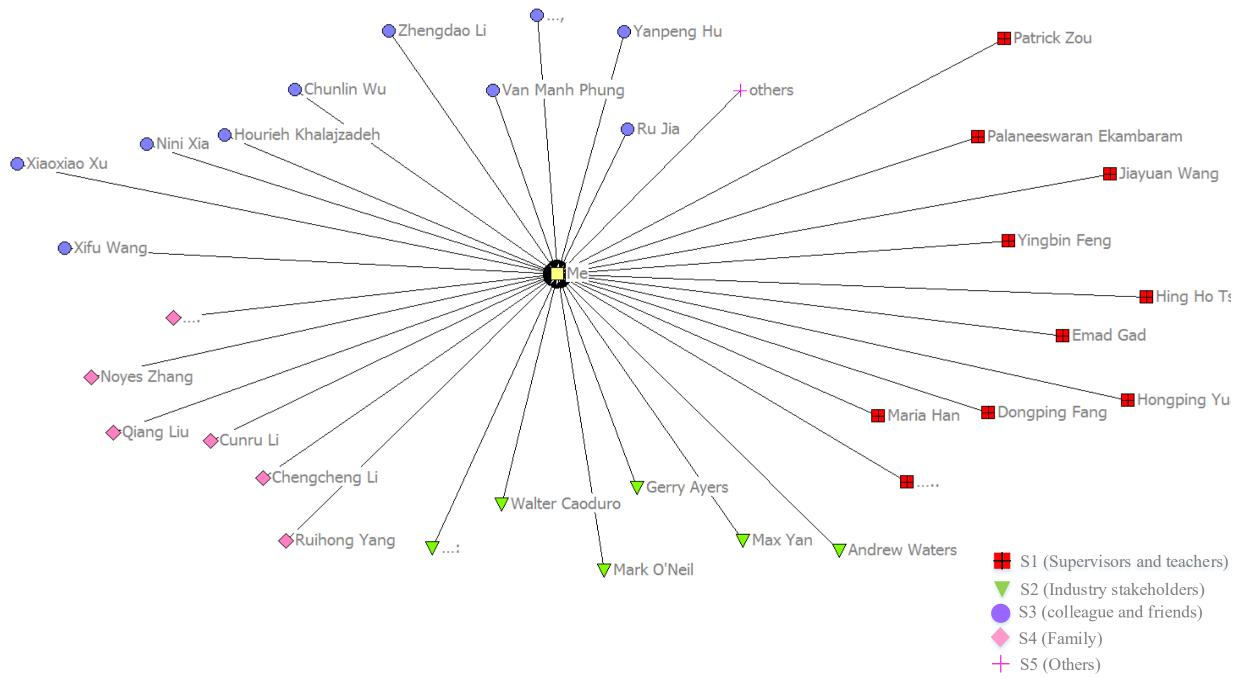

Figure: Relationship between the PhD candidate and stakeholders

Note:

1, The figure is built by Ucinet 6;

2, The figure only shows relationships between the PhD candidate and stakeholders, the relationships between stakeholders are not shown.

The first stakeholder group S1 refers to my supervisors and teachers. I would like to express my sincere gratitude to my principle supervisor Prof. Patrick Zou for his continuous support of my Ph.D study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis. I have learnt valuable lessons from him and it has been such a privilege to work with him. Thanks also to Associate professor Palaneeswaran Ekambaram and Professor Jiayuan Wang for their assistance throughout the course of my study as well as valuable experiences in communicating with industry stakeholders. Furthermore, I am grateful for the assistance of Dr Yingbin Feng and other researchers for their insights in improving the quality of my thesis.

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Pengpeng Li

August 2018

Declaration

‘I hereby declare that this submission:

1, contains no material which has been accepted for the award of any other degree or diploma, except where due reference is made in the text of the examinable outcome;

2. is my own work and to the best of the my knowledge contains no material previously published or written by another person except where due reference is made in the text of the examinable outcome;

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Chapter 1 Introduction

1.1 Research Background and Justification

(1) Bottleneck in construction safety management

Two thousand years ago, the Roman statesman Marcus Tullius Cicero argued that 'the safety of the people shall be the highest law'. An emphasis on health and safety and the protection of all human beings should be the mark of any advanced society. At a mundane level, the construction industry is one of the most dangerous ones and has an accident rate that is much higher than that of other industries (Fang et al., 2006). Despite the improvements in construction safety over the last few decades, injuries and fatalities still occur on a regular basis, and construction safety appears to have reached a plateau (Howell et al., 2002, Bhattacharjee and Gosh, 2011, Langford et al., 2000, Guo et al., 2016) (as shown in Fig. 1.1). Global estimates by the International Labour Organization show that the construction industry accounts for more than 60,000 fatalities annually, equating to approximately 10%–20% of the world's work-related fatal injuries (ILO, 2015). In Australia, the construction industry is reported to have the third highest number of fatalities of all industries in 2014, representing 15% of all worker fatalities from 2003 to 2014 (Safe Work Australia, 2015b). Specifically, 401 work-related fatalities in the construction industry occurred over the 11-year period from 2003 to 2013—an average of 36 deaths each year. According to the Health and Safety Executive (2017), around 64,000 construction workers in Great Britain sustained a non-fatal injury at work. In Australia, 59,000 individuals claimed injuries, which is equal to 156 injuries each day (Safe Work Australia, 2014).

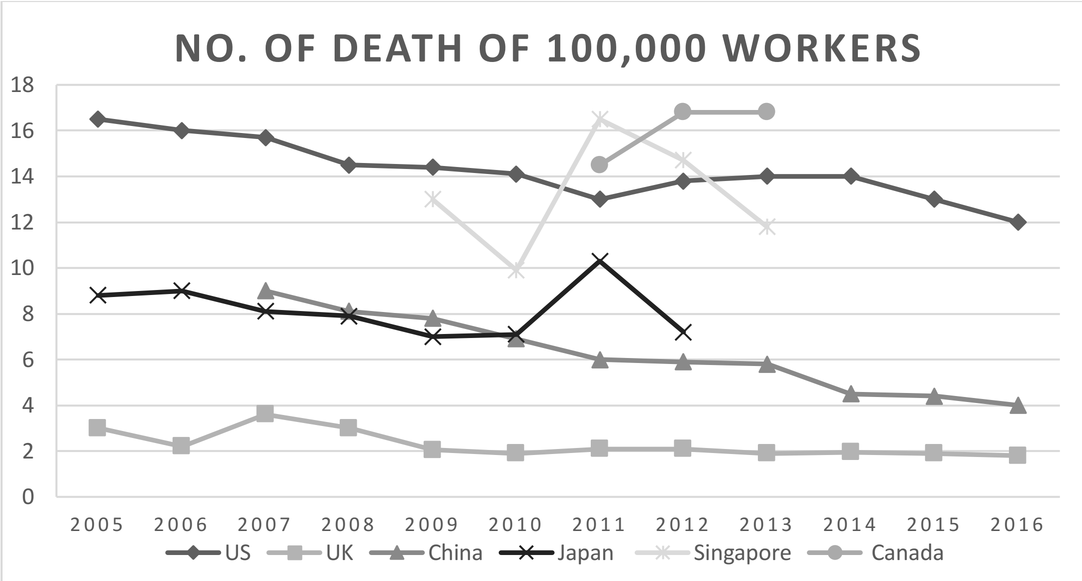


Figure 1.1 Death rate in the construction industry for major countries during 2005–2014

The construction industry is characterised as one-time and non-repeatable, and possesses production relative independence. These features mean that the industry has limited resistance to external interference and resilience. As a result, construction organisations would suffer more direct and indirect losses when major incidents happen compared with other normal organisations (Wu et al., 2016). Furthermore, the occurrence of one major incident could place construction companies in a vulnerable position because they are both economically and socially affected. Given the severe safety situation and the considerable impacts of safety incidents, exploring the causes of safety incidents and implementing efficient strategies to improve construction safety are important.

(2) Unsafe behaviours in construction

Generally speaking, workers and FLMs' safety behaviours in construction context have two aspects: safe behaviour and unsafe behaviour. This research is focus on unsafe behaviours as construction employees' unsafe behaviours are regarded as the most obvious and direct causes of on-site accidents (Garavan and O'Brien, 2001, Fleming and Lardner, 2002, Haslam et al., 2005, Choudhry, 2012, Choi and Lee, 2017). Hence, to enhance safety performance in the construction industry, exploring the causes that underpin these unsafe behaviours is crucial.

Currently, two modes of risky behaviour explain why workers tend to behave unsafely: unintentional and intentional risk behaviours (Canadian Occupational Safety, 2015). Unintentional risk behaviours refer to cases in which risks are not considered or when workers fail to pay attention to risks, as they may have no idea how to perform a task in a safe/right way (Abdelhamid and Everett, 2000). These unintentional risk behaviours are easy to prevent through specific safety training to develop safety awareness and improve relevant operating skills. Intentional risk behaviours indicate situations in which employees are willing to expose themselves to risks either by deciding to proceed with work activities once an existing unsafe condition has been identified or deciding to act unsafely regardless of initial conditions of the work environment (Abdelhamid and Everett, 2000, Liao et al., 2016). These risk behaviours are far more difficult to ascertain and prevent given that the processing of information about risk is complex and blurred (Tchiehe and Gauthier, 2017). Decisions to take risks are usually subjective; thus, understanding how workers process and respond to construction safety risks is necessary because interventions for unsafe or risky behaviours rely heavily on a clear understanding of how people think about risk (Weber et al., 2002, Xia et al., 2017).

(3) Human factors that contribute to unsafe behaviours

One important research area in construction safety is the investigation of the contribution of human factors to unsafe behaviours, which is also the area of this study. In modern society, despite stringent regulations, advanced process automation, safety management systems and the well-intentioned efforts of investigators, work accidents still happen on construction sites. One possible reason is that no matter how automated and advanced a production process or complex a management system is, people cannot be entirely separated from the production process. People still plan, design, operate, supervise and control tasks. Sometimes, intervention is a must when unplanned events happen. Tasks performed by construction people are not only the main components of a project, but they also increase the complexity of management in construction because of the interdependence of such tasks. The high volume of practitioners and the complex relationships among them cause difficulty in identifying every single unsafe act, let alone implementing further safety improvement (Zou et al., 2006a).

Another reason is that human beings are not purely rational when dealing with risks. Simon et al. (2000) believed that people make choices that do not strictly follow the mathematical modelling of decision making, as they seek a satisfactory solution rather than an optimal one. To explain these behaviours, he proposed bounded rationality as an alternative basis for the mathematical modelling of decision making, in which decision making is regarded as not always purely rational, and the individuals' subjective judgement, personality and environment can contribute to the decision making process. As a result, predicting and managing individuals' behaviours is difficult. This argument has been confirmed and applied in construction safety research. Rawlinson and Farrell (2009) pointed out that workers' unsafe behaviours are not simply caused by inadequate safety knowledge and deficiencies in education and training; their subjective and blurred risk judgement also plays a critical role. Following this argument, many human factors have been explored to ascertain how they can influence unsafe behaviours. For construction workers, the contributing factors are analysed from background information (age, education level and trades), physical characteristics, psychological features, attitude, working skill and behaviours (Khosravi et al., 2014, Shin et al., 2015b, Mohammadfam et al., 2017, Seo et al., 2015, Abbe et al., 2011, Leung et al., 2012, Techera et al., 2018, Hwang et al., 2018). For construction management personnel, management skills, and leadership and management behaviours (Wu et al., 2015, Wu et al., 2016, Sunindijo and Zou, 2013, Sunindijo and Zou, 2011, Feng, 2013) were evaluated. From the perspective of construction organisation, human-related factors, including safety climate, safety culture, safety investment, safety supervision and inspection, were discussed (Lu et al., 2016, Wu et al., 2010, Zhao et al., 2014, Zahoor et al., 2017, Pinion et al., 2017, Gao et al., 2017, Alruqi et al., 2018) . These studies not only emphasised and enriched the theory of human factors in safety management but also investigated how construction safety can be improved by teaching, training and reminding workers about how to avoid unsafe behaviours. However, current studies lack investigations on risk tolerance, which is a key element in risk information processing.

(4) Risk tolerance and risky behaviours

Risk tolerance is of considerable concern for safety professionals because employees are often confronted with workplace risks (Ji et al., 2011). Risk tolerance is defined as the amount of risk an individual is willing to assume in pursuit of a goal (Hunter, 2002). This trait is thought to be critical in determining safety behaviours. For instance, airplane pilots may continue to fly in adverse weather because they want to complete their mission and arrive at their destination soon; thus, to achieve this goal, pilots become more willing to accept the risks of this goal. Generally, risk tolerance may be influenced by the personal values attached to the goal of a particular situation (Hunter, 2002). In other words, the risk/benefit trade-off is considered to determine whether or not to tolerate risks for achieving a specific goal. If people perceived positive consequences in taking risks, then they tend to accept and/or tolerate a certain level of risks to achieve certain benefits, and the risk-taking is likely to continue (Saari, 1994, Slovic, 2016).

Given the importance of risk tolerance for risk behaviours, the relationship of how risk tolerance influences risk behaviours seems to be a complex problem. For example, some studies have shown that pilots who take risks (e.g. by flying into adverse weather) tend to be more risk-tolerant than pilots who do not take such risks (Hunter, 2001, Wiggins et al., 1996, O'Hare and Wiegmann, 2003). However, other research found no relationship between risk tolerance and hazardous aeronautical events (Hunter, 2002, Knecht et al., 2004). Clearly, indirect effects of risk tolerance on risk behaviour may exist. Nevertheless, these possible indirect effects of risk tolerance on risky behaviours are rarely studied. Barsky et al. (1997) suggested that a small fraction of behaviour variance can be explained by risk tolerance alone. Thus, what role risk tolerance plays in influencing risk behaviours seems to be an interesting question. Accordingly, the present research aims to take both risk tolerance and social cognitive variables (risk perception and perceived safety climate) into account as sources of variation in behaviours and provide more explanation power than either one alone.

In individual behaviour research, it is of great value to investigate the cognitive variables that can shape individuals' safety behaviour (Wang et al., 2018 and Xu et al., 2018) . Variables such as risk perception, attitude, social norms, perceived behavioural control and perceived safety climate have been frequently applied to the investigation of risky behaviours (e.g. Ji et al., 2011 and Fang et al., 2016). In particular, risk perception has attracted more interest in these studies. Risk perception is an important determinant of risk behaviours (Simon et al., 2000, van Winsen et al., 2014, Fung et al., 2012). The empirical findings of Sitkin and Weingart (1995) established that decision makers' risk perceptions serve as direct determinants of their behaviour in risky situations. Risk perception can act as a mediating influence between individuals' risk behaviour and other indirect factors (e.g. situational, organisational and individual factors) by channelling their cognitive processes, such as information gathering and sense-making. Thus, risk perception does play a particular role in the relationship between risk tolerance and risk behaviours (a detailed explanation of the relationships between risk tolerance, risk perception and risk behaviours is provided in Section 2.4.2).

In addition, perceived safety climate seems to be important in influencing risk behaviours. According to social cognitive theory, the environment an individual is raised in may influence later behaviours (Bandura, 2009). Safety climate refers to the employee's perception of their organisation's safety policies, procedures and practice (Zohar, 1980, Zohar, 2000, Neal and Griffin, 2006). As a shared understanding of workplace safety issues, the perceived safety climate could serve as a frame of reference to guide normative and adaptive work behaviours by providing cues regarding expected contingencies in behaviour outcomes (Schneider, 1975, Zohar, 1980, DeJoy, 1994). For example, Probst (2004) investigated the moderating effect of organisational safety climate on employees' job security and safety outcomes. They found that a strong safety climate can reduce or eliminate the adverse effect of employees' perception of security on safety knowledge, safety compliance, employee accidents, near-miss incidents and workplace injuries. Clearly, the way construction employees think about and respond to risks can be moderated by perceived safety climate (a detailed explanation of the relationship between perceived safety climate and risk behaviours is given in Section 2.5).

(5) Importance of the comparison of risk behaviour patterns between construction workers and first-line management (FLMs)

In construction safety, workers and FLMs are regarded as having a greater impact on project performance in relation to health and safety risk (Phoya et al., 2011), and their shared attitudes towards safety risks have important effects on safety management. However, these two parties may not share the same perceptions and views regarding the same safety risks. With regard to risk tolerance, Rodrigues et al. (2015a) examined the safety risk tolerance of workers, employers and supervisors in the furniture industry and found that supervisors have lower risk tolerance than workers, whereas employers are more intolerant of risks because they are more concerned about the costs of accident prevention. The reason of these perception difference can be explained by different risk targeting. Risk targeting is important lies in its unknown nature (Sjöberg 2000). It means that people assess risk differently for themselves compared to their standpoints and background, such as their families, countrymen, or other people in general (Sjöberg 2000, Hermand et al. 2003). As workers and FLMs have different positions and responsibilities in construction work, their risk targeting determines that they may have different views even regarding the same safety risks.

However, in the field of construction safety, current studies mainly examine the risk judgement of construction workers and the first line-management (FLMs) separately, and this lack of comparison may ignore one possible reason that helps explain the high rate of safety violations in construction sites. Given that shared values, attitudes and judgement of risks are essential to safety success, the comparison of risk behaviour patterns (which, in this study, refers to how risk tolerance, risk perception and perceived safety climate influence workers' safety behaviours and FLMs' involvement in safety management) between workers and FLMs is expected to provide fresh insights for safety improvement.

The human side of construction safety is seen as a key factor to promote safety performance improvement in the construction industry. Many construction industry leaders have realised that gaps and residual injuries often remain after solutions (such as improving tools, processes and management systems) are implemented because injuries are often driven by either deficient safety management or inner risk-taking desire, or sometimes a combination of the two. To effectively improve safety performance, organisations must understand how employees think of risks and what drives these decisions.

Existing evidence clearly suggests that risk tolerance together with social cognition variables (risk perception and perceived safety climate) are related and may work together to affect safety behaviours. However, these relationships have not been clearly investigated in the construction setting. In addition, frontline workers and FLMs are important contributors during construction, and they may face the same safety risks and perform corresponding actions. The above discussions indicate that these two parties may have different risk behaviour patterns even when confronted with the same safety risks. Thus, a comparative study of risk behaviour patterns (which, in this study, refers to how risk tolerance influences safety behaviours) between workers and FLMs is necessary for safety management because it can provide proof of what difference occurs between them and why such disparity exists.

In essence, a key for organisations or individual employees to improve safety is that they must have an awareness of how to judge risk and behave accordingly (Carter and Smith, 2006). Therefore, this research focuses on risk tolerance to explore its role in construction workers and FLMs' safety risk behaviours. Figure 1.2 illustrates the research focus of this study.

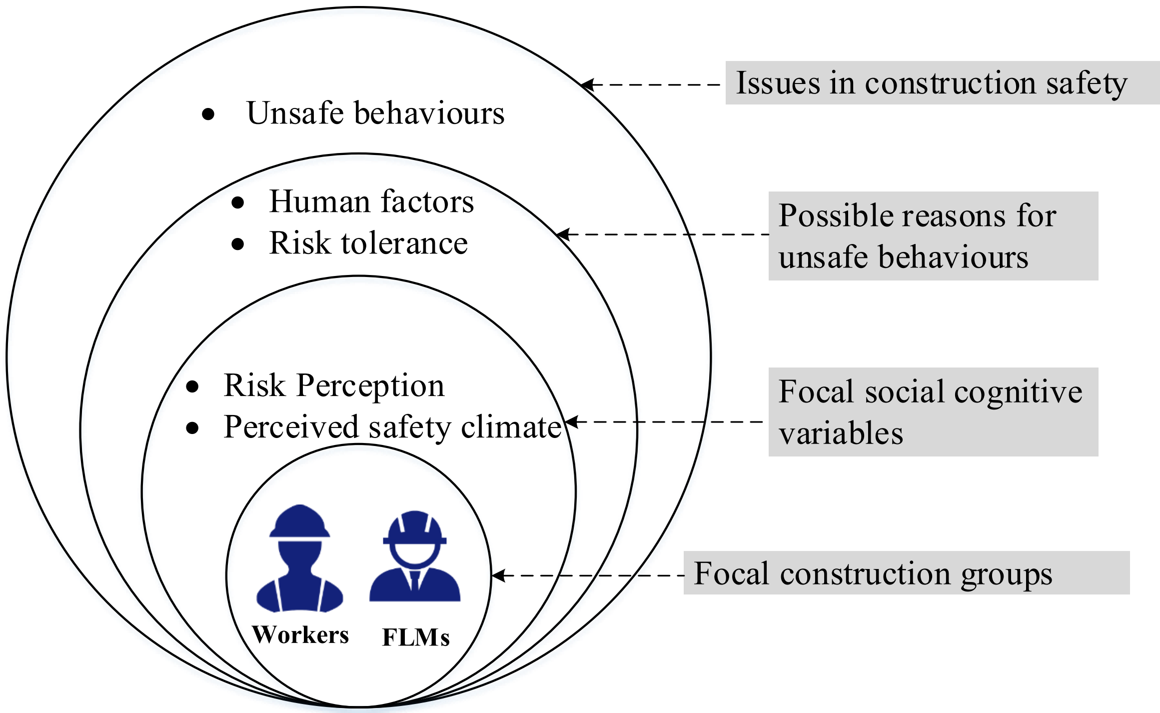


Figure 1.2 Research scope

1.2 Research Questions

As discussed in the previous section, this study regards risk tolerance as an important human factor that contributes to safety behaviours. On the basis of this line of argument, the primary research question is 'How can construction safety be improved by investigating the influences of risk tolerance on workers' and FLMs' safety behaviours?' Specifically,

1. What are workers and FLMs' risk tolerance levels when confronted with different safety risk scenarios?
2. What is the mechanism by which risk tolerance influences safety behaviours?

   2.1 Does risk tolerance influence safety behaviour?

   2.2 How does risk tolerance influence safety behaviours?
3. What are the critical factors influencing risk tolerance?
4. How do construction organisations develop employees' risk decision making skills, especially manage their risk tolerance, to contribute towards improving safety management?

1.3 Research Aim and Objectives

The principal aim of this research is to investigate the effects of risk tolerance on the safety behaviours of two parties: frontline workers and FLMs. To achieve this aim, several research objectives are formulated as follows.

(1) To investigate and compare risk tolerance levels among workers and FLMs.

(2) To explore the mediating effect of risk perception between risk tolerance and safety behaviour.

(3) To explore the moderating effect of perceived safety climate in risk information processing.

(4) To determine and compare the critical influential factors of workers' and FLMs' risk tolerance.

(5) To propose strategies for construction organisations to improve safety management by managing risk tolerance.

1.4 Significance of this Research

This research is significant both theoretically and practically. The main theoretical significance of the research is that it enriches knowledge about the driving force of unsafe behaviour on construction sites. Although numerous variables have been revealed as contributing factors for unsafe behaviours, less focus is given to the factor of risk tolerance, especially in the construction safety setting. This study analyses how construction employees' safety behaviours are influenced by the integrated effects of risk tolerance and social cognitive variables (risk perception and perceived safety climate). On the basis of these results, a further understanding of why unsafety behaviours happen is obtained.

The main practical significance of this research is that it reveals the risk behaviour pattern differences between workers and the first-line management personnel. Construction workers and the first-line management personnel are the two main contributors in construction projects, and most of the time, they must respond to the same safety risks. However, questions as whether or not they have the same safety risk tolerance, how much these differences could be and in what particular risk scenarios that the differences tend to be significant have not been clearly answered. As a result, deficiency safety management could happen if mangers are not aware of these differences. This study contributes to workers and FLMs' safety behaviour differences by revealing their difference in risk tolerance levels at different safety risks, the differences in influential factors of risk tolerance, the difference in response to the perceived safety climate and the difference in risk behaviour patterns when confronted with common injury risk and fatal risk scenarios. Based on these findings, tailored safety management strategies for workers and FLMs could be designed and implemented.

1.5 Thesis Structure

This thesis has seven chapters, which are described briefly below. The research process is presented in Figure 1.3.

- Chapter 1 – Provides a detailed introduction to this research, including research background, research questions, aims, objectives and thesis structure.
- Chapter 2 – Reviews current studies on six aspects: (1) human factors in construction safety research; (2) introduction of basic concepts of risk tolerance, including definition of risk tolerance, difference between risk tolerance and risk appetite, and risk tolerance assessment in an organisation; (3) current research on risk tolerance level analysis; (4) current research on risk tolerance and safety behaviours, including the hypothetical relationships between risk tolerance, risk perception and safety behaviours (for FLMs, as safety management involvement); (5) perceived safety climate in risk behaviours; and (6) research on factors that influence risk tolerance. At the end of this chapter, research questions in this study and the research hypotheses are summarised.
- Chapter 3 – Discusses the research methodology in the construction safety field and the methods applied in this study. Research methods in construction safety studies are first reviewed and analysed. Then, a mixed methodology is introduced. Accordingly, the research design of this work is decided.
- Chapter 4 – Presents the results, findings and contributions of the quantitative analysis showing (1) risk tolerance level between construction workers and FLMs, (2) relationships between risk perception, risk tolerance and safety behaviours, (3) moderating effect of different dimensions in perceived safety climate and (4) the critical factors that influence safety risk tolerance.
- Chapter 5 – Provides and examines the results of the qualitative part of this research. The process of conducting thematic analysis is expounded along with a discussion on the four themes identified based on quantitative analysis.
- Chapter 6 – On the basis of the results from Chapters 4 and 5, a comprehensive comparison regarding the difference of risk tolerance between workers and FLMs is

summarized and explained. Also, a safety risk tolerance management framework for construction projects is developed.

- Chapter 7 – Concludes this research by stating the key findings and the achievement of the research objectives. The theoretical and practical contributions based on the qualitative and quantitative results are also provided. Then, the research limitations and suggestions for further research are discussed.

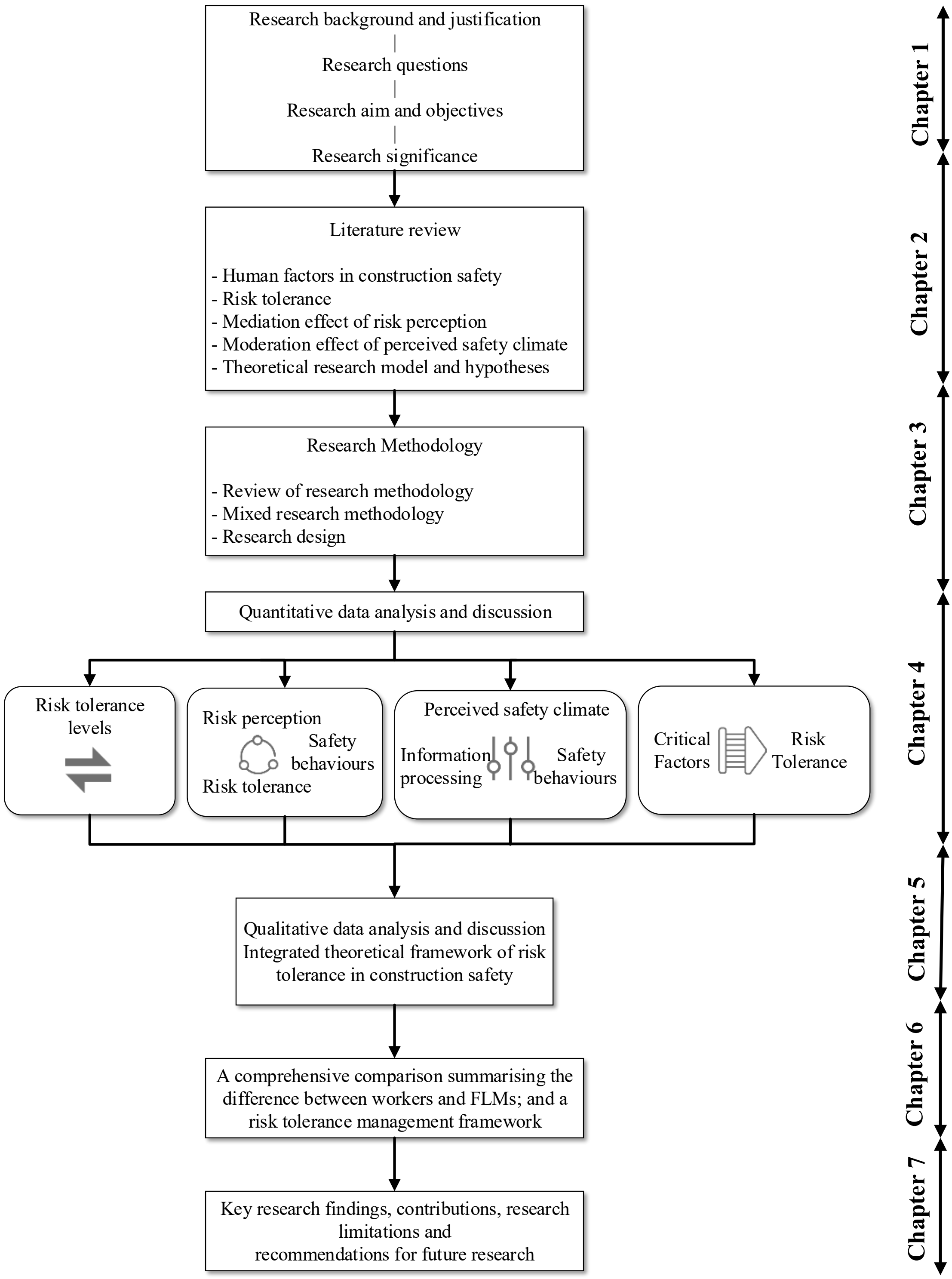


Figure 1.3 Research process

Chapter 2 Literature Review

This chapter consists of six sections. The first section provides a comprehensive review of 227 studies on human factors in construction safety. Accordingly, the research status quo and relevant research limitations about the said factors are discussed. The second section introduces basic concepts of risk tolerance, including definition of risk tolerance, difference between risk tolerance and risk appetite, and risk tolerance assessment in an organisation. The third section evaluates literatures concerning risk tolerance level analysis. In the fourth section, a review of the relationships between risk tolerance, risk perception and safety behaviours were conducted and accordingly, proposed relevant hypotheses. The fifth section discusses the moderating role of perceived safety climate in the construction employees' risk judgement, and the sixth section reviews current research regarding the influential factors of safety risk tolerance.

2.1 Human Factors in Construction Safety

Practically, the labour intensiveness and multi-stakeholders' participation inherent in the construction industry establishes people as its greatest resource (Zou et al., 2006a), including workers in different trades, subcontractors, general contractors, suppliers, owners and inspectors from the government and the union. As mentioned, the tasks performed by these people not only function as the main components of a project but also increase the complexity of management in construction because of the interdependence of such tasks. The high volume of practitioners and the complex relationships among them create difficulty in identifying every single unsafe act, let alone accomplishing further safety improvement.

Theoretically, management failure, unsafe acts of workers, non-human-related events (e.g. earthquake and storms) and unsafe working conditions (e.g. layout of a workplace and status of equipment) are regarded as the main reasons for construction incidents (Abdelhamid and Everett, 2000). Non-human-related events are hard to control due to the great power of nature, and unsafe working conditions are easier to identify and manage because construction environments have become dramatically safer over the past several decades (Shin et al., 2014). Hence, the safety reasons related to construction practitioners are gaining increased attention. In addition, considering that the number of incidents caused by human factors accounts for nearly 90% of the total (Helander, 1980, Fleming and Lardner, 2002) and that these human factors are more difficult to identify and prevent than unsafe conditions (Gould and Joyce, 2009), analysing the causes of construction incidents from the human perspective is of great importance.

To conduct a systematic and in-depth review of human factor research in construction safety, this section is structured as follows: Firstly, the review method is introduced and an overview based on the identified papers is presented, which covers the research time trend, focal groups, research methods and approaches for collecting and analysing data. Then, the research topics are examined in detail. Finally, discussions for the current research are provided.

2.1.1 Methods of Reviewing Human Factors in Construction Safety

2.1.1.1 Paper selection

The scientific method for literature selection is a critical step for gaining an overview of the current status quo for research topics. For this topic, different categories of human factors exist in research on construction safety. Hence, two parts of literature selection, namely, (1) extensive and (2) intensive selection, were conducted to identify in-depth and comprehensive relevant studies on this topic.

The aim of extensive literature selection is to identify construction safety studies that involve human factors. A systematic method that contains four steps was applied to find samples. In Step 1, the Scopus database was employed as the main source for literature selection. For the field 'Title/Abstract/Keyword', 'construction safety' and 'human factor' were used as seeds for selecting preliminary papers. Consequently, 1,692 papers were identified. In Step 2, further selection was implemented to screen and filter the 1,388 papers based on the following criteria: (1) time range: 1991 to present; (2) subject area: engineering and social sciences, (3) document type: article and article in press; and (4) language: English. Within these criteria, 443 relevant papers were identified. On the basis of their 'Source Title', papers from some journals focusing on transportation, nuclear and public roads were also included. To identify the highly relevant papers under a construction industry background, Step 3 was performed to remove irrelevant journals, such as *Health and Place*, *Traffic Injury Prevention*, *Ergonomics* and *AIDS Care: Psychological and Social Medical Aspects of AIDS HIV*. In Step 4, a comprehensive and detailed review of these papers was conducted to ensure that they are highly relevant to the topic of construction safety and human factor. At the end of this step, 176 papers were selected.

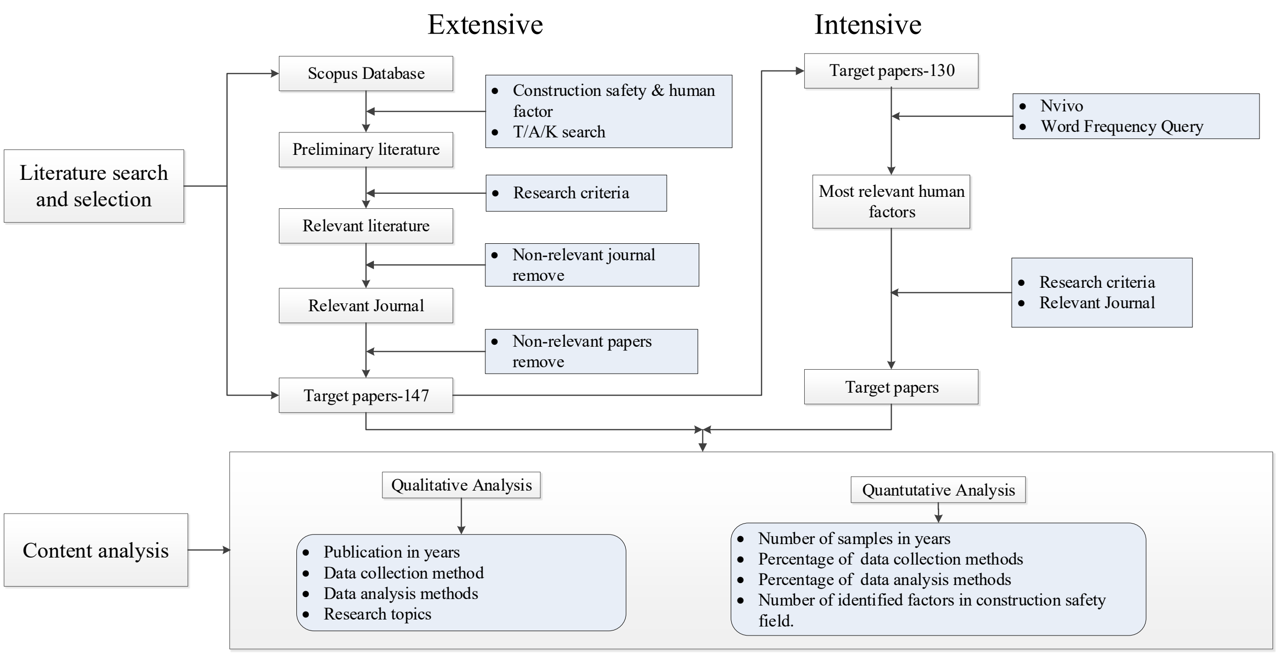


Figure 2.1 Main process of literature selection and content analysis

These 176 papers are highly relevant to the topic of human factors in construction safety. However, some studies that discuss human factors and do not use 'human factor' as keywords in their papers may be ignored. To include additional relevant studies, an intensive literature selection was implemented. For the intensive search, NVivo 11.0 was utilised to find the most frequently mentioned human factors among the 176 papers. By running the 'word frequency query' of Nvivo, we identified the top 300 frequent words, except for the words that are unrelated to human factors, such as construction, factors and difference. Frequently mentioned human factors emerged, including behaviour, knowledge, stress, motivation, perception and communication. Then, a combination of 'construction safety' and these highly frequent words was used to search for more relevant papers in the identified 13 journals by using the same search criteria in the extensive stage. Subsequently, another 51 papers were identified. At the end of the literature selection, 227 identified papers constituted the target sample for a detailed review.

Table 2.1 Journals and papers in Scopus

Journal name	**No. of papers**	**Web of Science Impact Factor**	
		2015 I.F.	**Five years I.F.**
Safety Science	79	2.157	2.284
Accident Analysis and Prevention	25	2.070	2.702
Journal of Safety Research	20	1.504	2.19
Journal of Construction Engineering and Management	31	1.152	1.731
International Journal of Occupational Safety and Ergonomics	22	0.381	0.711
Construction Management and Economics	9	-	-
Applied Ergonomics	7	1.713	2.107
Automation in Construction	7	1.84	2.223
Journal of Management in Engineering	12	2.442	2.827
International Journal of Industrial Ergonomics	5	1.000	1.451
Journal of Engineering Design and Technology	4	-	-
Journal of Civil Engineering and Management	4	1.530	1.419
International Journal of Injury Control and Safety Promotion	2	0.888	0.867
Total papers	**227**		

2.1.1.2 Content analysis

According to Krippendorff (2012), content analysis can systematically and objectively make valid inferences based on collected data to describe and quantify specific phenomena. Further, content analysis allows for both qualitative and quantitative analyses (Chan et al., 2009). In qualitative analysis, specific phenomena can be recorded and categorised systematically, which is helpful for representing the main features of the prior study (Krippendorff, 2012). Conversely, quantitative analysis can help transform the features identified by qualitative content analysis into a quantitative format, which makes disclosing the latent contents of prior studies easier by presenting an objective and direct account of events that are not immediately apparent (Krippendorff, 2012). The robustness of content analysis in the research on construction management has already been confirmed (Chan et al., 2009). Thus, content analysis is an appropriate method for revealing trends in research on human factors in construction safety and for ensuring the reliability and validity of this research. Figure 2.1 illustrates the content analysis procedures of this study. For the analysis portion, qualitative and quantitative analyses were conducted. Qualitative content analysis was used to identify publications in years, identify data collection and data analysis methods, and conduct an in-depth examination and analysis of the human factors in the construction safety field. Quantitative content analysis was utilised to determine the number of samples in years and regions, the percentages of each data collection and analysis method, and the numbers of identified human factors in the said field. On the basis of these analyses, discussions of current issues in human factors and construction safety are given.

2.1.2 Review of Publications

2.1.2.1 Publications distributed in years

Figure 2.2 depicts the trend of sample papers over time. A noticeable publication difference occurred before and after 2008. From 1991 to 2008, few relevant papers were published annually, with approximately one or three papers on the topic of human factors in construction safety. However, the figure suddenly increased since 2008, growing to 13 in 2008. In 2015, a total of 25 papers on this topic were published, which is almost 10 times the average number before 2008. Note that this search result was obtained before Aug 2018. Therefore, this review only includes parts of relevant publications in 2018. In general, although fewer than five papers were found from 1991 and 2008, the overall trend of research on human factors in the construction safety field goes upward, and it increased from 1 in 1991 to 50 in 2018. Obviously, the topic of human factors in construction safety has attracted increasing attention from academia, especially in recent years.

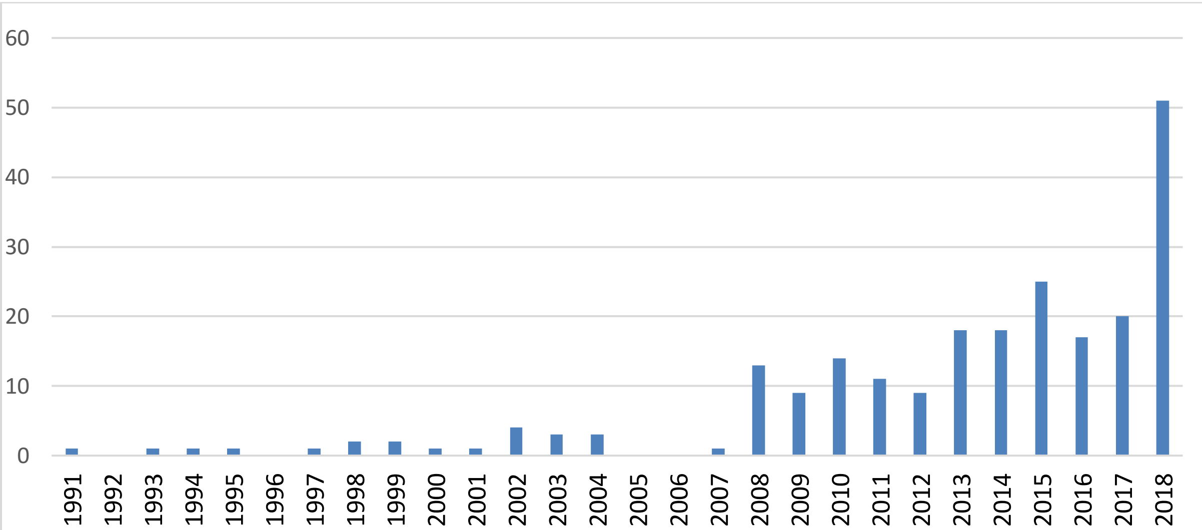


Figure 2.2 Year profile of publications

2.1.2.2 Publications distributed by focal group

A construction project involves several shareholders. Thus, each part plays an important role in safety management. This section seeks to ascertain how much attention is given to each group to provide an overview for both practitioners and researchers. For the papers that contain more than one group, each group was accounted for once in the analysis. For example, Garrett and Teizer (2009) summarised and analysed human errors relating to construction safety from the perspective of the executive manager and supervisor. Zhou et al. (2008) investigated the managers', workers' and supervisors' perception of the safety climate. Figure 2.3 shows that construction workers have been given the highest attention among the selected sample papers, with more than half of the sample papers focusing on worker factors in construction safety, such as fatigue (Fang et al., 2015a), perception of the safety program (Wilkins, 2011) and safety attitude (Grau et al., 2002). Construction managers rank second, accounting for nearly a quarter of the selected papers on this topic, followed by the supervisor, contractors and engineers. Given that the last four groups play a direct or indirect management role in overseeing construction workers, they can be called the managerial staff as a whole. Thus, both managerial staff and frontline workers receive almost half the attention on the topic of human factors in construction safety.

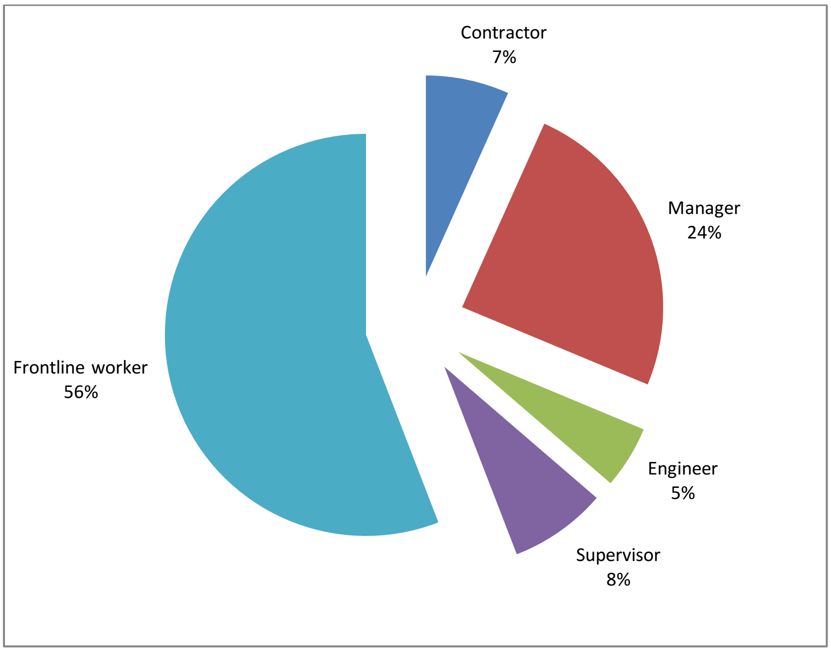


Figure 2.3 Number of publications distributed by focal group

2.1.2.3 Identification of Human Factors in Construction Safety

According to the report of *Health and Safety Executive*, '*Human factors refer to environmental, organisational and job factors, and human and individual characteristics,* *which influence behaviours at work in a way which can affect health and safety*'. Specifically, human factors in the organisation include work patterns, the culture of the workplace, resources, communications and leadership. Human factors in the individual perspective refer to competence, skills, personality, attitude and perception. On the basis of these criteria, two categories of human factors that contribute to construction safety are identified, including (1) occupational role-related factors, such as frontline workers, management staff, designer, contractor/company, client and government; and (2) organisation-related factors.

Table 2.2 summarises the identified human factors in construction safety. Note that frontline workers received the highest attention, in which 27 factors were identified. That group was also analysed from the broadest aspects, including background information, attitude, physical characteristics, psychological features, skill and behaviours. For other stakeholders, only some of these characteristics were examined. From the perspective of the proportion of factors, organisational environment factors were the most studied aspects among the identified papers. Nearly one-fourth of the papers discussed how these factors contribute to construction safety.

Table 2.2 Summary of human factors impacting construction safety

Category	Items	Factors
Occupational role	Workers' background information	Age, work experience, trades, nationality, education, length of service with the company
	Workers' attitude	Race/ethnicity, alcohol and drug abuse, safety attitude and work attitude
	Workers' physical factors	Fatigue, physical symptoms, physical stress
	Workers' psychological factors	Job stress, individual personality, motivation, emotion, psychological stress
	Workers' skill	Risk perception, use of equipment/PPE,

		safety knowledge, competence, risk decision making, safety awareness, risk tolerance
	Workers' behaviours	Safety involvement and unsafe acts
	Managers' background information	Position
	Managers' psychological factors	Motivation, unstable sensitivity, lack of collective responsibility
	Managers' skill	Management skill, competence, risk perception, risk tolerance
	Managers' behaviours	safety system and procedure, safety supervision and inspection, risk management, poor housekeeping, Resource allocation, reward system, goal-setting, health and safety program, poor instruction
	Designers' attitude	Safety attitude
	Designers' skill	Safety knowledge
	Designers' behaviours	Safety design
	Contractors' background information	Company size
	Contractors' attitude	Safety responsibility
	Contractors' skill	Safety awareness
	Contractors' behaviours	Safety investment
	Clients' attitude	Safety emphasis
	Clients' skill	Safety awareness
	Clients' behaviour	Safety involvement
	Government's behaviour	Safety inspection and safety penalty
Organisation	Organisational environment (OE)	Safety education and training, communication, safety climate, management commitment, leadership, supply of PPE, safety culture, workmate's influences, support environment

2.1.2.4 Research Topics on Human Factors in Construction Safety

According to the sample papers in this review, the subject of human factors in construction safety has two main research areas: (1) explanation of construction safety issues, such as workers' unsafe behaviours, construction accidents and poor safety management, and (2) exploration of specific human factors in the construction safety field, such as risk information processing, human factors in certain safety issues and comparison of human factors. These topics are shown in Figure 2.4.

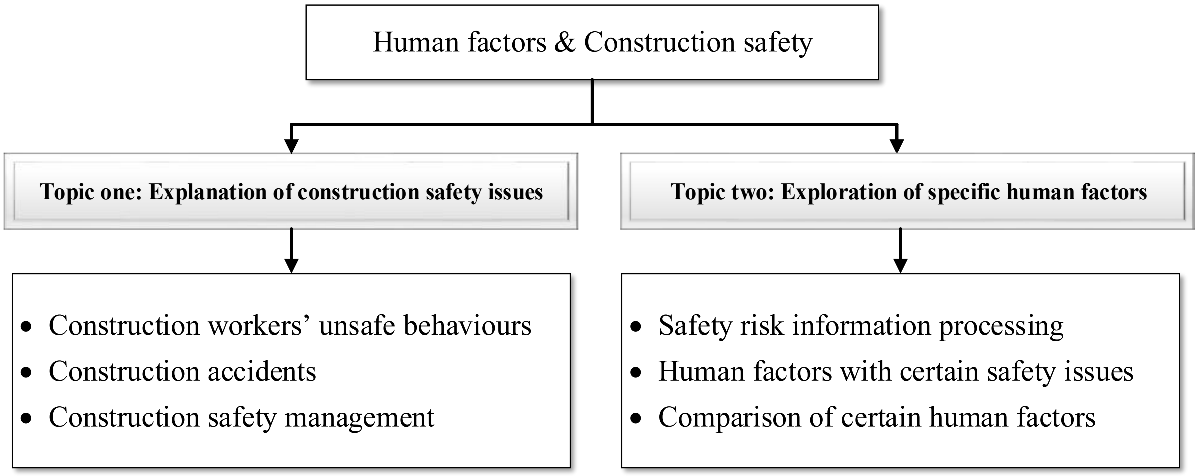


Figure 2.4 Research topics on human factors in construction safety

(1) Explanation of construction safety issues

Human factors in explaining construction workers' unsafe behaviour:

An exploration of the causes of frontline workers' unsafe behaviours is one of the most important topics in the field of construction safety because such behaviours are regarded as the direct reasons for construction incidents. Nearly one-third of the reviewed papers discussed how human factors contribute to workers' unsafe behaviour. With regard to workers themselves, the contribution factors are analysed according to their background information, physical characteristics, psychological features, attitude, working skill and behaviours. Among them, six human factors are given the highest attention, including four factors in the workers' psychological aspects, namely, motivation (Khosravi et al., 2014, Shin et al., 2015b, Mohammadfam et al., 2017), personality (Seo et al., 2015, Shin et al., 2015b), job stress (Guo et al., 2016, Choudhry and Fang, 2008) and emotion (Abbe et al., 2011, Leung et al., 2012); one in attitude, i.e. the worker's safety attitude (Mohamed et al., 2009, Khosravi et al., 2014, Mohammadfam et al., 2017); and one in working skill, i.e. safety knowledge (Larsson et al., 2008, Zhou et al., 2008, Shin et al., 2015b). Note that factors from the organisations received considerable attention as well. Nine human factors in organisations are identified to have an effect on workers' unsafe behaviours, and six of them, namely, safety training (Sertyesilisik et al., 2010, Arboleda and Abraham, 2004, Chi et al., 2013), safety climate (Pousette et al., 2008, Tholén et al., 2013, Seo et al., 2015, Fang et al., 2015), communication (Blackmon and Gramopadhye, 1995, Bust et al., 2008, Hallowell and Yugar-Arias, 2016), management commitment (Larsson et al., 2008, Khosravi et al., 2014) and supply of personal protective equipment (PPE) (Chi et al., 2013, Leung et al., 2012), were revealed to have significant effects on workers' safety behaviours in more than five studies.

Human factors in explaining construction accidents:

Prevention of construction accidents is one of the main aims of construction safety research. More than one-third of the reviewed papers identified the causes of construction accidents from industry and government reports. The involved human factors mainly come from frontline workers, managers, designers, organisations and contractors. One of the most discussed factors involve the inappropriate use of equipment/PPE. PPE is the main method for protecting worker safety, and it is easily understood that improper use of PPE is an unsafe act, which is a direct cause of accidents (Chi et al., 2015, Cheng et al., 2012, Cheng et al., 2010). From the perspective of the organisation, safety training plays an irreplaceable role in preventing construction accidents, and eight studies in this review indicated that safety training could prevent construction accidents by increasing the workers' safety awareness and avoiding unsafe behaviours (Wu et al., 2010, Zhao et al., 2014).

Human factors contributing to construction safety management:

The development of site management is another important topic in construction safety. Interestingly, construction safety management involves more stakeholders than in the above two topics. The worker, manager, client, contractor/company, designer, government and organisation all play important roles in improving site management. Communication, which mainly refers to the communication between workers and management staff on site, is the most mentioned and is regarded as one of the most important determinants for the success of safety management (Atkinson, 1998, Kines et al., 2010, Ismail et al., 2012). Safety supervision and inspection, safety training and safety climate come second. Safety investment is designated to a company and is also frequently mentioned. Feng (2013) found that basic safety investments have a stronger positive effect on accident prevention under higher safety culture and project hazard levels, whereas the effect of necessary safety investments on accident prevention might not be positive given low project hazard and safety culture levels. Lu et al. (2016) analysed safety investment from different agent perspectives and found that different safety investments can have different impacts on construction productivity. Moreover, the safety supervisor's inspection may cause lower productivity as the safety incident rate increases, whereas a proactive construction management system can help prevent unsafe behaviours without interfering with production (Lu et al., 2016). From the perspective of frontline workers, how they perceive safety risks is also discussed extensively. In conclusion, construction safety management is influenced by various aspects, and it cannot succeed without joint effort from all stakeholders.

(2) Exploration of specific human factors

Human factors in risk information processing:

The above studies summarised the highly discussed human factors in construction safety and pointed out the said factors in each topic of construction safety. This part involves studies focusing on revealing how individuals process safety information and make risk decisions. The study of Loosemore (1998) started with an explanation for the model of accident prevention, which included monitoring, comparing, affecting, implementation and feedback. Through the application of this model in four construction projects, the psychological mechanisms regarding organisational conditions in each stage that underpin poor health and safety performance are identified through content analyses. Such mechanisms include natural resistance to change, ambiguous goals in monitoring, lack of collective responsibility and dispute in comparing, and centralisation of decision making responsibility during implementation. This study provides a systematic method to identify influential factors and illustrates how people's behaviour change throughout behaviour processes. Following this logic, Shin et al. (2014) described construction workers' mental process regarding their safety attitudes and safety behaviours, and also examined the effects of optimism, habituation and post-accident factors on decision making behaviours. Goh and Ali (2016) presented a simulation framework to integrate truck drivers' safety behaviours into an earthmoving construction session. On the basis of this simulation, influential factors from human agents, working process, machine agents and environment were identified. Descriptions of patterns of safety behaviours are fundamental and essential for understanding the vulnerable part of construction safety management. Through the use of system dynamic thinking, eight common behaviour archetypes of construction safety were captured by Guo et al. (2015), which consist of the interactions between a wide range of factors within and among various hierarchical levels (such as government, company project and individual) and subsystems (such as regulation, procurement and human resources).

Human factors with certain safety issues:

Under this topic, a detailed analysis of the deeply discussed human factors in certain groups is given. The focal human factors essentially come from three perspectives: (a) perceptions of safety-related issues, (b) certain behaviours and (c) skills. In the first group, how construction practitioners perceive safety training programs and the health and safety on site is investigated. Wilkins (2011) explored construction workers' perception regarding safety training programs, revealed some dissatisfaction with current training effectiveness and pointed out that the problem of distinguishing the characteristics of adult learning remains unaddressed. Individuals' perceptions of general safety/risks conditions in the workplace are also explored. Gyekye (2006) and Ulubeyli et al. (2014) investigated African and Turkish workers' perceptions of the site safety environment (such as supply of PPE, co-worker support, breaks and medical reports) of local construction sites, which provides an overview of the personnel's satisfaction for current safety management. Meanwhile, perception of site safety was investigated among manager groups in Taiwan (Chen et al., 2013b) and in Australia (Biggs et al., 2013). With regard to the second topic of certain behaviours, a field experiment was conducted by Luo et al. (2016) to examine how construction workers respond to proximity warnings of static safety hazards. Results indicated that the difference in trades is one of the explanations for response behaviours. For example, relative to ironworkers, carpenters had longer response latency in hazardous areas. The reasons workers do not report work-related injuries are also investigated, such as insufficient feedback and communication (Taylor Moore et al., 2013). For the third focal topic, the conditions of the construction supervisors' competence for safety management are analysed, such as knowledge of pre-job planning, organising workflow, establishing effective communication and communication of routine and non-routine work tasks (Hardison et al., 2014). In addition, conceptual skill was considered by

Sunindijo and Zou (2013), and their findings indicated that visioning and scoping, as well as integration are important skills for conceptual capability.

Comparison of human factors in different construction groups:

Unlike the above topics, this part employs comparison as the main method for understanding the differences of specific factors between different groups. On the basis of this review, the construction practitioners' risk/safety perception is given considerable attention due to its important role in risk decision making. To obtain a comprehensive understanding of the current risk analysis status in the construction industry, Baradan and Usmen (2006) examined risk analysis of non-fatal and fatal injuries among 16 building trades, including brick masons, block masons, carpenters and concrete finishers. Results showed that different risk analysis levels exist among various trades, and ironworkers and roofers had the highest risk scores, whereas plasterers and stucco masons showed the lowest risk scores. Perceived differences also existed between workers and managers (Hallowell, 2010). Aside from the construction practitioners' level, safety risk perceptions were compared from the perspective of cultural background and the different construction sectors. Zou and Zhang (2009) compared the differences of construction personnel's perception of safety risks between China and Australia. Results indicated that in China, the main perception of safety risks comes from humans and/or procedures. By contrast, the major safety risks perceived in Australia were related to the environment and physical site conditions. Given the variation in working environments in each construction sector (such as residential, commercial and heavy civil sectors), Lopez del Puerto et al. (2013) explored workers' safety risk perception among these areas and found that diverse safety cultures in varied sectors generate the differences in injury rates.

Another point of comparison entails focusing on different views regarding construction safety management. Some studies explored and compared construction personnel's perception of relevant safety practices. Chen and Jin (2015) compared the perception of a subgroup of workers and of general contractor workers regarding a safety program implemented by general contractors. As for specific safety management programs, the perception of the effectiveness of health and safety inspection was also evaluated between contractors and inspectors (Geminiani et al., 2013). For an overall view of current safety management practices, Chen et al. (2013a) conducted a study that summarised six general safety management aspects (such as human error, safety equipment and training, and safety culture) and compared the perceptions of different construction managers (including safety managers, contractor managers, public works managers, design and audit managers, owner audit and control managers) about each of them.

2.1.3 Limitations of Current Research in Human Factors in Construction Safety

Academia has already conducted a considerable number of studies concerning human factors in construction safety, and these investigations have demonstrated many benefits for construction safety improvement. Approximately 50 human factors are identified as contributors to the six construction safety research topics in this review. The diversification of human factors and research topics shows that researchers and practitioners are exploring various paths to advance construction safety management levels. Nevertheless, this review still identified three research gaps, which will be discussed below.

(1) Lack of research on safety risk information processing. Workers' unsafe behaviours are widely recognised as intrinsically linked to workplace accidents (Mohamed et al., 2009, Zhou et al., 2015). Some studies endeavoured to explore why construction workers engaged in unsafe behaviours (Choudhry and Fang, 2008) and how to foster safe behaviours in construction sites (Teo et al., 2005). Although these studies and corresponding findings are

important to enable workers to work safely, they ignored the steps of helping workers process related safety risks objectively and correctly. Considering the complexity of individual differences, guaranteeing that construction workers would behave as they have been trained and taught is difficult. Understanding how construction workers process safety risks when they confront risk situations provides an opportunity and a possibility to ensure that such workers make objective and correct risk decisions by knowing their risk information processing patterns.

(2) Lack of consideration about how workers respond to safety risks under different safety climates. Increasing interest has been focused on utilising safety climate to improve construction, including the exploration of safety climate performance (Zahoor et al., 2017), how to contribute to a better safety climate in the workplace (Sunindijo and Zou, 2011, Zahoor et al., 2017) and how a good safety climate can improve construction safety management (Hon et al., 2014). Despite the importance of the safety climate in construction safety, previous studies have not focused on investigating how construction workers respond to safety risks under different safety climates. As a shared understanding of workplace safety issues, the safety climate serves as a frame of reference for employees that guides normative and adaptive work behaviours by providing cues regarding expected contingencies in behaviour outcomes (Schneider, 1975, Zohar, 1980). Construction workers working in certain safety climates are expected to be influenced when they are processing safety risk information. For example, Probst (2004) investigated the moderating effect of organisational safety climate on employees' job security and safety outcomes. They found that a strong safety climate reduces or eliminates the adverse effect of employee perception of security on safety knowledge, safety compliance, employee accidents, near-miss incidents and workplace injuries. Moreover, organisations with poor safety climates had significantly higher rates of underreporting of workers' injuries than those with positive safety climates (Probst et al., 2008). However, whether a good perceived

safety climate could improve risk thinking and the extent to which the perceived safety climate could do so remain unanswered.

(3) Current research mainly focuses on one particular group, such as construction workers, and seldom considers the human factor difference between workers and management personnel. Workers and FLMs are two primary participants in construction sites, and for them to share the same level of risk judgement and achieve a consensus of site risks are essential for efficient resource allocation and effective safety program implementation given that they are working for the same projects and confronting the same safety risks. However, extant literature often focuses on construction workers and FLMs separately, and less attention has been paid to uncovering the differences of risk information processing between them, and if this difference exists, the effect it will have on construction safety management.

Given the above discussion, the following important questions remain unresolved: 1) How do construction practitioners think about safety risks? 2) How and to what extent does safety climate exert an influence during this risk think process? and 3) What is the risk thinking difference between construction workers and FLMs? The review below will focus on risk tolerance to analyse how it works in influencing risky behaviours in current research and provide a hypothetical model for this study.

2.2 Risk Tolerance

In this section, a detailed review of risk tolerance is given. Firstly, we discuss how to understand risk tolerance by comparing the definitions of risk tolerance between financial risk decision making and safety risk decision making, and distinguished the difference of risk tolerance and risk appetite. Secondly, the main criteria and principle for risk tolerance assessment for an organisation are reviewed. After providing a picture of risk tolerance, relevant topics of risk tolerance in the individual’s risky behaviours are examined, including

(1) the current tolerance level of safety risks, (2) how risk tolerance influences unsafe behaviours and (3) the critical influential factors of safety risk tolerance.

2.2.1 Risk Tolerance Definition

The term 'risk tolerance' was first derived from financial risk decision making. Financial risk tolerance involves perceptions about how confident people are in their ability to make sound financial decisions, their views about borrowing money and how much of a risk regarding financial loss they believe they could accept to achieve economic gains in the longer term (Callan and Johnson, 2002). Risk experts and governmental agencies have discussed the conception of risk tolerance. From the perspective of governmental agencies, the Securities and Exchange Commission (SEC) explained risk tolerance as 'your ability and willingness to lose some or all of your original investment in exchange for greater potential returns' (SEC, 2010). Then, it is applied by the Financial Industry Regulatory Authority (2011) as a guideline for defining risk tolerance. Some researchers also gave their explanations of risk tolerance. Irwin Jr (1993) defined financial risk tolerance as 'the willingness to engage in behaviours in which the outcomes remain uncertain with the possibility of an identifiable negative outcome'. Grable (2000) explained the conception as 'investors' tolerance towards financial risk refers to the amount of uncertainty or investment return volatility that an investor is willing to accept when making a financial decision'. The definitions presented above focus on the financial field.

Given that the potential losses for financial risks and safety risks differ, applying the definition of risk tolerance into the health and safety field would be inappropriate. The ISO Guide 73:2009 provides a more general definition of risk tolerance as the 'organisation's or stakeholder's readiness to bear the risk after risk treatment in order to achieve its objective'. From the perspective of risk behaviour and decision making, Hunter (2002) defines risk tolerance as 'the number of risks that individuals are willing to accept in the pursuit of some goal'. Roszkowski and Davey (2010) also agree that this definition can provide a better understanding of decision makers' risk tolerance. From a psychological point of view, risk tolerance is regarded as a complex psychological concept. Callan and Johnson (2002) defined risk tolerance as a complex attitude that reflects the level of risk that an individual believes he or she is willing to accept. Specifically, risk tolerance reflects an individual's values, beliefs and personal goals, and overlaps with feelings of wanting to feel confident and in control (Young and O'Neil, 1992). Thus, in this study, we focused on risk tolerance that refers to the tolerated level of safety risks rather than financial risks.

2.2.2 Differences between Risk Appetite and Risk Tolerance

Before discussing risk, risk tolerance and risk appetite, it is necessary to define hazard. Hazard is any source of potential damage, harm or adverse health effects on something or someone. For example, an object could fall from a height. Risk is the chance or probability that a person will be harmed or experience an adverse health if exposed to a hazard. In this study, risk mainly refers to the safety risks which may occur under construction, while hazard refers to potential harm to workers and FLMs' safety.

Risk Appetite, Risk Tolerance and Risk Threshold are different kinds of risk levels and they refer to different concepts within the project risk management. These terms are mentioned in the risk management plan as the factors that determine the risk attitude. Although they both reflect the organizations or stakeholder attitude towards risk, they are different concepts. In this part we will discuss Risk Appetite, Risk Tolerance and Risk Threshold terms and their differences with the help of examples.

Table 2.3 lists the main definitions of risk appetite and risk tolerance. Note the many similarities between risk tolerance and risk appetite, such as amount, willing/readiness and achieve/pursuit. Distinguishing these items according to definitions only is not feasible. Several studies analysed these differences on the basis of their applications in an organisation.

Table 2.3 Main definitions of risk appetite and risk tolerance (adapted from Risk and Insurance Management Society, 2012)

Source	Risk appetite	Risk tolerance
ISO Guide 73:2009 Risk management vocabulary (Guide, 2009)	Amount and type of risk that an organisation is willing to pursue or retain.	Organisation or stakeholder's readiness to bear the risk of risk treatment to achieve its objectives.
COSO Strengthening Enterprise Risk Management for Strategic Advantage, 2009 (COSO, 2009)	A broad-based description of the desired levels of risk that an entity will take in pursuit of its mission.	Reflects the acceptable variation in outcomes related to specific performance measures linked to objectives the entity seeks to achieve.
BS 31100:2008 (British Standard)	The amount and type of risk that an organisation is prepared to seek, accept or tolerate.	The organisation's readiness to bear the risk after risk treatments to achieve its objectives.
KPMG Understanding and articulating risk appetite, 2009	The amount of risk, on a broad level, that an organisation is willing to take on in pursuit of value.	Risk thresholds, or risk tolerances, are the typical measures of risk used to monitor exposure compared with the stated risk appetite.
Towers Perrin, What's Your Risk Appetite, Emphasis 2009 by J. David Dean and Andrew F. Giffin	The amount of total risk exposure that an organisation is willing to accept or retain based on the risk–reward trade-offs: • Reflective of strategy, risk strategies and stakeholder expectations • Set and endorsed by the board of directors through discussions with management	The amount of risk an organisation is willing to accept in the aggregate (or occasionally within a certain business unit or for a specific risk category): • Expressed in quantitative terms that can be monitored • Often expressed in acceptable/unacceptable outcomes or levels of risk
ECIIA and FERMA, Guidance on the 8th EU Company Law Directive, article 42, 2011	The level of risk that the company is willing to take: high return–high risk, low risk–low return or a portfolio of different exposures. Risk appetite is strategic and relates primarily to the business model.	The maximum amount of risk that the company can bear despite controls. Risk tolerance is operational and relates primarily to the company's targets.

Regarding risk threshold, it refers to the level of risk exposure above which risks are addressed and below which risks may be accepted – PMBOK@Guide A threshold level is the level beyond which organization doesn't want to tolerate the risk. The organization will not tolerate the risk above the threshold. Risk threshold is a quantified limit beyond which your organization can not pass.

From the macro and micro perspectives, risk tolerance can be understood as the level of risk that an organisation can accept per individual risk, whereas risk appetite is the total risk that the organisation can bear in a given risk profile, usually expressed in aggregate (Manoukian, 2016). Risk tolerance is related to the acceptance of the outcomes of risks should they occur and having the right resources and controls in place to absorb or 'tolerate' the given risk, expressed in qualitative and/or quantitative risk criteria. Thus, to determine risk tolerance, an entity must examine the outcome measures of its key objective (such as revenue growth, market share and production growth) and consider the acceptable range of outcomes above and below the target. Conversely, risk appetite is related to the longer-term strategy of what must be achieved and the resources available to achieve it, expressed in quantitative criteria. Risk appetite can be understood as the set for risk tolerance (HSE, 2001). To better understand risk tolerance and risk appetite, several examples of risk appetite and risk tolerance statements are shown in Table 2.4.

Table 2.4 Example of risk appetite and risk tolerance statements

Statement of risk appetite	**Statement of risk tolerance**	**Statement of risk threshold**
The organisation has a higher risk appetite related to strategic objectives and is willing to accept higher losses in the pursuit of higher returns.	While we expect a return of 18% on this investment, we are not willing to take more than a 25% chance that the investment leads to a loss of more than 50% of our existing capital.	Let's assume that you are a sales manager of a real estate project. In order to speed up sales you proposed to your top management to make discounts. The sales price of a housing unit is 50,000 USD and the profit rate

		is %10. Your company have a policy that a discount rate which is more than profit rate can not be acceptable. Therefore your organization's threshold for this project is 5,000 USD.
A health service organisation has a low-risk appetite related to patient safety but a higher appetite related to the response to all the patient needs.	We treat ER patients within two hours and critically ill patients within 15 minutes. However, management accepts that in rare situations (5% of the time), patients in need of non-life-threatening attention may not receive attention within four hours.	Another example is that, your organization will participate in a tender. According to your calculations, total project cost will be around 500,000 USD. You assembled a meeting with your top management and they told you that they cannot allow you to go beyond 80,000 USD, apart from the 500,000 USD.
A manufacturer of engineered wood products has adopted a higher risk appetite relating to product defects in accepting the cost savings from lower-quality raw materials.	Target production defects of one flaw per 1,000 board feet	

Source: http://www.erm-strategies.com/blog/wp-content/uploads/2013/07/Risk-Appetite-and-Risk-Tolerance.pdf , https://www.projectcubicle.com/risk-appetite-risk-tolerance-threshold/.

Basically, risk appetite is a long-term and strategic item that provides a basic attitude towards risks for an organisation. By contrast, risk tolerance can be used in detailed planning and decision making processes regarding specific tasks/events.

2.2.3 Risk Tolerance Assessment in Organisations

2.2.3.1 Main criteria for deciding tolerable risks

Risk tolerance plays a critical role in risk management. According to Figure 2.5, which is adapted from ISO 31000:2018, risk assessment is the core element of risk management given that it provides a basis for the decisions about the most appropriate approach to be used to treat risks by offering decision makers an improved understanding of how potential risks could affect the achievement of objectives (ISO, 2018). After risk identification and risk analysis, risk evaluation is conducted to determine whether a risk is acceptable and/or tolerable (as shown in Figure 2.6). During the process, several principles and criteria can be used to decide tolerable risks.

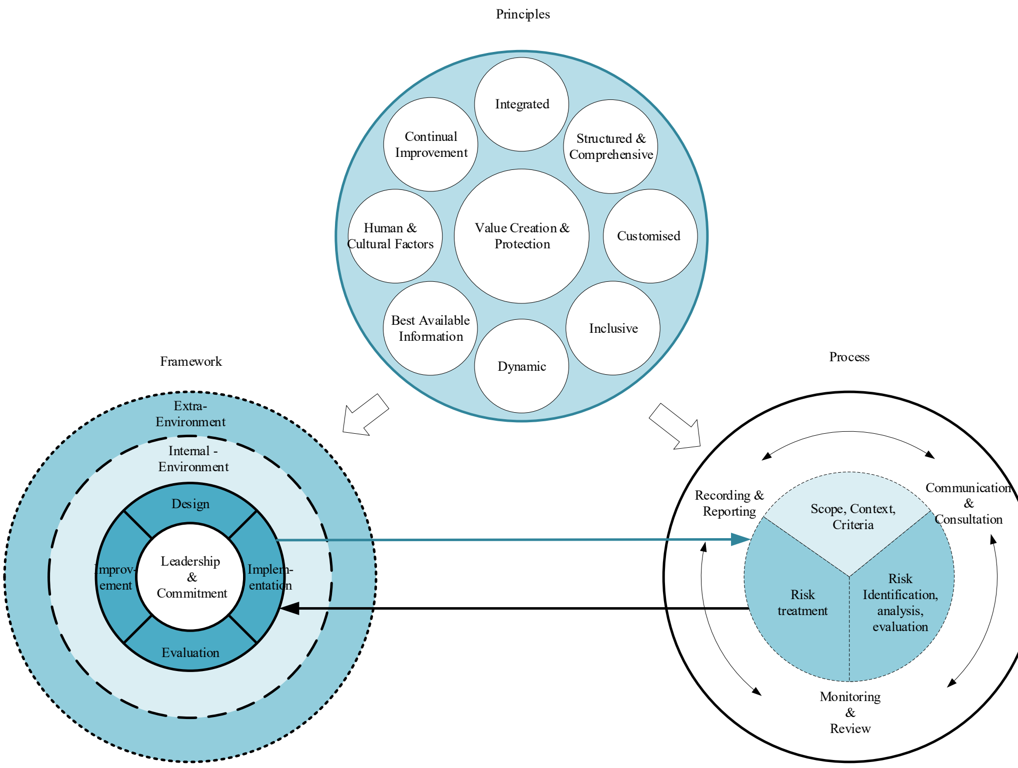


Figure 2.5 A typical risk management process (adapted from ISO 31000:2018)

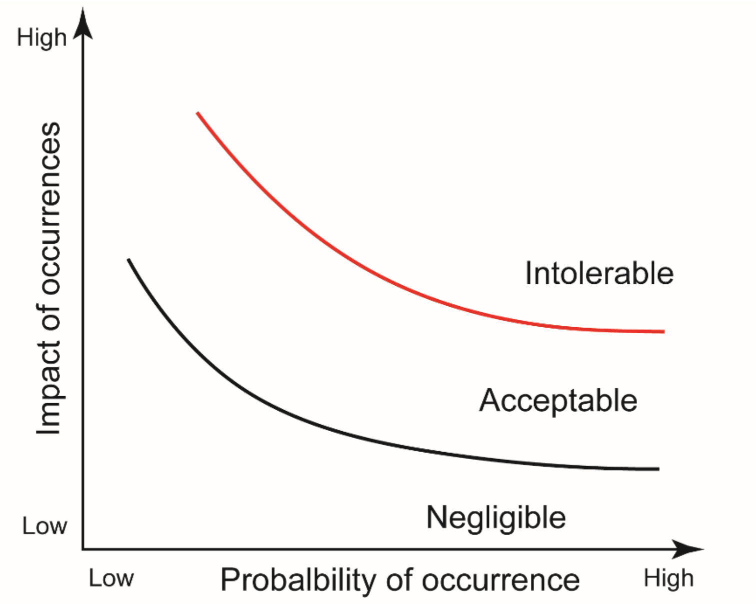


Figure 2.6 Risk probability, impact and tolerance

Given the importance of risk tolerance in risk decisions, how to assess risk tolerance level is a weighty concern. Currently, three criteria are used by regulators in the health, safety and environmental fields for assessing tolerable or intolerable risks (Table 2.5).

Table 2.5 Criteria for deciding risk tolerance

Criteria	Explanation
Equity-based criteria	These criteria start with the premise that all individuals have unconditional rights to certain levels of protection. In practice, this premise often converts into fixing a limit to represent the maximum level of risk above which no individual can be exposed. If the risk estimate derived from the risk assessment is above the limit and further control measures cannot be introduced to reduce the risk, then the risk is held to be unacceptable whatever the benefits.
Utility-based criteria	These criteria apply to the comparison between the incremental benefits of the measures to prevent the risk of injury or detriment and the cost of the measures. In other words, the utility-based criteria compare in monetary terms the relevant benefits (e.g. statistical lives saved and life-years extended) obtained by the adoption of a particular

	risk prevention measure with the net cost of introducing it and requires that a particular balance be struck between the two.
Technology-based criteria	These criteria essentially reflect the idea that satisfactory risk prevention is attained when state-of-the-art control measures (technological, managerial and organisational) are employed to control risks whatever the circumstances.

Source: HSE, 2001

Although these criteria work well on their own in many circumstances, their universal application has been found wanting. Some arguments regarding their disadvantages are discussed below.

An equity-based criterion may often, in practice, require making decisions on worst-case scenarios that bear little resemblance to reality. In such cases, the decisions reached are inevitably based on procedures that systematically overestimate risks, causing undue alarm and despondency among the public or resulting in benefits achieved at disproportionate costs (HSE, 2001).

A utility-based criterion tends to ignore ethical and other considerations and focuses merely on achieving a balance between costs and benefits. For example, some people believe that certain hazards should not be entertained at all because they are morally unacceptable. At the other extreme, utility-based criteria do not impose an upper bound on risk, whereas we believe that risks that society regards as unacceptable exist because they entail too high a likelihood that harm will actually occur to those exposed or the consequences are too extreme, however small the likelihood of the risk being realised, to countenance exposure to the hazard (HSE, 2001).

Technology-based criteria often ignore the balance between costs and benefits. They would, for example, require wood furniture manufacturers to adopt state-of-the-art technology developed for keeping clinically clean factories for manufacturing medicines—hardly a realistic proposition (HSE, 2001).

2.2.3.2 Main framework for risk tolerance

To ensure that the above three criteria are not regarded as mutually exclusive, a tolerability of risk (TOR) framework was designed by HSE to accommodate all three criteria.

As shown in Figure 2.7, the triangle represents an increasing level of risk for a particular hazardous activity as a move from the bottom of the triangle towards the top. The dark zone at the top signifies an unacceptable region. Conversely, the light zone at the bottom indicates a broadly acceptable region. The zone between the unacceptable and broadly acceptable regions is the tolerable region. Currently, deciding the tolerable limits involves several principles, as shown in Table 2.6. As the most widely known and studied approach in the occupational health and safety field (Tchiehe and Gauthier, 2017), the 'as low as reasonably practicable' (ALARP) principle is explained in detail below.

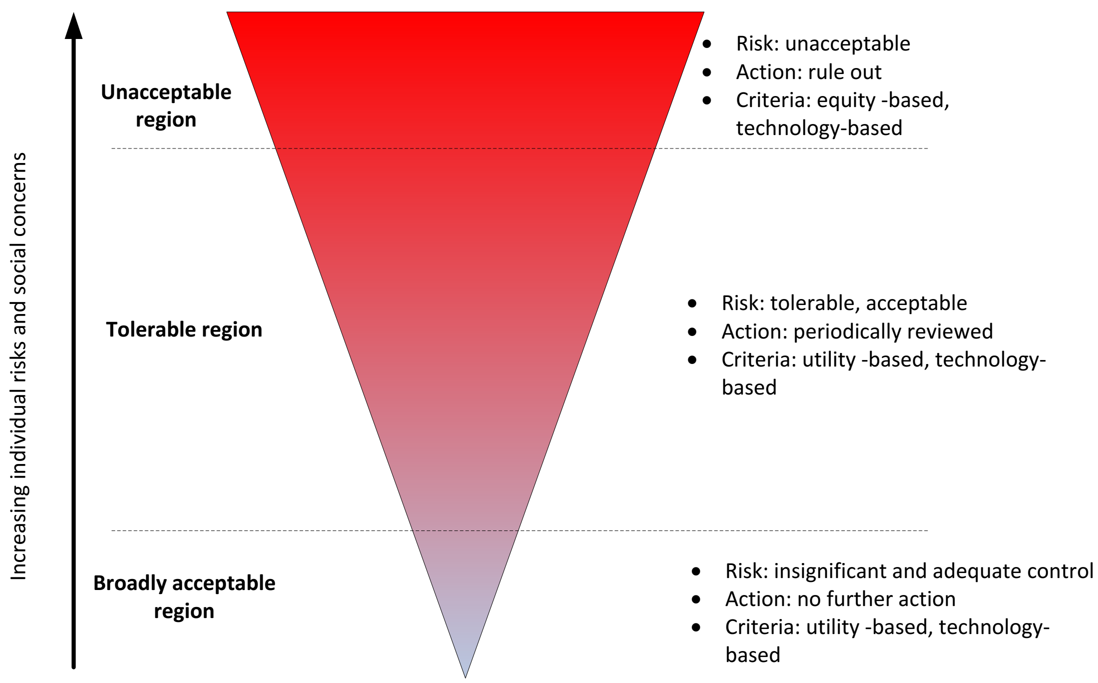


Figure 2.7 HSE framework for tolerability of risk

Table 2.6 Principles for deciding tolerable limit

Principle	Explanation	Application field
ALARP	As low as reasonably practicable	Occupational safety and health (HSE, 2001)
ALARA	As low as reasonably achievable	Radiation risks (Johansen, 2010)
GAMAB	At least as safe as the pre-existing one	Rail transportation industry (Schjølberg and Østdahl, 2008)
MEM	Minimum endogenous mortality	Death in safety of technical facilities (Johansen, 2010)

For the ALARP approach, a particular risk falling above the unacceptable line is regarded as unacceptable for practical purposes, whatever the level of benefits associated with the activity. Any activity or practice giving rise to risks falling in that region would be ruled out unless the activity or practice can be modified to reduce the degree of risk such that it falls in one of the regions below. Risks falling below the tolerable line are regarded as insignificant and adequately controlled. Regulators would not usually require further action to reduce risks unless reasonably practicable measures are available. The risk levels characterising this region are comparable to those that people regard as insignificant or trivial in their daily lives. They are typical of the risk from activities that are inherently not very hazardous or from hazardous activities that can be, and are, readily controlled to produce very low risks. Risks in the middle region represent typical risks from activities that people are prepared to tolerate to secure benefits.

Similar to the ALARP approach, the 'as low as reasonably achievable' (ALARA) approach was initially used in Europe to assess radiation risks, as well as therapy through radiation for which the exposure limit values are not well known (Johansen, 2010). The ALARA approach means making every reasonable effort to maintain exposures to ionising radiation as far below the dose limits as practical. This method is consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements about the state of technology, the economics of improvements in relation to the benefits to public health and safety, and other societal and socioeconomic considerations.

The GAMAB approach (*Globalement Au Moins Aussi Bon*, in French) was developed in France within the rail transportation industry and is increasingly considered in other sectors (Schjølberg and Østdahl, 2008). This technique means all new guided transport systems must offer a level of risk globally that is at least as good as the one offered by any equivalent existing system. This approach is essentially technological and uses the pre-existing system as a baseline (Johansen, 2010). Hence, the present safety level is a minimal requirement. Another version of the GAMAB called GAME (*Globalement Au Moins Équivalent*, in French) is generally employed to analyse new activities by comparing the known risks of a baseline activity to those of the new activity (Vanem, 2012). The GAME technique is also implemented by comparing the risk history contained in databases (Tchiehe and Gauthier, 2017).

The minimum endogenous mortality (MEM) approach is mostly used for the safety of technical facilities. The term *endogenous mortality* refers to death due to internal causes (for example, disease or ageing), as opposed to the term *exogenous mortality*, which denotes a death caused by external factors (such as accidents) (Tchiehe and Gauthier, 2017). This approach indicates that the individual risk due to a particular technical system must not exceed 1/20th of the minimum endogenous mortality.

Among these principles and criteria, the ALARP principle and cost–benefit analysis are often used to determine the tolerable lines: (1) All efforts should be made to reduce risks to the lowest level possible until a point is reached at which the cost of introducing further safety measurement significantly outweighs the safety benefits; and (2) a risk should be tolerated only if a clear benefit in doing so can be demonstrated (i.e. a compelling operational need exists in the organisation). According to the ALARP principle, three levels or risk tolerance are determined.

(1) **Unacceptable risks** are classified as undesirable regardless of the benefits associated with the activity. An unacceptable risk must be eliminated or reduced so that it falls into one of the two other categories, or exceptional reasons must exist for the activity or practice to continue.

(2) **Tolerable risks** are those that people are generally prepared to accept to secure their benefits. Tolerable risks must be properly assessed and controlled to keep the residual risk ALARP and must be reviewed periodically to ensure that they remain that way.

(3) **Broadly acceptable risks** are considered sufficiently low and well controlled. Further risk reduction is required only if reasonably practicable measures are available. Broadly acceptable risks are those that people would regard as insignificant or trivial in their daily lives, or which exist but have no practicable mitigator (e.g. most organisations accept that staff could be injured on their way to work but have little control over what happens on public roads) (ISO, 2009b).

2.3 Tolerance Level for Safety Risk

Risk tolerance is at the core of all safety decision making (Rae, 2007). Every safety decision is made with a subjective assessment of risk acceptability and a selection of one of the following alternatives: proceed as planned, invest resources to mitigate a portion of the safety risk or do not proceed (Hallowell, 2010). This observation implies the fundamental role of risk tolerance in the occupational setting. In this context, an effective decision making process is of paramount importance, and all information that can increase the effectiveness of the process is useful, particularly judgements about the stakeholders' risk tolerance level. Therefore, the essential issues that need to be understood are the level of risk that stakeholders regard as sufficiently low, how stakeholders form their opinion about a given risk and why they adopt a certain attitude towards risk.

Research on construction safety risks has not widely discussed the risk tolerance level of safety risks. Hallowell (2010) examined risk tolerance and compared the risk tolerance between workers and supervisors. In his research, all participants were provided with a definition of the injury severity level (e.g. from minor first aid injury to a fatality) and were asked to rate frequency in units of time, such as the number of days, weeks, months or years that would be acceptable for each of the severity levels. These values were used to represent the workers' risk tolerance. By employing this method, they found that a statistically significant difference exists in the risk tolerance between workers and managers. However, this analysis suffered from accuracy limitations:

(1) The method, which was used to measure risk tolerance by items such a near-miss and temporary discomfort, is believed to be unable to provide a specific risk scenario to workers and even FLMs. Some participants may have no idea about this terminology. Moreover, even though workers and FLMs know these items, the risks that they associate with them may vary possibly because the participants have different work experiences and working trade. Thus, only present certain risk terminology is argued to have accuracy limitations.

(2) Another popular way to measure risk tolerance is to describe common risk scenarios, such as 'a worker steps to an open-sided floor' and 'safety nets do not cover the building when construction is in progress'. Although these measures provide detailed risk scenarios, workers and FLMs may remain unable to give an accurate assessment because any risk scenario involves information on risk frequency and risk severity. If we do not point out specific risk frequency and risk severity, then

workers and FLMs would form assessments based on the frequency and severity that they are familiar with. For example, for the risk of slipping on site, some people may think such occurrence is not risky because people who slip would only need a day of rest and can then return to work. As a result, high risk tolerance will be given. However, if people know that one of their colleagues needed a month to recover after slipping on site, then they may have relatively low risk tolerance. Thus, if the risk scenarios do not mention the potential losses that may occur in a specific risk scenario, then the accuracy and objectiveness of responses cannot be ensured.

2.4 Risk Tolerance Influencing Safety Behaviour

2.4.1 Safety Risk Tolerance and Safety Behaviour

The relationship between risk tolerance and safety behaviours has been investigated by some studies. Lehmann et al. (2009) and Bhandari and Hallowell, 2017 pointed out that risk tolerance is a key component that can factor into the drivers of risk behaviours. According to Barsky et al. (1997), individuals' risk tolerance is positively related to risky behaviours, such as smoking, drinking and failing to have insurance. Maiti et al. (2004) also indicated that risk tolerance is an important issue for safety professionals because employees who are willing to tolerate more risks have been known to be more accident-prone. Research on pilots' safety behaviour found that pilots may continue to travel in adverse weather only because they want to complete their mission and arrive at their destination quickly; thus, the pilots' become more willing to accept the risks of this goal (Ji et al., 2011). Although these investigations indicate that a person with high risk tolerance is likely to take risky behaviours, no explicit research examines the mechanism of how risk tolerance influences safety behaviours. Does risk tolerance have a direct and single effect or does it need to work with other variables? The relationship of how risk tolerance shapes risk behaviours seems a complex problem. Some studies have shown that pilots who take risks (e.g. flying into adverse weather) tend to be more risk-tolerant than pilots who do not take such risks (Hunter, 2001, Wiggins et al., 1996, O'Hare and Wiegmann, 2003). However, other research stated that no relationship exists between risk tolerance and hazardous aeronautical events (Hunter, 2002, Knecht et al., 2004). Clearly, risk tolerance may have indirect effects on risk behaviour. However, such possible indirect effects are rarely studied, especially in the construction safety field.

Two driving forces may lead construction employees to tolerate more risks in the construction setting. Firstly, the inherent risky nature of construction site work (for instance, climbing a tower crane, crawling a cradle up the side of a building or walking on a scaffold 30 stories high) is believed to possibly lead to the construction workers accepting more risks than non-construction workers do. This risky nature is part of why some people like to work in construction, as they enjoy taking those risks; moreover, to fit into such a risky environment, construction workers must have, by the very nature of their work, a higher risk tolerance than workers in other industries (Rawlinson and Farrell, 2009). These high-risk tolerance characteristics may motivate the high willingness to undertake risk-taking behaviours (Lehmann et al., 2009, Wang et al., 2016). The second driving force is represented in terms of time and money (Rawlinson and Farrell, 2009). Construction workers who are paid on price or measure would work quickly because working speed is a determinant of income. However, speed always entails cutting corners and taking risks (Spanswick, 2007). Construction workers are often prepared to take risks simply to get the job done for money, for production or just to keep their employment secure (Choudhry and Fang, 2008, HSE, 2003). Accordingly, if construction workers have higher risk tolerance levels, then they are likely to undertake unsafe behaviours.

A similar hypothesis can also be made for the FLM. Note that aside from construction workers motivated by money and time, site supervisors often turn a blind eye to workers' risk-taking if the necessary production is achieved (HSE, 2001). As a result, the extent of involvement in safety management in such cases would be decreased. In addition, from the perspective of risk management, if risks were evaluated as intolerable, then management would allocate more resources to them (Kwak and LaPlace, 2005). In other words, the involvement of safety management in such risks is increasing. However, little research has focused on the influence of risk tolerance on management personnel's involvement in safety management. Thus, another hypothesis was proposed, suggesting that if the FLM perceives a lower risk tolerance level, then their involvement in safety management would improve.

2.4.2 Safety Risk Tolerance, Risk Perception and Safety Behaviour

2.4.2.1 Risk perception

Before discussing the relationship between risk tolerance, risk perception, and safety behaviours, risk perception must first be defined, especially for construction employees and how they perceive safety risks. Currently, two ways of perceiving risks are mentioned: (1) rational risk perception and (2) emotional risk perception. Rational risk perception means that people tend to perceive risks through a formulation of three parameters, namely, (a) the probability of risk occurrence, (b) the severity of risk impact and (c) the expected utility of risk, i.e. the multiplication of the risk's probability and severity (Aven and Renn, 2009; Lehtiranta, 2014; Micic, 2016). However, such rational risk perception can be problematic if applied for the construction employees' risk perception because it can be only possessed by experts in a particular field (Rundmo, 2002, Slovic, 2016). As for emotional risk perception, it means perceiving risks through direct and intuitive judgement (Slovic, 2016, Xia et al., 2017). Such perception is usually influenced by diverse factors, including internal factors of personal traits, risk attitude, knowledge and emotion (Ganzach, 2000, Baloi and Price, 2003, Wang and Yuan, 2011), and external factors of culture, political environment and job position (Hallowell, 2010, de Camprieu et al., 2007, Rees-Caldwell and Pinnington, 2013). Despite this complexity, researchers argued that real actions in risky situations are significantly affected by the decision makers' emotional and intuitive judgement of risk (Loewenstein et al., 2001; Slovic et al., 2004; Weber et al., 2002). In construction safety, this point of view has been proven by Lu and Yan (2013) and Xia et al. (2017), who employed an integrated analysis concerning the rational and emotional perspectives in risk perception and found that safety behaviour among construction employees relied mainly on emotional perception but not on rational calculations of risk. Thus, in this study, we consider risk perception as a direct emotional risk perception rather than a rational risk perception.

Table 2.7 shows the definitions of risk perception provided by different studies, in which risk perception is summarised as an assessment of risks. Such assessment reflects the decision makers' personalities, experiences, as well as the economic, cultural, policy and management environment they belong to.

Table 2.7 Definitions of risk perception

Author	Definition
Sitkin and Pablo （1992）	Risk perception is defined as a decision maker's assessment of the risk inherent in a situation.
ISO 31000 (2018)	Stakeholder's view on a risk. Risk perception reflects the stakeholder's needs, issues, knowledge, belief and values.
Lu and Yan (2013b)	Professionals' subjective judgment for risk factors' importance ranking.
Lund and Rundmo (2009)	Risk perception is the subjective assessment of the probability of experiencing a negative event.
Weinstein (1980)	Perception of risk is a social and cultural construct that reflects the values, symbols, history and ideology of people living in different cultures.

2.4.2.2 Risk perception and safety behaviour

The decision makers' risk perception is an important determinant of risk behaviours (Simon et al., 2000, van Winsen et al., 2014).

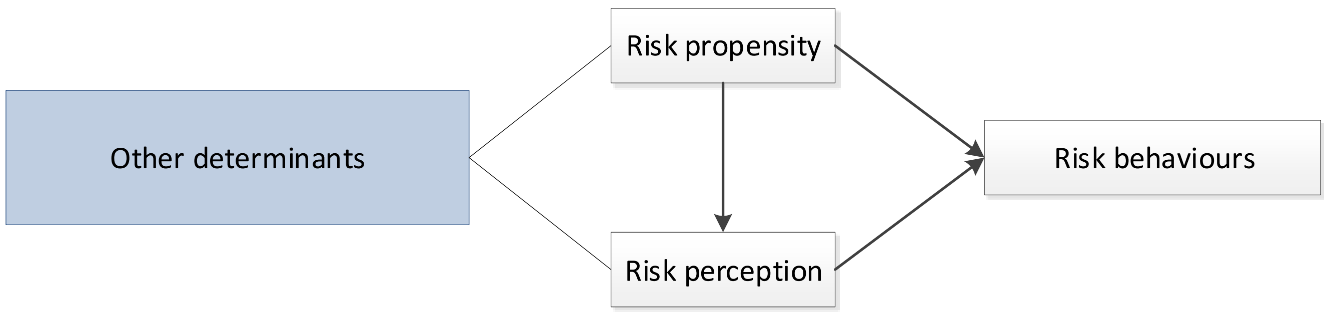


Figure 2.8 Conceptualised model of the determinants of risk behaviours (Sitkin and Pablo, 1992)

In the organisational management context, Sitkin and Pablo (1992) proposed a model to analyse the variables that influence individual risk behaviours (as shown in Figure 2.8). Two causal mechanisms were identified: risk perception and risk propensity. Both can act as mediating influences between the individuals' risk behaviour and other indirect factors (e.g. situational, organisational and individual factors) by channelling their cognitive processes, such as information gathering and sense-making. The empirical findings of Sitkin and Weingart (1995) supported that the decision makers' risk perceptions and propensities serve as direct determinants of their behaviour in risky situations. However, Simon (2000) indicated that a high-risk propensity is not necessary when individuals start new ventures and that risk-taking behaviour may proceed due to the decision makers' perceived small risk. In other words, risk perception might explain risk behaviours more than risk propensity does.

The relationship between risk behaviours and risk perception has been investigated in some studies. Decision makers are believed to become more concerned with losing assets (risk avoiding) when prior gains are available (a high-risk perception) (Kahneman and Tversky, 1979; Sitkin and Pablo, 1992). In other words, if a person deems an event as highly risky, then he or she is likely to carry out protective behaviour (Ji et al., 2011; Kouabenan et al., 2015; Lu and Yan, 2013; Wang and Yuan, 2011, Ji et al., 2018) . When safety risk is accurately perceived, workers are more likely to adopt responsive safety measures to prevent injuries; on the other hand, when safety risk is underestimated or inaccurately perceived, safe decisions are unlikely to logically follow and the likelihood of workplace injuries increases(Namian et al., 2018). One study on the link between two perceived food risks (contamination of chicken with salmonella or dioxin) and the behavioural reactions of 280 Dutch participants showed that people who perceived the risk as very high and saw themselves as vulnerable tended to avoid consuming contaminated chicken (Kuttschreuter, 2006). Similarly, Kouabenan et al. (2015) found that frontline managers become actively involved in safety management if they perceive that their supervisees are likely to be subject to high levels of risk in the workplace. However, little research has focused on the influences of risk perception specifically on the safety behaviours of safety construction workers (Griffin and Hu, 2013).

In hazardous industries, frontline workers and FLMs are directly exposed to danger and accidents in the workplace. Thus, we can conclude that if they perceived high risk, then they are likely to undertake more safety behaviours to avoid or mitigate risks. For construction workers, they may adhere to standard work procedures and carry out work in a safe manner. Obviously, these actions can be a direct and effective way for workers to prevent accidents or fatalities. For FLMs, if they perceive high safety risks, then they may promote safety programs, help workers with safety-related issues and attend safety meetings (Didla et al., 2009; Neal and Griffin, 2006). To summarise, in the workplace, workers and management personnel who perceive high risks are liable to engage in more safety actions as effective preventive measures to mitigate risks or hazards. Thus, the following hypotheses were developed:

The risk perception of construction workers will be positively associated with safety behaviours, whereas the risk perception of FLMs will be positively associated with involvement in safety management.

2.4.2.3 Risk tolerance and risk perception

On the basis of the above review, risk perception worked as the direct influencing factor of risky behaviours, and other variables may influence risk behaviours by influencing risk perception. Moreover, although risk perception may be influenced by a complex set of variables, such as internal and external factors, how risk perception can be influenced by risk tolerance has not been clearly discussed, especially for construction employees.

With regard to the relationship between risk tolerance and risk perception, non-objective risk perception might occur if no consideration was given to the individuals' risk tolerance (Hopkinson, 2012, Mu et al., 2014). As discussed above, risk perception refers to the subjective assessment of a risk, and individuals may decide how to behave based on this risk assessment. Risk tolerance refers to the individuals' tolerance level for a risk; the higher his/her tolerance is, the higher the capability that an individual believes he or she has for enduring relevant losses from risky actions. As a result, people with a high risk tolerance tend to underestimate risks, which means they have a lower risk perception. For example, in a gambling situation, one person is a millionaire and another is a white-collar worker, and they are facing a gamble of paying $5,000 for a chance to win $10,000. Obviously, the potential loss is $5,000. The millionaire may think this amount is not a big risk because he can tolerate such a loss. However, the white-collar worker may think $5000 is a big risk because he cannot tolerate such a loss. Some studies also claimed a negative relationship between risk tolerance and risk perception. Hunter (2002, 2006) indicated that the reason different risk tolerances lead to variations in airline pilots' risk behaviours is that individuals' risk perception is negatively related to their risk tolerance. Balaz and Williams (2011) emphasised the effect of risk tolerance on immigrants' risk perception and demonstrated that the more risks immigrants could accept, the more likely they were to underestimate the seriousness of potential risks. Ji et al. (2011) examined the relationship between risk tolerance, risk perception, hazardous attitudes and the safe operations of airline pilots. Results showed that risk tolerance has an indirect effect on safe operation through influencing the level of hazardous attitudes. Specifically, pilots with high risk tolerance scores tended to perceive the risk related to aviation accidents as small and exhibit a positive hazardous attitude. Accordingly, individuals with a higher tolerance for potential losses tend to believe the confronted risks are not that unsafe, which means they have a lower perception of risks. Thus, the hypothesis is that if workers have high risk tolerance, then they tend to have low risk perception. For site management personnel, if they assess risks as intolerable (which means they cannot tolerate potential losses even if the relevant risk treatment has been applied), then they tend to assess these risks as high.

Considering the hypotheses proposed above, we can conclude that safety behaviours may be motivated by a high level of risk perception in general. Furthermore, high risk perception (e.g. a risk is assessed as highly dangerous) can be derived from low risk tolerance. This observation leads to the following hypotheses: For workers, risk perception mediates the influence of risk tolerance on the workers' safety behaviours. Similarly, for FLMs, risk perception mediates the influence of the FLMs' risk tolerance on their safety management involvement.

2.5 Perceived Safety Climate in Risk Judgement

A pure discussion of the relationship between risk tolerance, risk perception and safety behaviour is not appropriate in practice, given that construction employees' risk judgement is influenced by particular safety climates (Hale and Glendon, 1987). In safety research, safety climate refers to the employee's perception of their organisation's safety policies, procedures and practices (Zohar, 1980, Zohar, 2000, Neal and Griffin, 2006), which consequently influences their safety behaviours (Wishart et al., 2017). As discussed, safety climate, as a shared understanding of workplace safety issues, serves as a frame of reference for employees that guides normative and adaptive work behaviours by providing cues regarding expected contingencies in behaviour outcomes (Schneider, 1975, Zohar, 1980, DeJoy, 1994). In other words, employees' behaviours are shaped or influenced by their perceived safety climate within the organisational context.

2.5.1 Safety Climate versus Safety Culture

The terms safety climate and safety culture have been used interchangeably and have caused a lot of confusion on what they actually refer to. In their report, Health and Safety Commission (1993) mentioned that the meaning of the term safety culture appears to be very similar to that of safety climate. In other cases, some studies on safety climate were included in the publication of special issue on safety culture whilst a book treats studies on safety climate and safety culture as one field of research (Antonsen, 2009).

Safety culture is a set of values, perceptions, attitudes and patterns of behaviour with regard to safety shared by members of the organisation; as well as a set of policies, practices and procedures relating to the reduction of employees' exposure to occupational health and safety risks, implemented at every level of the organisation, and reflecting a high level of concern and commitment to the prevention of accidents and illnesses (Muñiz, Montes-Peón, & Vázquez-Ordás, 2007). Health and Safety Executive (2005) proposed three distinct but interrelated dimensions of safety culture: psychological, behavioural, and corporate. The psychological dimension is about how people feel about safety and safety management systems. The behavioural dimension is concerned with what people do within the organisation, which includes the safety-related activities, actions, and behaviours exhibited by employees. The corporate dimension can be described as what the organisation has, which is reflected in the organisation's policies, operating procedures, management systems, control systems, communication flows, and workflow systems.

The psychological dimension of safety culture actually refers to the safety climate of the organisation, which encompasses the attitudes and perceptions of individuals and groups towards safety. This shows that safety climate is in fact part of safety culture, a conceptualisation that has been argued in previous studies (Cooper, 2000; Cox & Flin, 1998; Glendon & Stanton, 2000; Guldenmund, 2000; Wiegmann, Zhang, von Thaden, Sharma, & Mitchell, 2002).

2.5.2 Moderating Effect of Perceived Safety Climate on Risk Judgement

Current research has demonstrated that safety climate improvement in an organisation has a positive impact on employees' safety behaviours (Wills et al., 2009, Zou and Sunindijo, 2013, Fang et al., 2015b). These positive effects can be represented by the role of safety climate in the moderation of employees' thinking and behaviour patterns. Moderators indicate when or under what conditions a particular effect can be expected. Specifically, a moderator may increase, decrease or change the strength of a relationship (Baron and Kenny, 1986). Occupational safety studies have examined the moderating role of safety climate. For example, Probst (2004) investigated the moderating effect of the organisational safety climate on employees' job security and safety outcomes. They found that a strong safety climate can reduce or eliminate the adverse effect of employees' perception of security on safety knowledge, safety compliance, employee accidents, near-miss incidents and workplace injuries. In addition, organisations with poor safety climates had significantly higher rates of underreporting of workers' injuries than organisations with positive safety climates (Probst et al., 2008). Wishart et al. (2017) demonstrated that safety climate could significantly moderate the effect of thrill and adventure seeking trait on driving behaviours. That finding suggested that the development of a strong safety climate has the potential to improve work driving safety behaviours by reducing the impact of particular personality traits, such as thrill-seeking, within an organisational context. Accordingly, during the process of workers' risk judgements, the perceived safety climate is believed to possibly moderate the ways that workers interpret and evaluate safety risks.

However, the moderating role of perceived safety climate has not been clearly examined in workers and FLMs' risk judgement. One reason is that the way construction employees process safety risks has not been explicitly revealed; thus, examining safety climate's moderating role is difficult because a validated relationship is a prerequisite for testing a moderator (Baron and Kenny, 1986). Hence, the general hypothesis is that if construction workers and FLMs perceive a better safety climate, then the negative effect from risk tolerance to safety behaviours will be reduced (a more specific hypothesis will be given after ascertaining the relationships between risk tolerance, risk perception and safety behaviours).

2.5.2 Dimensions of Perceived Safety Climate

In this study, safety climate is introduced with the aim to explore how perceived safety climate could influence workers' and FLMs' risk judgement. Given that safety climate is composed of several dimensions, discussing each dimension's role in the construction employees' risk thinking process is necessary. Table 2.8 presents the dimensions of perceived safety climate as summarised from previous studies. Safety climate studies have been conducted across industries and countries, indicating the wide popularity of the concept in safety research.

Table 2.8 Dimensions of safety climate

Researcher(s)	Industry	Dimensions	Number of items

Zohar (2000)	Israeli manufacturing companies	1. Supervisory action 2. Supervisory expectation	10
Zohar and Luria (2005)	Israeli manufacturing companies	1. Supervisory active practices 2. Supervisory proactive practices 3. Supervisory declarative practices	16
Lingard et al. (2009)	Australian construction and maintenance authority	1. Supervisory safety leadership 2. Co-workers' ideal safety 3. Co-workers' actual safety	44
Fang et al. (2015b)	Hong Kong construction organisations	1. Workmate's influence 2. Supervisory environment 3. Workers' involvement 4. Competence	17
Clarke and Ward (2006)	UK-based glassware manufacturing organisation	1. Supervisory action 2. Supervisory expectation	10 (based on Zohar, 2000)
Kouabenan et al. (2015)	French nuclear plants	1. Upper management attitude towards safety 2. Immediate supervisory environment 3. Being called upon by subordinates	50

A lack of standardisation of agreement in determining the dimensions of safety climate is noted (Chen et al., 2018). Thus, safety climate dimensions are selected based on two rules: (1) considering the repetitive dimensions, as Zou and Sunindijo (2013) suggested that dimensions that resurface repetitively should be considered important and included in a safety climate survey; and (2) considering the multilevel nature of the safety climate. The assumption is that because employees are confronted with a multitude of (often inconsistent or contradictory) policies, procedures and practices, they attempt to make sense of it all by construing discrete policies and procedures as global patterns indicative of bottom-line priorities at the workplace. Therefore, the core meaning of climate relates to socially construed indications of desired role behaviour, originating simultaneously from policy and procedural actions of top management and supervisory actions exhibited by shop-floor or frontline supervisors (Zohar and Luria, 2005).

According to the safety climate dimensions presented in Table 2.8, the shared safety value may come from four aspects: (1) safety attitude from management (immediate supervisors and upper management), (2) interactions or exchanges between supervisors and their subordinates with regard to safety, (3) influence from co-workers and (4) perceived safety support. Thus, five dimensions of safety climate are determined.

Safety attitude of top management. Top managers are concerned with policy making and the establishment of procedures to facilitate policy implementation. Policies define strategic goals and their means of attainment, whereas procedures provide tactical guidelines for actions related to these goals and means (Zohar and Luria, 2005). Safety attitude, which can be perceived and felt from these policies and procedures, may influence employees' safety values.

Safety attitude of immediate supervisors. Immediate supervisors execute the procedures designed by top management by turning them into predictable, situation-specific action directives (Zohar and Luria, 2005). Their attitude can be reflected by the quality of their safety management behaviours. For example, when supervisors display a consistent pattern of actions supporting safety, it conveys to workers that safety is of significant value for the supervisors. As Ye et al. (2018) mentioned, supervisory behaviour may affect the way individuals and team members handle in the workplace, together with their ability to make decisions based on the risk perception profile of both the supervisor and the entire team.

Co-workers' influence. In the workplace, employees' safety perception might be influenced not only by top management and immediate supervisory environment but also by co-workers in the same group (Jiang et al., 2010). Burnkrant and Cousineau (1975) suggested that one of the most pervasive determinants of individuals' behaviour is the influence of those around them. From the perspective of interactionism, group members with similar backgrounds are likely to be a credible referent group for individuals (Ashforth, 1985). Therefore, co-workers' safety perception and behaviours are likely to play an important role in shaping group safety climate.

Communication between FLMs and workers. For workers, the immediate supervisors' safety attitude contributions to the shared safety value and communication, such as offering frequent and immediate feedback to workers, are of the same importance. Communication with immediate supervisors can make workers feel more direct safety emphases. As Hofmann and Morgeson (1999) mentioned, exchanges between leaders and group members regarding safety were significantly related to safety commitment. For FLMs, the interaction between workers refers to their feelings of being called upon by supervisees on safety issues. FLMs may share experiences with operators placed under their supervision, and that might motivate them to use their leadership role to better promote safety (Kouabenan et al., 2015). Thus, 'communication with supervisors' is used to determine the interaction between the worker and FLM groups.

Safety support. Safety support, derived from situational aspects of safety environment, is part of policies, procedures, regulations and safety management systems (HSE, 2005). According to Kemp (1991), safety support, which refers to measures to support injured workers (such as compensation, emergency planning and financial support from employers), is important to workers' risk judgement as it impinges upon people's willingness to tolerate risks. Generally, if people perceive a high safety support, which can reduce risks to a de minimis level, then they tend to tolerate more risks and continue risk-taking behaviours. This opinion was also confirmed by an interview with safety experts. Thus, the moderating role of safety support is considered in this study.

The moderating role of perceived safety climate can be explained from the subtle influence of safety climate. With regard to the selected five safety climate dimensions, the safety attitude of management personnel can be reflected by the extent of their management action, such as executing safety procedures; turning safety policies into predictable, situation-specific action directives; and expressing personnel management's concern and attitudes towards safety. According to their observance of management personnel's actions, employees tend to be aware of their safety expectations and adopt similar safety attitudes (Zohar, 2000). Effective communication with immediate supervisors is also important, given that certain instructions are passed on through interaction with supervisors. Easy and accessible communication reflects a positive safety climate. Co-workers' influence contributes to the group-level safety climate given that construction workers are accustomed to working together; thus, they may adopt similar risk perceptions and safety attitudes (Fang et al., 2006, Zhou et al., 2008). Workers would make consistent risk decisions according to their cognition (Fang et al., 2015) of workmates' and supervisors' safety-related attitudes and behaviours, and they would be more motivated to engage in safety activities than individuals who work in groups with a negative safety climate (Neal & Griffin, 2006). Hence, in general, if employees perceive a good climate (such as positive safety attitude from management personnel, active interaction between supervisors, safety behaviours from co-workers and strong safety support), then they would feel that safety is of high priority, and the negative influence of risk tolerance on safety behaviours would be weakened.

The moderating effect of safety climate can also be explained from the cultural nature of risks. Risk is a cultural construct (Adams, 1995), and therefore, risk information processing is driven by individual personality traits and the situation with which the individual is presented

(Michel et al., 2004). Safety climate in construction sites is believed to shape employee risk information processing. The workplace environment and its social processes and norms provide an important frame of reference for risk judgement regarding health and safety issues (Tulloch and Lupton, 2003, Rawlinson and Farrell, 2009). As risky behaviours they are not cultural but merely a manifestation of it, individuals' risk judgement, which works as the input of working behaviours, would be influenced by the perceived safety climate.

2.6 Influential Factors of Risk Tolerance

Numerous factors can be used to assess if a risk is tolerable, intolerable or negligible. Some studies have focused on influential factor identification, including Chang et al. (2004), Lehmann et al. (2009), Huang et al. (2013) and Vanem (2012). According to their findings, the influential factors of risk tolerance can differ depending on the geographic areas, the social and organisational culture background, or the industries (Tchiehe and Gauthier, 2017).

From a general point of view, Lind (2002a) mentioned that the influential factors of risk tolerance are not absolute, which means they may derive from many considerations, such as time principle and social, economic, cultural and political factors. In his subsequent work, Lind (2002b) stated that the criteria for tolerable risks involve a comparison of scalar quantities, such as expected gain or loss of life versus cost. It also requires considerations of political, social, moral, emotional and cultural judgements. Hartford (2009) considered the influential factors of risk tolerance from the perspectives of engineering and natural science. This study found that the criteria of risk tolerance constitute a complex matter of socio-economics and politics, and to fully consider risk tolerance assessment, people must think of historical legacy and the legal context.

Taking a given industry into consideration, the identification of risk tolerability influential factors remains complicated (Wenping and Xia, 2012). Numerous industry-based factors must be considered, such as the type of risks, the safety objectives to be achieved and the risk information availability (Rodrigues et al., 2011). To establish the risk tolerability criteria factors in a given context, researchers can consider (1) current, historical or estimated levels of risk in similar contexts and (2) the comparison of such levels with other societal risks in general. Following this method, Tchiehe and Gauthier (2017) identified the risk tolerance criteria in the field of occupational health and safety (OHS). Through a comprehensive literature review, eight parameters that consist of 19 criteria and 14 variables were identified. The eight parameters are the economic, personal, cultural, political, social, ethical, psychological and characteristics of the risk. To be more focused on OHS*, Canadian Occupational Saf*ety (2015) described seven factors that increase an employee's risk tolerance, namely, overestimating capability or experience, familiarity with the task, voluntary actions and being in control, overconfidence in the equipment, overconfidence in PPE and profit or gain from actions and role models accepting risks; and three factors that decrease it, namely, seriousness of the outcome, personal experience with a serious outcome and cost of noncompliance. In the field of construction safety, Wang et al. (2016) divided the factors that influence construction workers' safety risk tolerance into two categories: internal and external. Internal factors are subjective perception, safety knowledge and emotion, and external factors include production stress and safety climate. In accordance with to this review, the influential factors of risk tolerance in the construction safety field can be summarised in Table 2.9.

Table 2.9 Identified influential factors of risk tolerance

No.	Factors	Descriptions
F01	Working experience	Rich working experiences make workers more familiar with potential risks regarding projects, thus likely reducing risk-taking behaviour.
F02	Familiarity with tasks	This occurs when a worker has completed a task successfully multiple times and has the skill to complete it successfully without thinking, a state referred to as 'unconsciously competent'. Research shows that

		workers in this state can become unaware of potential hazards. This kind of autopilot complacency occurs without the worker having to refocus or refresh, thus creating a blind spot to potential hazards (Occupational Safety, 2015).
F03	Control of safety risk	Workers with a high capability to control safety risks may underestimate safety risks (Occupational Safety, 2015).
F04	Risk management knowledge	If individuals have a clear understanding of their risk management policy, then they would be more careful about their behaviours.
F05	Safety knowledge	The more safety knowledge they have, the clearer workers are about the seriousness of risk-taking in a construction project, and lower risk tolerance may happen (Pohjola, 2003).
F06	Emotion	Indicates whether workers are happy or not, as sometimes working with anger or sadness may result in irrational risk decision making (Segal et al., 2005).
F07	Belief in good luck	If individuals believe they are lucky all the time, then they would have higher risk tolerance because they may believe they would never be in unsafe situations.
F08	Voluntary action at work	When exposure to risk is seen as a voluntary action and part of an action where the employee is in control, the associated risks are more easily accepted. Formalized work planning built around solid and specific procedures creates a structure. A structured and regimented work routine reduces the sense that activities are voluntary, and this reduces employees' acceptance of risk (Occupational Safety, 2015).
F09	Emphasis on safety	This refers to how much workers realise and emphasise their safety.
F10	Work ability	This refers to workers' abilities to analyse and judge problems according to their own knowledge and experience. This ability plays an important role within the process of risk tolerance assessment.
F11	Confidence in rescue	As surprising as it may sound, employees may consciously or subconsciously expose themselves to risk thinking of the emergency response plan if something goes wrong. Employees' participation in emergency response training and practice drills or scenarios needs to reinforce that the protective system may fail and rescue only reduces the

		severity of impact; it does not prevent the incident from happening (Occupational Safety, 2015).
F12	Role model accepting risk	When an employee's supervisor or manager is seen to be taking shortcuts or intentionally taking a risk, the behaviour is normalised. Supervisors and managers regarded as the leaders that 'walk the talk' need to be involved in ongoing training. Training programming must include a discussion of normalisation of risk and how to prevent it (Occupational Safety, 2015).
F13	Regulators' safety attitude	Regulators' safety attitude decides the implementation of safety procedures on-site as part of the safety climate, and it will influence workers' assessment of risk tolerance.
F14	Communication with supervisors	Effective and trustworthy communication with supervisors can help strengthen understanding of safety risks; as a result, objective risk tolerance will be enhanced (Kemp, 1991).
F15	OHS regulations	Clear and specific safety regulations help workers realise the punishment against such regulations, thereby lowering their risk tolerance.
F16	Peer behaviours	The effect of peer behaviour indicates that workers would do what their peer workers do. If other workers complete work earlier by taking risks, then it will enhance an individual's risk tolerance towards taking the same risks.
F17	Managers' safety attitude	This immediate supervisors' safety attitude would affect workers' safety risk tolerance (Wong et al., 2016).
F18	Supervision from top-level managers	Supervision from government or supervisor may lower workers' willingness to take risks, thereby lowering their risk tolerance.
F19	Personal reputation	People will care about their reputation, and if they are known to have higher risk tolerance and like to take risks, then finding an employer would be difficult for them.
F20	Potential gain of profit from risk action	The implications of taking shortcuts must be part of every training and refresher training program. Strong messaging needs to come from the senior leadership, and it should be incorporated into the regular communication or refresher training to create a strong connection between the senior leader's message and the need to follow the procedures (Occupational Safety, 2015).

F21	Employers' reputation	If employers have a good safety reputation, then employees would be influenced by a good safety climate; consequently, risk tolerance would be lower.
F22	Production stress	If workers are working under high pressure, then they would have no time to think how to behave safely, and they would just want to finish the work as soon as possible.
F23	Little time to assess confronting risks	In some abrupt cases, quick response and decision making are required, given that little time is left for thorough discussion and consideration. In these cases, workers' risk tolerance varies depending on time allowed for making a decision.
F24	Completeness of relevant project information	Relevant project information is vital in making the right decision, and many risk assessments are carried out concerning the limited available historical accident data, while other considerations are ignored (Fung et al., 2012).
F25	Visible of project	If a project is visible, then people will behave safely (Kwak and LaPlace, 2005).
F26	Confidence in equipment	Overconfidence occurs when a worker places excessive or unwarranted trust that the equipment or tool will always perform exactly as designed. When a worker becomes familiar with particular tools and equipment and has not experienced any failures, he or she can become overly trusting that the equipment or tool will never fail. This confidence can occur with simple equipment, such as hand tools, or even complex systems, such as computer controls (Occupational Safety, 2015).
F27	Family responsibility	Family responsibility could help make individuals realize that they have family to take care of, so they cannot take safety risks.
F28	Insurance coverage	Insurance coverage represents potential safety support, especially for employees who suffer injuries on site (interview).

Although the reviewed studies contributed to the understanding of how risk tolerance is assessed, limitations exist. Firstly, current research mainly focuses on qualitatively identifying the influential factors of risk tolerance, which is hard to distinguish from the critical ones. This missing information increases difficulties for efficient management. Secondly, in the research of construction safety, previous studies paid attention only to workers' risk tolerance, and FLMs' safety risk tolerance has been ignored. This deficiency creates challenges for comprehensive risk management given that both workers and FLMs are important contributors to a construction project. These limitations show a significant knowledge gap in risk tolerance literature. To fill this gap and to achieve research objective four (see Section 1.3), this study plans to (1) identify the critical influential factors of safety risk tolerance for both construction workers and FLMs and (2) compare the differences between workers and FLMs.

2.7 Summary of Literature Review and Research Hypotheses

The human side of safety is widely accepted to play an important role in improving safety performance in the construction industry. Risk tolerance has been identified as one of the key factors in risk judgement. However, the following issues remain unresolved: What are the risk tolerance levels for construction safety risks? How does safety risk tolerance influence construction employees' safety behaviours? What are the critical influential factors of risk tolerance? Given the importance of risk tolerance, a comprehensive literature review regarding studies of risk tolerance and construction safety management was conducted, as shown in the prior sections. Accordingly, relevant research limitations and corresponding research directions for the proposed research questions are identified, as shown in Figure 2.9.

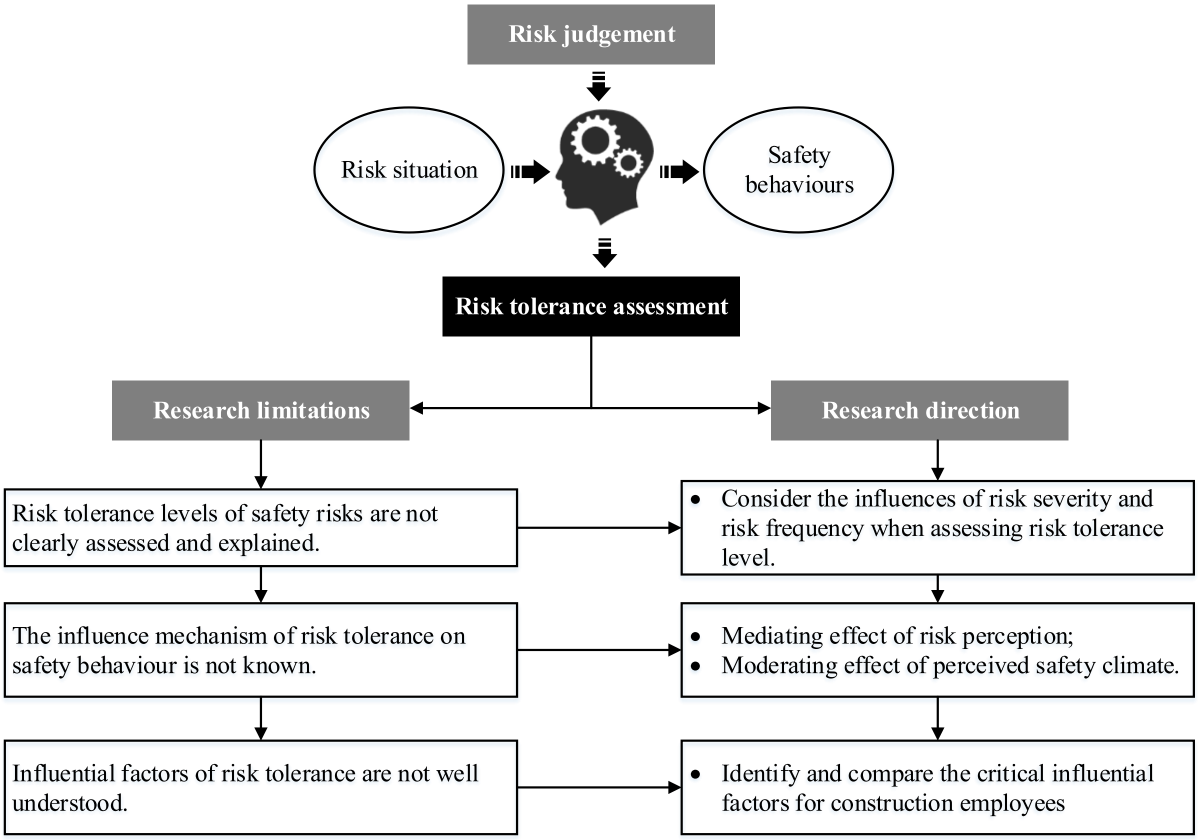


Figure 2.9 Summary of literature review

Risk tolerance level of safety risks is not well assessed and explained. As discussed in Section 2.3, current studies suffered limitations of assessing risk tolerance by only considering risk frequency without the influence of risk severity. Thus, considering both risk frequency and risk severity when assessing risk tolerance level is recommended.

Influential factors' contribution to risk tolerance are not well-understood. The literature review indicates that the influential factors of risk tolerance seem less known in the field of OHS, especially in the construction industry. Current research on the influential factors of risk tolerance is relatively lean. This implicit and poorly defined issue would oblige workers and employers to resolve the dilemma regarding accepting or refusing a risk on the basis of more or less explicit criteria. As a result, they may accept precarious situations by being unable to objectively justify the grounds for their decisions. Thus, identifying and comparing the critical influential factors of risk tolerance in workers and FLMs group is suggested.

The influence mechanism of risk tolerance on safety behaviours is not known. Current studies show that risk tolerance is an important factor that can influence safety behaviours in the field of occupational health and safety. However, no study provides empirical evidence to show how risk tolerance affects safety behaviour in the construction safety domain. The above literature review indicated that risk perception and perceived safety climate are critical factors in the influence mechanism between risk tolerance and safety behaviours (as discussed in Sections 2.4 and 2.5). To investigate their relationships, eight hypotheses were proposed, and the theoretical research model can be seen in Figure 2.10.

Hypothesis 1: Risk tolerance is negatively related to construction workers' safety behaviours.

Hypothesis 2: Risk tolerance is negatively related to construction workers' risk perception.

Hypothesis 3: Risk perception mediates the relationship between the construction workers' risk tolerance and safety behaviours.

Hypothesis 4: For construction workers, the relationship between risk tolerance, risk perception and safety behaviour will be moderated by the perceived safety attitude of top management (4a), safety attitude of immediate supervisors (4b), communication with supervisors (4c), co-workers' influence (4d) and safety support (4e).

Hypothesis 5: Risk tolerance is negatively related to FLMs' safety management involvement.

Hypothesis 6: Risk tolerance is negatively related to FLMs' risk perception.

Hypothesis 7: Risk perception mediates the relationship between FLMs' risk tolerance and safety management involvement.

Hypothesis 8: For FLMs', the relationship between risk tolerance, risk perception and safety management involvement will be moderated by the perceived safety attitude of top management (8a), safety attitude of immediate supervisors (8b), being called upon by workers on safety issues (8c), co-workers' influence (8d) and safety support (8e).

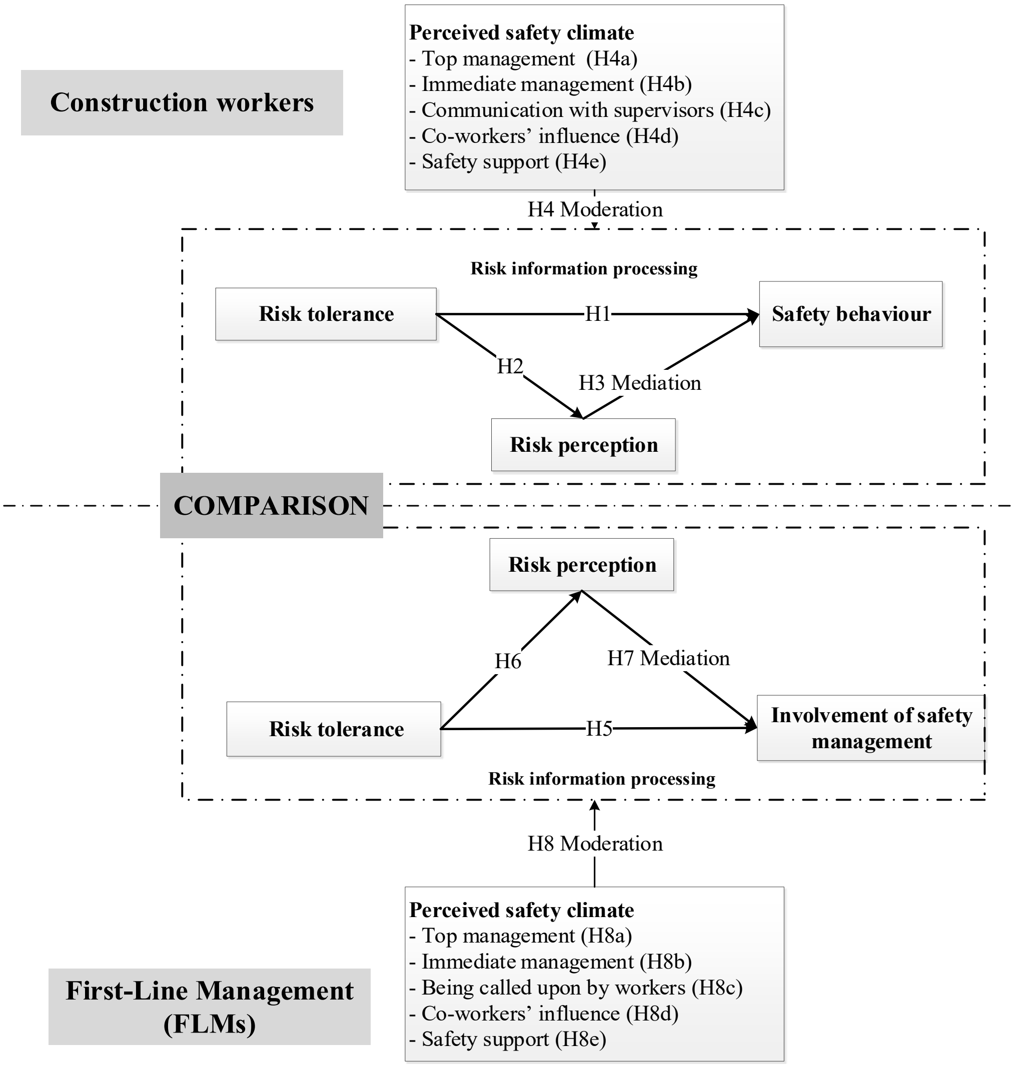


Figure 2.10 Theoretical research model and hypotheses for risk tolerance and safety behaviours

The research questions, aim and objectives presented in Chapter 1 along with the literature review in this chapter lead to three research directions in the study of risk tolerance in construction safety management. Moreover, the conceptualisation of relationships between the four research variables, namely, risk tolerance, risk perception, safety behaviours and perceived safety climate, was proposed. Subsequently, a theoretical research model and research hypotheses were developed. In the next chapter, the research methodology will be discussed.

Chapter 3 Research Methodology

This chapter covers four sections. The first section explains the four types of philosophical assumptions, which act as the foundations for the chosen research methods and methodology. The first section also reviews research methods that are commonly adopted in the study of human factors in construction safety and accordingly summarises the employed methodologies. The second section describes a detailed and comprehensive research design on the basis of the research questions and aims, including the research process, research methodology and adopted methods. The third section focuses on the process of questionnaire development and distribution, along with the sampling methods and analysis methods. The last section introduces the qualitative data collection and analysis methods.

3.1 Overview of Research Methodology

Research is a process of steps, including posing a question, collecting data, and analysing and interpreting it to increase our understanding of a topic or issue. The research topic acts as the heart of the research process that initiates the investigation (Creswell, 2002). In the context of this research, for instance, the research problem is to improve safety management in the construction industry by investigating the mechanism of risk tolerance in influencing safety behaviours. Before selecting an appropriate research methodology to solve this research problem, researchers should be fully aware of the philosophical assumptions they espouse (Zou et al., 2014, Creswell and Clark, 2007, Zou et al., 2018).

Worldview (also known as a paradigm) is the core of philosophical assumption and thus, all researchers must be aware of the implicit worldviews they bring to their research (Creswell and Clark, 2007). Worldviews directly affect the assumptions that researchers make about reality and the way to obtain knowledge (Creswell and Clark, 2007). Four main worldviews are found in research: positivism, postpositivism, constructivism and pragmatism. Positivism believes that knowledge is based on natural phenomena, which is unbiased and cannot be affected by the researchers' subjective view (Macionis and Gerber, 1999). As an amendment to positivism, postpositivism states that the subjective view of the researcher can influence what is observed (Seaman, 1995). To pursue objectivity, postpositivists use checks to recognise the possible effects of biases and eliminate them. Contrary to positivism and postpositivism, constructivism is a worldview that is made up of the understanding and meaning of phenomena formed through the researched person and their subjective view. Researchers and researched persons are believed to be dependent on each other. Creswell and Clark (2007) pointed out that, in constructivism, researchers start with the researched persons' views and build up to patterns, theories and generalisations. Positivism and postpositivism are associated with quantitative methods, while constructivism is associated with qualitative methods. Given the opposition of worldviews, a protracted debate exists between positivism (postpositivism) and constructivism, which has further evolved into the conflict between qualitative and quantitative research methodologies. Under this background, pragmatism was born. Pragmatism is problem-oriented, and according to this principle, whether qualitative or quantitative, a method that can solve research problems is a good method. With the support of pragmatism, the mixed methods approach has developed rapidly.

For an in-depth understanding of worldviews, five main philosophical considerations in research are proposed (Creswell and Clark, 2007, Tashakkori and Teddlie, 1998).

1. Ontology studies the nature of reality, and researchers with different philosophical assumptions could have varying views on the nature of reality. For example, positivism believes a singular reality, while constructivism believes in multiple realities.
2. Epistemology explores the nature of knowledge, justification and the relationship between cognition and reality.

3. Axiology mainly examines whether or not researchers include biased perspectives.
4. Logical inference focuses on the way to acquire knowledge, including induction and deduction.
5. Rhetoric concentrates on the language of research. For positivism, a formal style with a clear definition of variables is used. By contrast, the informal style, e.g. description, is adopted in constructivism.

According to the above five philosophical considerations, researchers could easily recognise the worldview in their research and clearly know what methodology they should use, as shown in Table 3.1. For example, if a researcher believes that both singular and multiple realities may lie behind the research problem that can be addressed based on practicality, then he has the worldview of pragmatism, which means he has multiple stances (biased and unbiased) and uses the combination of deductive and inductive logical inference with both formal and informal styles and writing. In this situation, mixed methods may be a good choice. Table 3.1 lists the worldviews and their philosophical considerations.

Table 3.1 Worldviews and their philosophical considerations

Philosophical consideration	Positivism	Postpositivism	Constructivism	Pragmatism
Ontology (what is the nature of reality?)	Singular reality	Singular reality	Multiple realities	Singular and multiple realities
Epistemology (what is the relationship between the researcher and the researched?)	Researchers and the researched are dependent on each other	The subjective view of the researcher can influence what is observed	Closeness (e.g. researchers visit participants at their sites to collect data)	Practicality (e.g. researchers collect data by 'what works' to address research problems)

Axiology (what is the role of values?)	Unbiased (researchers cannot be affected by the researched)	Unbiased (researchers recognise the possible effects of biases and use checks to eliminate them)	Biased (e.g. researchers actively talk about their biases and interpretations)	Multiple stances (e.g. researchers include both biased and unbiased perspectives)
Logical inference (what is a process of research?)	Deductive	Deductive basis	Inductive	Combining (e.g. researchers collect both qualitative and quantitative data and mix them)
Rhetoric (what is the language of research?)	Formal style (e.g. researchers use agreed-on definitions of variables)	Formal style	Informal style (e.g. researchers write in a literary manner)	Formal or informal (e.g. researchers may employ both formal and informal styles of writing)
Methodology	Quantitative	Quantitative basis	Qualitative	Qualitative and Quantitative

Source: Based on Creswell and Clark (2007) and Tashakkori and Teddlie (1998)

According to different worldviews, three common research methodologies are adopted in social research: quantitative, qualitative and mixed methods. A detailed explanation, including the merits, shortcomings, supporters and critics of each method, is presented in the following sections.

3.1.1 Quantitative Research

Quantitative research is the systematic empirical inquiry of observable phenomena by using statistical, mathematical or computational techniques (Given, 2008), and is the dominant methodology in natural and social sciences (Bryman, 2015). This methodology is associated with numerical data obtained from surveys, experiments and records (e.g. statistical yearbook, report and literature) (Leong et al., 2015). To ensure reliability and validity, the process of quantitative research is indubitably strict and can be standardised and repeated. Three main research designs are employed to conduct quantitative research (Creswell, 2013, Leong et al., 2015):

1. Experiment – This aims to determine causal relationships or test cause-and-effect hypotheses (Dane, 1990). Although experiments vary greatly in objective and scale, all of them must demonstrate repeatability and reproducibility. Typically, an experiment is designed to manipulate a single independent variable and minimise the effects of other variables. Through a comparison between experimental and control groups, the cause-and-effect hypothesis could be supported, refuted or validated.

2. Quasi-experiment – An empirical study for estimating the causal impact of an intervention on a specific population without random assignment limited by actual conditions (DiNardo, 2010). The quasi-experiment method has been widely used in engineering, psychology and social sciences, especially when manipulating the variable that the researcher wants to study is not logistically ethical or feasible (Harris et al., 2006).

3. Surveys – They study a sample of individual units from a population and provide quantitative information about the trends, states, attitudes or opinions of the sample being researched. Data in a survey are typically collected via structured interviews, questionnaires, structured observations or data acquisition equipment with the aim to establish generalisations (Zou et al., 2014).

Given that data are in the form of numbers from precise measurement and that a formal rhetoric is adopted in research, quantitative research cannot be easily misinterpreted (Leong et al., 2015). Its results and findings are acceptable because of the rigorous procedure of data collection and analysis that can be standardised and repeated. Quantitative research can produce exact numerical results and also present uncertainty and fuzziness, e.g. Monte Carlo simulation and fuzzy mathematics. Although the quantitative research method is genuinely popular with researchers, it is not free from criticism. Carr (1994) stated that most quantitative research does not explore the phenomenon in a natural setting because it aims to control or eliminate the impact of extraneous factors on the result of the study. Furthermore, quantitative research usually requires a large sample size to ensure the accuracy and representativeness of the results, which is expensive and time-consuming (Morgan and Smircich, 1980). Given resource constraints, large-scale research sometimes becomes impossible. Moreover, quantifying some variables (e.g. emotion and culture) under the existing level of knowledge can be challenging for researchers. Lastly, while quantitative research produces exact numerical results, it reflects what is happening rather than why it is happening (Zou et al., 2014).

3.1.2 Qualitative Research

Qualitative research is used to gain an understanding of the what and how of a phenomenon, and it emphasises words and meaning in data collection and analysis (Zou et al., 2014, Denzin and Lincoln, 2011). Qualitative research is typically seen as an interpretive naturalistic approach to reality. In other words, qualitative research is applied to study things in their natural settings, interpreting phenomena based on the meanings people bring to them (Denzin and Lincoln, 2011). Five popular research designs are utilised for conducting qualitative research (Creswell and Clark, 2007):

1. Ethnography is a descriptive research for a particular human society, such as describing a group or culture (Fetterman, 2010). In ethnography, researchers must be thoroughly immersed in the activities of the human society under investigation (participant observation).
2. Grounded theory is a systematic methodology in the social sciences involving the development of theory from empirical data through inductive thinking (Martin and Turner, 1986). Unlike the traditional model of research, ground theory does not carry out logical deduction based on assumptions set by the researchers themselves, but conducts induction from raw data.
3. A case study is an idiographic report of an individual, organisation, event, activity or process that exists in a specific time and place (Rolls, 2014, Rubin and Babbie, 2016). When researchers focus on cases, they could gain in-depth understanding through a variety of data collection methods, which cannot be achieved with large samples and a small amount of money (Zou et al., 2014).
4. Phenomenology is a research design that aims to understand the human consciousness and self-awareness, e.g. their perceptions and perspectives of a particular situation (Farina, 2014, Leedy, 1993). A typical method used in phenomenology research is a lengthy interview with respondents who have had direct experience with the phenomenon being studied (Leedy, 1993).
5. Narrative typically focuses on the lives of individuals (Zou et al., 2014). Narrative research often uses field texts, e.g. interviews, photos, field notes, letters and family stories, to investigate the way an individual creates meaning in their lives (Clandinin and Connelly, 2000).

Qualitative research is usually conducted in the early stages of a study when researchers do not have a systematic understanding of what is being researched. Through discussions, open-ended answers and explanations shared by participants, researchers could gain information and ideas beyond what they could obtain from surveys and secondary data (AlModhayan, 2016). Despite these advantages, qualitative research is the subject of a common and constant criticism. Many researchers argue that qualitative study is subjective, which means that it can be easily influenced by researchers. In reality, qualitative research is difficult to repeat or replicate. Even with the same procedure and sample, different researchers may have different findings due to their varying perceptions. Furthermore, critics pointed out that limited samples in qualitative research cannot represent populations, which can be seen as a weakness.

3.1.3 Mixed Methods Research

Mixed methods research is a research design that integrates qualitative and quantitative methodologies in the same research study. Many researchers believe that the use of mixed methods research could help enrich and improve the understanding of various phenomena of interest that cannot be fully understood by single methodologies (Lopez-Fernandez and Molina-Azorin, 2011, Venkatesh et al., 2013). Mixed methods research design has four major types (Venkatesh et al., 2013).

1. Triangulation design: The non-overlapping weakness and differing strengths of quantitative methods are brought together with those of qualitative methods (Patton, 1990). Triangulation design is often applied when researchers want to contrast and compare qualitative findings with quantitative statistical results or to validate or expand quantitative results with qualitative data (Creswell and Clark, 2007, Zou et al., 2014).
2. Embedded design: This involves the use of quantitative data (or qualitative data) to provide a supportive secondary role in a study based primarily on qualitative data (or quantitative data) (Creswell et al., 2003). For example, one type of embedded design

is to make qualitative data more quantitative, such as scoring interview responses and using a word cloud.

3. Explanatory design: This is the use of qualitative data to explain or build upon initial quantitative results (Creswell et al., 2003). For example, a quantitative survey study is first used to identify the law of occupancy, and then an in-depth qualitative study is applied to explain why this law exists.
4. Exploratory design: The results of qualitative research can help develop or inform quantitative research when measures or instruments are unavailable, the variables are unknown or no guiding framework or theory is available (Creswell and Clark, 2007).

Mixed methods research cannot be concluded to be more effective than qualitative research or quantitative research, yet realising the advantages and disadvantages of these methodologies, as well as their applicable conditions, is necessary. Mixed methods research is based on pragmatism, which is problem-centred and real-world practice-orientated (Creswell, 2013). Some critics argue that qualitative and quantitative methods carry different epistemological commitments that may not be combined (Zou et al., 2014). Qualitative data is multidimensional, that is, they could provide insights into a host of interrelated conceptual issues (Bazeley, 2004). By contrast, quantitative data is one-dimensional and fixed, which means they are composed of a single set response that represents a conceptual category created before data collection (Driscoll et al., 2007). Moreover, they do not change as insight changes. Therefore, loss of information could transpire when converting qualitative data into quantitative data. The distinctions between quantitative, qualitative and mixed methods are shown in Table 3.2.

Table 3.2 Distinctions between quantitative, qualitative and mixed methods (Bryman, 2015, Creswell, 2013)

	Quantitative approach	Mixed methods approach	Qualitative approach
Scientific method	Deductive or 'top–down' Test hypotheses and theory with data	Deductive and inductive	Inductive or 'bottom–up' Generate new hypotheses and theory from collected data
Most common research objectives	Description Explanation Prediction	Multiple objectives	Description Exploration Discovery
Focus	Narrow-angle lens Testing specific hypotheses	Multi-lens	Wide and deep-angle lenses Examine the breadth and depth of phenomena to learn more about them.
Nature of study	Study behaviour under artificial, controlled conditions	Study behaviour in more than one context or conditions	Study behaviour in its natural environment or context
Form of data collected	Collects numeric data using structured and validated instruments	Multiple forms	Collects narrative data using semi- or unstructured instruments
Nature of data	Numeric variables	A mixture of numeric variables, words and images	Words, images, themes and categories
Data analysis	Identify statistical relationships	Statistical and holistic	Holistically identify patterns, categories and themes
Results	Generalisable findings General understanding of respondent's viewpoint	Corroborated findings that may be generalisable	Particularistic findings In-depth understanding of respondents' viewpoint

	Researcher-framed results		Respondent-framed results
Form of final report	Statistical report, including correlations, comparisons of means and statistically significant findings	Statistical findings with in-depth narrative description and identification of overall themes	Narrative report, including contextual description, categories, themes and supporting respondent quotes

3.1.4 Analysis of Research Methods in Human Factors in Construction Safety

The above discussion explains the characteristics of different research methodologies, which comprise quantitative, qualitative and mixed methods. The discussion serves as a foundation for understanding and selecting appropriate methodologies for research on human factors in construction safety. This topic has received increasing interest in recent years and a concurrent expansion of the types of research methods employed. As a result, examining the prevailing methods, the research questions they can answer and the nature of knowledge that they can generate is necessary in studies on human factors in construction safety. This review can ensure that the methodology adopted in this research is suitable to address the research problems and produce research findings. Thus, this section aims to assess the research methods utilised in the topic of human factors in construction safety.

Given that searching every related research is impossible, delimitation for determining the research boundary is often necessary (Chen et al., 2015). The comprehensive literature review introduced in Chapter Two indicates a significant increase in research on human factors in construction safety since 2008. This review was limited to the period of 2008 to 2018 due to time constraints. The reviewed papers were selected based on the journals chosen in Table 2.1. Table 3.3 shows the number of papers related to human factors in construction safety in the 13 selected publications.

Table 3.3 Papers published in 2008–2017 on the topic of human factors in construction safety

Journal name	No. of papers
Safety Science	63
Accident Analysis and Prevention	20
Journal of Construction Engineering and Management	24
International Journal of Occupational Safety and Ergonomics	17
Journal of Safety Research	10
Automation In Construction	6

Journal of Management In Engineering	5
Applied Ergonomics	4
International Journal of Industrial Ergonomics	4
Journal Of Engineering Design and Technology	3
Journal of Civil Engineering and Management	4
International Journal of Injury Control and Safety Promotion	2
Construction Management and Economics	2
Total	164

A total of 164 papers were identified for methodology review. Given that the methodological position in some articles was not clearly stated, efforts were made to identify the methodology based on the characteristics of data collection and analysis. According to the explanations of quantitative, qualitative and mixed methods methodologies, the selected papers were classified based on the methods they adopted.

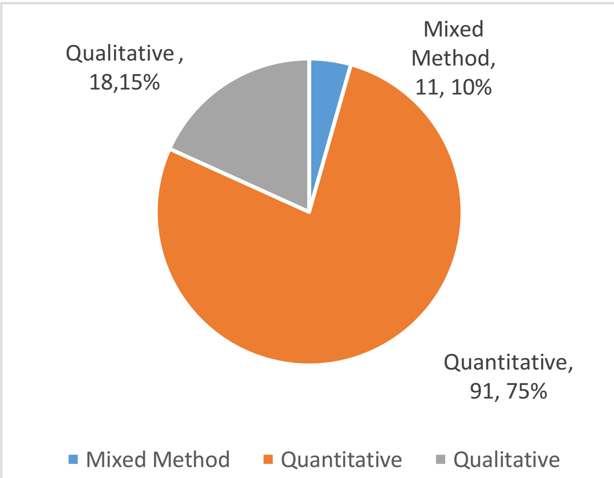


Figure 3.1 Research methodologies adopted in selected papers

Figure 3.1 presents the panorama of the research methodologies adopted in current research on human factors in construction safety. Ninety-one (75%) applied quantitative methods, 18 (15%) employed qualitative methods and 11 articles (10%) can be considered mixed methods research. These results indicate that quantitative research is the dominant methodology, which is similar to many other research fields, such as behavioural sciences (Lopez-Fernandez and Molina-Azorin, 2011), construction safety (Zou et al., 2014) and construction management (Dainty, 2008).

Further efforts were made to classify the methods employed within the qualitative, quantitative and mixed methods research, as presented in Figure 3.2. The most widely used method is advanced regression (51%), including SEM (structural equational modelling) and multiple regression, other analysis methods include descriptive statistics (17%), content analysis (13%), experiment (7%), grounded theory (3%), simulation (4%) and DM (data mining) / ML (machine learning) (5%), respectively.

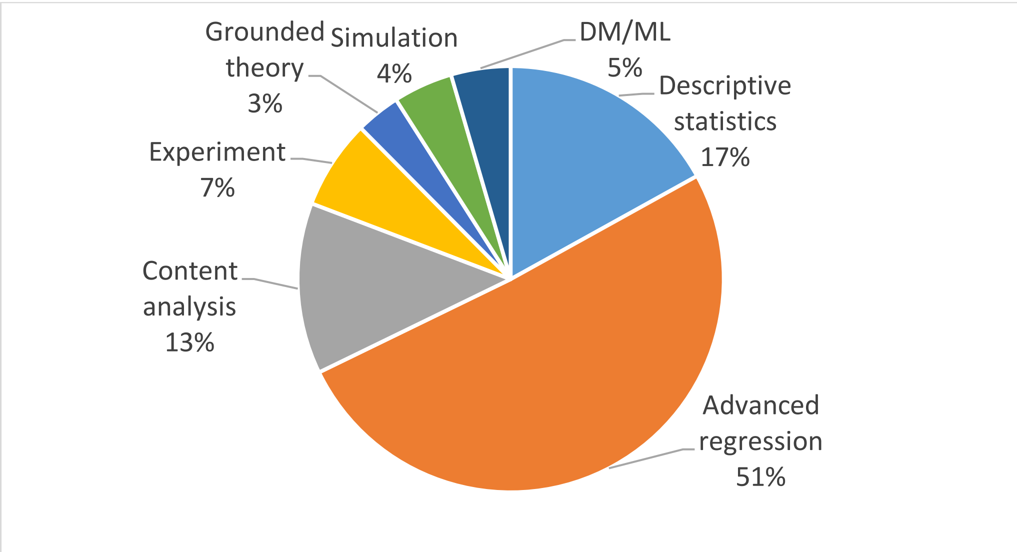


Figure 3.2 Research methods used in studies on human factors in construction safety

3.1.5 Discussion

The review of research methods in studies on human factors in construction safety indicates that researchers still mainly adopt the objectivist philosophical position, as reflected by the high percentage of quantitative research methods (Zou et al., 2014). This outcome further implies that past research has focused more on 'what' rather than 'why' and 'how'.

Through a list and analysis of the research questions of the 164 articles, these articles were found to mainly solve three types of research questions: (1) identification of human factors in construction safety issues, (2) the relationship between influential factors and safety behaviour and (3) human factors' work pattern. The three research questions are not mutually exclusive because several studies cover more than one question. For example, the paper 'Critical factors and paths influencing construction workers' safety risk tolerances' covers the first and the third research questions. The first type of research question focuses on identifying human factors that contribute to construction incidents. This identification combines both qualitative and quantitative methods. Content analysis helps identify relevant human factors from incident reports and archives, and statistical methods provide statistical evidence to uncover the extent of effects. The second type of research question concentrates on quantifying the relationships between human factors and safety behaviours. Unsafe behaviours are acknowledged as the primary and direct reasons for construction incidents (Mohamed et al., 2009); human behaviours can also be shaped by attitudes, perception, skills and working environment. Thus, this research direction has been the focus of most studies. The third type of research question is about revealing human factors' work patterns. For instance, how is an organisation's safety climate measured? What is the difference between the perceptions of people with different backgrounds? How does risk processing occur? Currently, most behaviour patterns are quantified by using measurement scales. However, quantitative data are used to show what the behaviour is. If researchers want to explain why and how the behaviour pattern is generated, then qualitative methods should also be used.

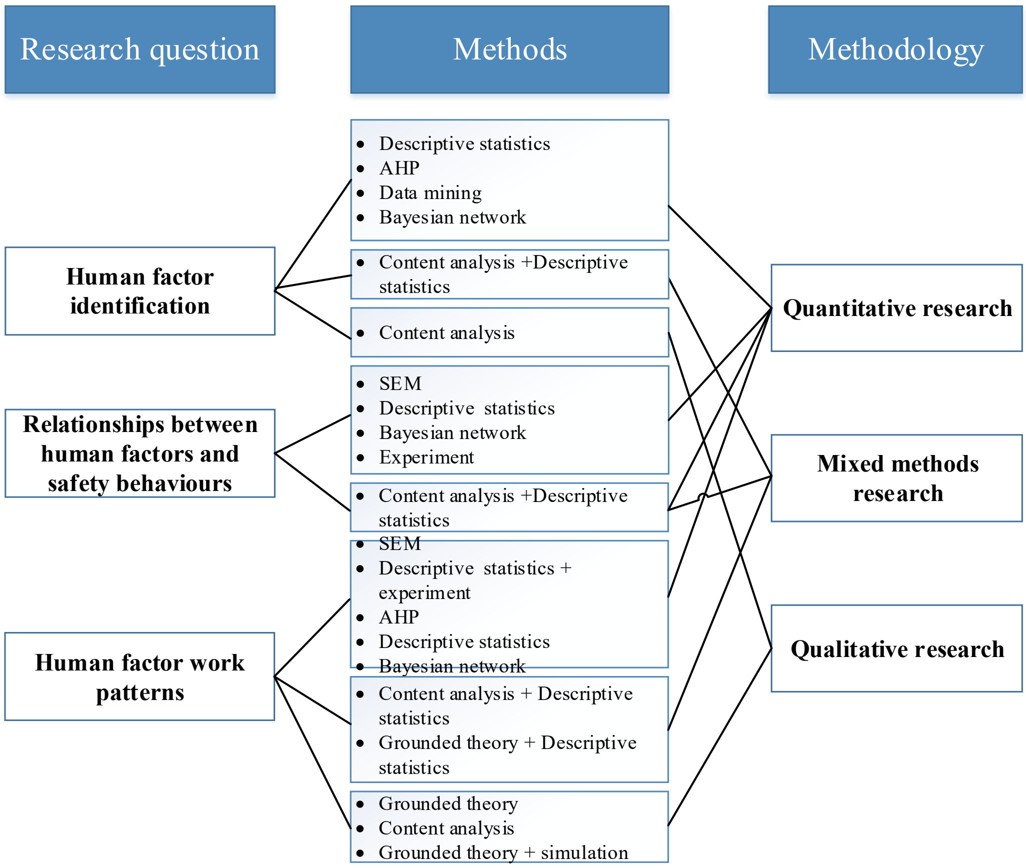


Figure 3.3 Types of research questions in human factors in construction safety and corresponding research methods and methodology

A high percentage of quantitative research and the research questions they addressed suggest that research on human factors in construction safety has focused more on 'what' has happened rather than 'why' and 'how' construction safety issues occurred. This characteristic implies that researchers in the area of human factors in construction safety still mainly adopt the objectivist philosophical position. Under this philosophical standpoint, safety policy, safety climate and safety procedures are the main objects of construction safety research. Given that these objects operate without human influences, quantitative research also aims to measure human factors in an objective way (such as through a measurement scale) and investigate the relationships between them. As a result, some quantitative methods, such as SEM, BN and correlation analysis, are employed to quantify the effects of human factors, including stress, safety commitment and risk perception, on construction safety management to derive an intuitive understanding of the influences of human factors on construction safety.

Quantitative research generates fundable and implementable results. However, researchers should recognise the importance of social and cultural factors in applying these findings to practice. Specific workplace traditions have a significant role in safety knowledge and skill development (Baarts, 2009). In this context, researchers must take a step back and perform further foundational work by exploring how knowledge is constructed in the first place (Tsoukas and Mylonopoulos, 2004). Therefore, adopting more constructivist ontological and interpretivist epistemological positions is a prudent approach that researchers must take. Qualitative research can provide answers to 'how' and 'why'. Although qualitative research accounts for 15% of the reviewed papers, a deep understanding of the 'why' of a research phenomenon is of considerable importance because it provides ways through which practitioners (1) can interpret the world around them, (2) can obtain actual answers from respondents by considering a research problem, (3) can offer the chance to learn phenomena in random events and (4) explain practical reasons to comprehend theoretical findings. Given the characteristics of qualitative analysis, it can help in exploring the knowledge of risk tolerance in the construction safety field, which serves as a foundation for further analysis. Moreover, after the investigation of relationships between risk tolerances, risk perception and safety behaviours, the practical explanations behind these findings are needed to answer why the research phenomenon happens to validate the theoretical model and/or offer a practical interpretation for easier understanding. Thus, a qualitative method, such as an interview, is necessary for this project.

Figure 3.1 shows that mixed methods research was applied by 10% of researchers of human factors in construction safety. Mixed methods research is not as simple as combining different research methods; rather, it is a research design with philosophical assumption and methods of inquiry. For better understanding of the current status of mixed methods research, 11 articles that used mixed methods to study human factors in construction safety are listed in Table 3.4. Mixed methods research covered three types of identified research questions, which means that mixed methods research has a wide range of application in research on human factors in construction safety. The most popular type of mixed methods in these studies is ‘interview + traditional statistics’. The interview plays two roles in these mixed methods research, namely, affording an understanding of focused factors and explaining or validating the quantitative results. The 11 articles demonstrate that mixed methods research not only offers insight into the ‘what’ but also into the ‘why’ and ‘how’ types of research problems. However, the 11 articles also show that mixed methods research on human factors in construction safety is in its infancy. Thus, this study adopted mixed methods research, as explained in the next section.

Table 3.4 Mixed method adopted in research on human factors in construction safety

No.	Title	Research problem	Description of mixed methods research
1	Human Safety Risks and Their Interactions in China’s Subways: Stakeholder Perspectives(Wang et al., 2017)	What are the human safety risk factors in subway construction in China and how do they interact from stakeholder perspectives?	The embedded design is used; qualitative research provides human safety risk factor identification by interviews, and statistical methods provide quantified interaction results.
2	Managing Cultural Diversity at U.S. Construction Sites: Hispanic Workers’ Perspectives (Al-Bayati et al., 2017)	What are the cultural barriers in U.S. construction sites?	A triangulation design is used; the researchers employed questionnaire survey (quantitative) and focused group interview (qualitative) to solicit Hispanic workers’ perspectives of cultural differences.
3	Investigating the effectiveness of fall prevention plan and success factors for program-based safety interventions (Goh and Goh, 2016)	What is the effectiveness of a fall prevention plan in reducing falls from a height and what are the influential factors?	An exploratory design is applied in this research. Observations and interviews were conducted to facilitate the design of the questionnaire.
4	Cognitive Factors Influencing Safety Behaviour at Height: A Multimethod Exploratory Study (Goh and Binte Sa'Adon, 2015)	What are the cognitive factors that influence safety behaviours at height?	This research uses the embedded design. Qualitative methods, such as on-site observations and interviews, are used to understand the critical safety behaviours and underlying factors that influence these behaviours. Then, questionnaire survey with data mining is applied to identify the critical influential factors.
5	Factors that affect safety of tower crane installation/dismantling in the construction industry (Shin, 2015)	What are the factors that contribute to accidents during tower crane installation/dismantling?	This paper uses the embedded design. Firstly, statistical methods help understand previous accident reports. Then, the focus group interviews allow the key influential factors to be identified.

6	If you've seen one construction worksite stretch and flex program… you've seen one construction worksite stretch and flex program (Goldenhar and Stafford, 2015)	How are stretch and flex programs structured and implemented, what are the associated costs and what are the perceived goals and benefits of implementation?	Embedded design is used in this research. Firstly, qualitative interviews were conducted to gain an in-depth understanding of construction stretch and flex programs. Then, a quantitative survey was undertaken to quantify the perceived costs and benefits.
7	Conceptualising safety management in construction projects (Sunindijo and Zou, 2013)	What constitutes the project management personnel's conceptual skill and how can this skill be developed and applied in the context of construction safety?	An explanatory design is used in this article. Firstly, SEM helps quantify the relationships between conceptual skills, safety management tasks and safety climate. Then, interviews were conducted to explain such relationships.
8	Safety leaders' perceptions of safety culture in a large Australasian construction organisation (Biggs et al., 2013)	How can safety leaders' perception of safety culture in a large construction organisation be understood?	An exploratory design is applied in this research. On the basis of the result of interviews with safety leaders, a quantitative perception survey was designed to confirm the key themes identified in the interviews.
9	An analysis for the causes of accidents of repair, maintenance, alteration and addition works in Hong Kong (Hon et al., 2010)	What are the causes of accidents of repair, maintenance, alteration and addition works in Hong Kong?	An embedded design is used in this article. Qualitative interviews were employed to derive the cause categories of RMAA accidents. Then, sequential quantitative research was used to quantify the relative importance of these categories.
10	Factors influencing worker use of personal protective eyewear (Lombardi et al., 2009)	What factors influence workers' decision to wear personal protective eyewear and what are the barriers?	An embedded design is used; the researchers use a qualitative approach to capture important factors influencing the expected themes. Then, quantitative method was used to quantify the importance of factors related to the use of personal protective eyewear.

11	The implementation of health and safety practices: Do demographic attributes matter? (Agumba and Haupt, 2014)	Could valid and reliable health and safety practices be implemented based on demographic attributes?	An embedded design is applied in this study. The Delphi method helped identify 31 categories of health and safety practices. Then, a quantitative survey was conducted to quantify the effects of demographic attributes on these health and safety practices.

3.2 Research Design

Rigorous, high-quality studies result from well-designed research procedures. In accordance with the review of research methodology in the field of human factors in construction safety, this research adopted quantitative and qualitative methodologies to answer the proposed research questions. A detailed research design is presented in Figure 3.4.

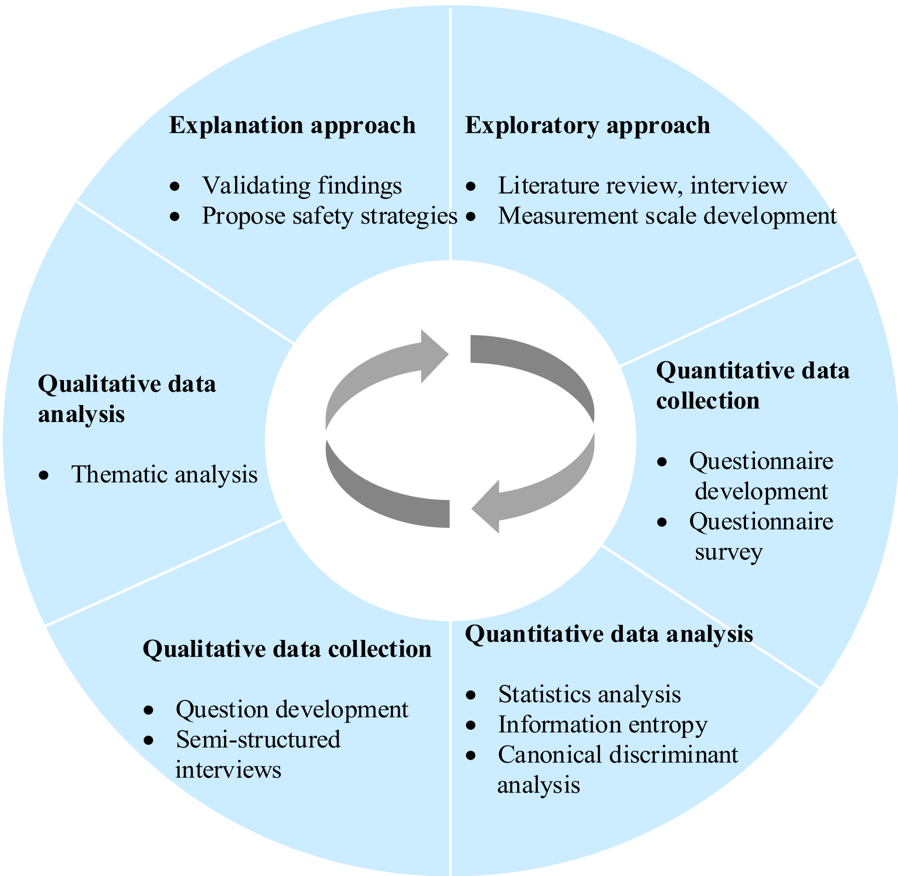


Figure 3.4 Research design

The first key factor that researchers must consider when choosing an appropriate research design is whether or not the design could match the research problems (Creswell and Plano Clark, 2007). Exploring how to understand and measure risk tolerance for safety risks in the construction industry is the first aim of this study. Thus, an exploratory sequential design is employed. The first phase of achieving this research aim is a qualitative exploration of risk tolerance. Relevant information will be collected through a literature review and an interview with construction practitioners. The second phase, which involves a quantitative approach, will follow up on the qualitative phase to develop a measurement scale of risk tolerance. Qualitative data are collected initially because an instrument of risk tolerance in the construction safety field is unavailable, and little guiding theory is available.

After obtaining the instrument of risk tolerance, the next research aims are to compare risk tolerance in worker and FLM groups, to determine how risk tolerance can influence safety behaviours and to identify the critical factors of risk tolerance. Answering these questions requires quantitative outcomes. Thus, quantitative research is designed, in which a questionnaire survey collects data on focal variables, including workers' and management personnel's background information; assessment of influential factors of risk tolerance; and instruments of risk tolerance, risk perception, safety behaviours and safety climate. After data collection, a series of quantitative analysis methods is employed, including

- Independent t-test: to assess whether the means of the two groups statistically differ from each other.
- Cronbach's alpha coefficient: to assess the reliability of the developed instrument.
- Factor analysis: to assess the construct or factorial validity of the questionnaires.
- Multiple regression: to determine the mediating role of risk perception and the moderating role of perceived safety climate (which is to test the proposed hypotheses 1-8).
- Information entropy evaluation method: to give weight for each factor according to opinion distribution.
- Canonical discriminant analysis: to identify the most different influential factors of workers' and FLMs' risk tolerance.

Results of the above quantitative analyses provide a comprehensive picture of understanding of risk tolerance in the construction safety field. In the next step, qualitative research methodology, rooted in the interpretivist philosophical assumption, is adopted to validate the quantitative findings and interpret them from the perspective of construction practices. This design is called an explanatory approach because it is a follow-up to help explain or build on initial quantitative results. At this stage, semi-structured interviews were held with several construction safety management experts. All the interviews were transcribed and analysed by NVivo, a computer-aided qualitative data analysis software program that can help code the transcribed interviews. Then, thematic analysis was employed to identify recurring themes and subthemes. Finally, a systemic knowledge of risk tolerance towards safety risks in the construction industry was gained by the designed mixed methods.

3.3 Quantitative Research Methodology

3.3.1 Questionnaire Development

This research employs a self-assessed questionnaire survey to measure risk tolerance, risk perception, perceived safety climate and safety behaviours, and to assess the effectivity of the listed influential factors of risk tolerance. Table 3.5 enumerates the questionnaires used in this research. During the development of the questionnaire, several rounds of meetings were conducted with the management personnel of the targeted construction organisations to obtain their support. A content information statement accompanying the questionnaire was also used to briefly introduce this project, where we discussed the project aim, the questionnaire content and the expected time to finish the questionnaire, and offered a guarantee that the information provided will be kept confidential and used solely for research purposes.

Two versions of the questionnaires were designed for construction workers and FLMs. Each survey had three parts: (1) part one: demographic information, (2) part two: 28 influential factors of risk tolerance and (3) part three: measurement of risk tolerance, risk perception, perceived safety climate and safety behaviours. All questionnaires could be completed in approximately 40 minutes. The questionnaires are shown in Appendix 1.

Table 3.5 List of questionnaires

<table>
<tr><th>No.</th><th colspan="2">Factors being measured</th><th>Questionnaire</th></tr>
<tr><td>1</td><td colspan="2">Risk perception</td><td>Literature review, interview with construction experts and a safety report on the Australian construction industry were employed to develop the questionnaire</td></tr>
<tr><td>2</td><td colspan="2">Risk tolerance</td><td>Literature review, interview with construction experts and a safety report on the Australian construction industry were employed to develop the questionnaire</td></tr>
<tr><td>3</td><td colspan="2">Safety behaviours</td><td>Safety behaviours by Fang et al. (2015b) for workers and the
involvement of safety management by Kouabenan et al. (2015) for FLMs</td></tr>
<tr><td rowspan="6">4</td><td rowspan="6">Perceived safety climate</td><td>Safety attitude of top management</td><td>Top management safety attitude by Kouabenan et al. (2015)</td></tr>
<tr><td>Safety attitude of immediate supervisors</td><td>Group safety climate by Fang et al. (2015b)</td></tr>
<tr><td>Co-workers' influence</td><td>Group safety climate by Fang et al. (2015b)</td></tr>
<tr><td rowspan="2">Communication between workers and FLMs</td><td>Communication with immediate supervisors -
Measurement scale by Hofmann and Morgeson (1999) and Cigularov et al. (2010)</td></tr>
<tr><td>Communication with workers -
Measurement scale by Kouabenan et al. (2015)</td></tr>
<tr><td>Safety support</td><td>Literature review and discussion with construction experts were employed to develop the questionnaire</td></tr>
</table>

3.3.1.1 Risk perception and risk tolerance questionnaire

The literature review indicates that the scenario-based survey is a common and appropriate way to measure practitioners' risk perception and their willingness to tolerate risks in occupational health and safety (Haslam et al., 2005, Hunter, 2006, Ji et al., 2011, Rodrigues et al., 2015). For instance, to evaluate pilots' risk perception, Hunter (2006) developed a self-assessed measurement that consisted of 26 sentences that describe an event or situation, including high flight risk, altitude risk, driving risk and everyday risk during pilots' operation. With regard to subjective risk tolerance (willingness to tolerate risks), Hunter (2002) and Pauley et al. (2008) created a measurement scale that consists of 16 sentences describing situations such as aircraft system failure risk, crew operation risk and flight weather risk. For example, '*When the aeroplane climbed to 19,000 feet altitude layer in the north of 42 sea miles from the airport and airspeed was 300 knots, the aircraft encountered severe turbulence. The pilot disconnected the autopilot to turn 60° to the right area from thunderstorms blocked and decided to continue the flight*'. In the above examples, participants were asked to indicate their level of acceptance with the behaviour. A higher score indicates that the person is willing to tolerate higher risks. These risk scenario-based measurement scales provide opportunities to understand risk-related attitudes. However, the risk scenario design has two obvious flaws, especially in the construction safety field.

The literature review (Section 2.3) shows that current research on risk tolerance level is limited in (1) using insufficiently described risk scenarios and (2) assessing risk tolerance without considering risk frequency and risk severity. To cope with this limitation, four criteria were used to design safety risk scenarios (adapted from Rodrigues et al., [2015a]).

- Accident injury types should include common physical injuries on site, mental injury and fatal;
- Each risk scenario should contain information on risk frequency and risk severity;
- Each injury type should contain three scenarios, including the least, medium, and worst frequency and severity;
- Some scenarios need to have the same risk level for further analysis of the influence of risk frequency and risk severity.

The use of a mid-point Likert scale is also questionable. The widespread use of rating scales in social research has generated considerable debate over the optimal number of scale points to use (Garland, 1991). The mid-point category in Likert scales is argued to possibly facilitate social desirability bias, which arises from respondents' desire to please the interviewers or appear helpful or to not be seen to give what they perceive as a socially unacceptable answer. Garland (1991) examined the effect of survey results obtained by using a Likert scale without a neutral or mid-point. Results indicate that social desirability bias can be minimised by eliminating the mid-points on a Likert scale. Therefore, this research uses a six-point Likert scale to measure responses.

In accordance with the above discussions on risk scenario design, this research performed a comprehensive review of construction injury data reported by Safe Work Australia (2015) and discussed with construction experts to ensure the feasibility and practicability of the designed risk scenarios. With regard to injury type, the Construction Industry Profile reported by Safe Work Australia in 2015 showed that falls from ladders is the most common cause of injuries, accounting for 30% of the total injury claims from 2008 to 2014 in Australia. Injuries caused by exposure to inanimate mechanical forces accounted for 62% of serious injury claims. During the design of this questionnaire, a safety expert mentioned that 'Slipping on constructions site is also a common injury type, and almost 80% construction workers have witnessed or experienced it. Also, the legs and knees are the most vulnerable body parts in slipping on site'. Hence, the three common injury types were considered in the risk scenario design.

In terms of the injured body part, *Work-related fatalities*, a report by Safe Work Australia, indicated that the most commonly injured body parts in construction hospitalisation cases were the wrist and hand, accounting for 43%, and leg-related injuries compose 12%. In addition, the lower back is the most frequently injured body part while working in the construction industry, which accounted for 15% of serious claims. Aside from this common physical injury, from 2010 to 2013, an 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 with other injuries. Thus, mental stress is also being considered in this research. According to suggestions from safety experts, we must also consider the fatal risk scenarios, even if they are uncommon. However, if a fatal risk exists, then understanding how construction employees really think of it is necessary. Thus, the three common body injuries, mental injury and fatal were considered in the risk scenario design.

With regard to the injury frequency and time lost, the *Statistics on Workers in Australia* published by Safe Work Australia shows that in building construction, the incident rate (serious claims per 1,000 employees) is from 9–27.7 annually, the time lost for each serious claim is from 4.8–6.4 weeks annually and the average number of fatalities in the construction industry is 36 workers per year. Hence, these data work as a baseline for injury frequency and potential loss design.

After a discussion with safety experts and a review of Australian construction safety data, five risk scenarios with common injuries and risk behaviours were designed, including a back injury from a fall, a wrist injury from exposure to disconnected power tools, a leg injury from slipping on sites, mental stress and fatal. Given that workers are more sensitive to the visible severity of potential risks, three different severity levels for each physical injury type were provided based on discussions with safety experts (the safety experts claimed that although workers are familiar with common physical injuries on site, they may still have different tolerance judgements due to various injury severities). As mental stress and fatal seldom occur on site, one risk frequency for mental stress and two risk frequencies for fatal were designed. Accordingly, 12 construction risk scenarios were developed. Questions were used to measure workers' risk perception and risk tolerance. Examples include 'For the scenarios below, please indicate how risky you think they are' and 'Please indicate the extent of your tolerance to the situations below'. Two six-point Likert scales were used for responses (for risk perception, from 1 = not risky at all to 6 = very risky; and for risk tolerance, from 1 = definitely intolerable, to 6 = definitely tolerable).

3.3.1.2 Safety behaviour and involvement in safety management

In the construction workers' group, the instrument for measuring safety behaviours contains two indicators: (1) SB1: self-reported own safety behaviours, and (2) SB2: self-reported workmate's safety behaviour. For each indicator, two expressions were given—one normal and one reversal (Brown et al., 2000, Fang et al., 2015). For FLMs, six items were used to measure the extent to which FLMs feel they are being involved in risk prevention actions, for example, (1) being involved in accident analysis and (2) participating in prevention plans with contractors (Kouabenan et al., 2015). A six-point Likert scale (1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = frequently and 6 = always) was used to measure workers' safety behaviours and FLMs' involvement in safety management.

3.3.1.3. Perceived safety climate questionnaires

Safety climate was assessed using a six-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = slightly agree, 5 = agree and 6 = strongly agree) with five sub-dimensions: safety attitude of top management, safety attitude of immediate supervisors, communication between immediate supervisors and workers, co-workers' influence and safety support. Perceived safety attitude of top management was evaluated using a questionnaire developed by Kouabenan et al. (2015) consisting of four statements, such as 'Top management always refers to safety when talking about the company, especially to the public' and 'Top management takes safety into account when planning work procedures'. Safety attitude of immediate supervisors was measured by a questionnaire developed by Fang et al. (2015) with six statements, such as 'My supervisors give us frequent safety training' and 'My supervisor makes sure we receive all the equipment needed to do the job safely'. Communication with supervisors was evaluated by questionnaires developed using the measurement scale by Hofmann and Morgeson (1999) and Cigularov et al. (2010) with three items, for example, 'I feel comfortable discussing safety issues with my supervisors' and 'I feel that my supervisors encourage open communication about safety'. Regarding co-workers' influence, a questionnaire designed by Fang et al. (2015) was used in this research. Sample items include 'My co-workers' behaviours could sometimes influence my decisions'.

According to construction safety research, no relevant measurement instrument is available for safety support. Therefore, developing a new, reliable and valid instrument was necessary for this research. Discussions with construction safety experts were conducted to understand safety support for construction workers in the Australian construction industry. If construction accidents happen, then workers may suffer physical and/or psychological injuries. Support is needed to cope with these situations, including insurance coverage, employers' caring and financial support (Feng and Wu, 2015, WorksafeVictoria, 2016, Work Safe Australia, 2015a). Accordingly, nine items (shown as SS01–SS09 in the questionnaire) were designed to represent safety support for injured workers.

1. If I were injured at work, I would not be worried about medical costs because the insurance I get through my employer would cover them.
2. If I were injured at work and needed three weeks off, the weekly payment I would receive during my time off would cover my basic living expenses.
3. If I were injured at work, my employers would do what they could to support me.
4. If I were injured at work, my employer would provide enough information about my rights and responsibilities.
5. My employer would treat me fairly during the claim process.
6. My employer would treat me fairly after the claim process.

7. We have sufficient first-aid materials at our site.
8. I am happy with my current income from construction work.
9. I feel my job is secure.

3.3.2 Quantitative Data Collection

Prior ethical review is required for all proposed human research activity conducted under Swinburne auspices. A human research proposal must be determined to meet the requirements of the *National Statement on Ethical Conduct in Human Research (2007)* and deemed ethically acceptable before research can begin. Researchers who wish to conduct studies involving humans, such as interviews, questionnaires surveys and observations, are required to submit an application form to the Human Research Ethics Committee. This study followed this policy and started data collection only after ethics approval was granted by the Swinburne University Human Research Ethics Committee.

Before large-scale data collection began, the questionnaire was administered to a small pilot sample of two academics and four construction practitioners to ensure that it would be easy for workers to understand and that no ambiguous and/or confusing expressions were included. Feedback from the pilot sample was positive, with only slight rewording required.

3.3.2.1 Sampling

This research employed cluster sampling method as its sampling strategy. Cluster sampling is utilised when the population cannot be defined as homogeneous, making random sampling from classification impossible. This sampling strategy offers the practical advantage of enabling the creation of a good sampling frame of clusters (Zou & Sunindijo, 2013).

The first stage involves determining the target population. Given the research aims and objectives, frontline construction workers and FLMs at leading construction organisations in Australia were selected as the target population. These construction organisations consider safety as their top priority and have sophisticated safety management systems. Information about top construction companies can be found on the website of the Australian Constructors Association (ACA) (http://www.constructors.com.au). One of ACA's commitments is to promote construction industry safety by requiring all its members to follow safety principles in terms of safety culture, safety in design, safety leadership and capabilities. This dedication is highly aligned with the research aim of this study. Therefore, members of the ACA were chosen as the sampling frame in the sampling population.

The second stage involves further selecting construction organisations and approaching the appropriate ones. The ACA is composed of 19 construction organisations, and ensuring that the targeted members have similar types of services and projects is important. After checking the organisation profiles and their ongoing projects, four construction organisations were approached and invited to participate in the research. Invitation letters explaining the purpose of the survey and its potential benefits for the construction industry were distributed to the main safety managers or general managers in these organisations. Meetings were then held with construction leaders from the four companies that showed interest in this study. In the end, three organisations agreed to participate in this research.

The third stage involves determining which projects under construction in the selected construction organisations would be the appropriate ones and the arrangement of a questionnaire survey. A discussion with the construction leaders of these three organisations revealed that they have similar projects under construction, with the same construction type-intermixing of commerce and residence, similar building type-shear wall structure and similar location (Melbourne CBD). Thus, this research focused on these projects to conduct the questionnaire survey. Following meetings with the project managers, the questionnaires were distributed to workers and FLMs during toolbox talks to avoid occupying the workers' time and to ensure the high quality of data. A brief introduction to the survey was given, including its research aims, potential benefits for employees, the structure and content of the questionnaire, and ethical issues. While the questionnaires were being completed, no project management staff was allowed to be present and no communication occurred between the workers.

Data collection was conducted from October 2016 to May 2017 at a total of seven construction projects. After six months of conducting strictly controlled surveys, 262 questionnaires were received from construction workers, with 192 valid responses that were useful for further analysis. For the FLM respondents, 200 questionnaires were collected, of which 164 valid responses were selected for subsequent analysis. Some responses were dropped due to either incomplete or arbitrarily completed questionnaires. The arbitrariness was manifested by the responses to the safety behaviour measure for workers and safety management involvement for FLMs. In these measurement scales, several reverse questions were asked. For example, 'I follow all the safety procedures for the jobs that I perform' and 'I take chances to get the work done'. Such indirect questions constitute a common and effective way to ensure the quality of responses (Zou and Sunindijo, 2015).

This response sample size meets the rule of thumb for the minimum sample size recommended by Nunnally and Bernstein (1994): 'If there are only two or three independent variables and no preselection is made among them, 100 or more subjects will provide a multiple correlation with little bias' (p. 189). Among the valid respondents, 96.9% were male workers. Most were aged between 25 and 40. Twenty-one (11%) workers were aged 24 or less, 127 (66%) were aged between 25 and 40, and 44 (23%) were aged 41 or over. Over half of the valid participants (50.4%) had high school certificates, and one-third graduated with vocational education and training diplomas. The average time working in construction was around nine years. The main working trades included in the valid sample were carpenters (21%), electricians (16%), plasterers (13%), heavy equipment operators (12%), roofers (11%) and plumbers (10%). In the FLM group, 26 (16.1%) participants were female. Most were aged between 25 and 40 (68%). Nearly three-thirds of them have a bachelor's degree.

3.3.3 Quantitative Data Analysis Methods

Four main quantitative analysis methods were applied in this research: mediating effect analysis, moderating effect analysis, information entropy and canonical discriminant analysis. Mediating analysis was used to validate the proposed hypotheses between risk tolerance, risk perception and safety behaviours. Then, according to the mediating test results, moderating analysis was conducted to test the proposed moderating role of perceived safety climate. Information entropy is mainly used to check the distribution of the participants' opinion on each measurement scale, and the distribution is used as the basis for deciding the entropy weight for each influencing factor. Canonical discriminant analysis applies the idea of classification to categorise participants into workers or FLMs according to the factors that indicate the greatest difference between them.

3.4 Qualitative Research Methodology

This research adopted a mixed method design of explanatory design. As the name implies, qualitative research methodology aims to confirm quantitative findings and provide practical explanations for the mathematical relationships. Semi-structured interviews were used to collect data in this qualitative research methodology. On the basis of the findings of quantitative research, a list of questions was developed, and the interviewees were required to provide answers or discussions. The interviewees were asked the same questions; thus, the wording would be similar from one participant to another. However, this qualitative research focuses on the views provided by participants that are important in explaining and understanding the proposed questions.

3.4.1 Interview Question Development

According to the quantitative research objectives, parts of interview questions were designed to obtain validations and explanations for current findings. In Part One, some warm-up questions were asked to help introduce the interview aims. In Part Two, questions attempt to validate and obtain practical explanations for the quantitative findings. In Part Three, queries aim to seek strategies for facilitating safety management from the perspective of risk decision making. Thus, the detailed interview questions were designed after completion of quantitative analysis. The designed interview questions can be seen in Appendix 2.

3.4.2 Qualitative Data Collection and Analysis

The semi-structured interviews were conducted in two ways: face-to-face and phone interviews, as determined by the interviewee's convenience. To give interview participants basic information, an interview information package was sent to them one month before the interviews. Several important contents were included: (1) permission to allow audio recording during the interview, (2) interview questions and (3) approximate duration of the interview.

Unlike in the questionnaire survey sampling, purposive sampling was employed to select the interview participants in this qualitative research. At the end of a quantitative questionnaire survey, participants were asked, 'Do you want to further discuss these research findings? If yes, please leave your contact information'. With the use of the collected contact information, interview details were sent to these people who expressed interest in being interviewed. A total of 10 interviews were conducted, and the profiles of the interview participants are shown in Table 3.6. The research acknowledges that the sample size is small. Thus, the results must be cautiously interpreted and applied. However, in this research, this qualitative research sample is argued to be adequate for the following reasons: Firstly, the thematic analysis (shown in Chapter 5) found that not much new code can be extracted from the penultimate interview (the sixth interview), which indicated theme saturation. Secondly, the interview sample represents various positions in construction management. Thus, comprehensive perceptions, opinions and decisions about the scene can be achieved. Thirdly, the interview participants had an average of 15.6 years of experience in safety management in the construction industry, which ensures that they have sufficient experience and capability to provide valuable insights on the proposed problems. Fourthly, no strict requirement exists for the number of interview samples. Some qualitative research contends that a small size (often less than 10) is much more important in the search for depth of meaning. In other words, for such depth to be achieved, a more important detail is for the research to be intensive, and thus persuasive, at the conceptual level, rather than to be extensive with the intent to be convincing, at least in part, through enumeration (Crouch and McKenzie, 2006, Creswell et al., 2007).

The thematice analysis method is applied for qualitative analysis, the detail of this method can be seen in Section 5.2.

Table 3.6 Profile of interview participants

Code	Position	Gender	Age	Education	Experience (year)
OHSM-01	OHS manager	F	35–39	Bachelor's degree	15
PM-02	Project manager	M	30–34	Master's degree	14
CM-03	Construction manger	M	50–54	Master's degree	34
SM-04	Site manager	M	30–34	Master's degree	6
CM-05	Construction manager	M	35–39	Master's degree	12
OHSM-06	Occupational Health and Safety manager	M	35–39	Bachelor's degree	13
WHSS-07	Work Health and Safety specialist	M	35–39	Bachelor's degree	15

OHSM-08	Occupational Health and Safety manager	M	40–55	Bachelor's degree	19
OHSM-09	Occupational Health and Safety manager	M	35–39	Bachelor's degree	12
SM-10	Site manager	M	35–39	Bachelor's degree	16
				Average = 15.6	

3.5 Summary

This chapter begins with an overview of the methodology applied in social sciences, including philosophical assumptions and the characteristics of quantitative, qualitative and mixed methods approaches. Thereafter, a comprehensive literature review of the employed methods in the research on human factors in construction safety was conducted, and results indicate that quantitative methodology with the objectivist philosophical assumption is the dominant methodology in this area. However, the mixed methods technique emerged in recent years because (1) it offers strengths that offset the weakness of separately applied quantitative and qualitative research methods, and (2) it encourages the collection of more comprehensive evidence for answering questions that quantitative and qualitative methods alone cannot answer. Consequently, this research adopted mixed methods research design, in which quantitative and qualitative methodologies were employed.

A questionnaire survey was used in this research for quantitative data collection. This survey helps identify the critical influential factors of risk tolerance and measures the levels of risk tolerance, risk perception, perceived safety climate and safety behaviours. The questionnaires were distributed during toolbox time in seven projects in Australia, and 192 valid responses from construction workers and 164 valid responses from FLMs were received. Multiple regression was utilised to validate the proposed hypotheses, and the information entropy was employed to identify the critical factors which influence risk tolerance.

Subsequently, qualitative methods, such as semi-structured interviews with 10 construction safety experts, were used to collect qualitative data, while thematic analysis was adopted to extract the important views that can validate and further facilitate understanding of the quantitative results.

The next chapter will present the results and findings of the quantitative analysis. Discussions will focus on (1) construction workers' and FLMs' risk tolerance pattern, (2) the mediating effect of risk perception between risk tolerance and safety behaviours, (3) the moderating effect of perceived safety climate in risk judgement and (4) the critical factors of safety risk tolerance assessment.

Chapter 4 Quantitative Analysis and Discussion

This chapter consists of four sections answering research questions proposed in previous chapters. Note that the results of each section are not isolated from one another. The first section describes the risk tolerance levels of construction workers and FLMs. It also conducts a comparison to explore the differences in risk tolerance patterns within different risk scenarios between these two parties. Results of the first section indicate that the participant's risk tolerance has a significant difference in common injury and fatal risk scenarios. Thus, the second section, which investigates the mediating role of risk perception between the relationship of risk tolerance and safety behaviours, was conducted in common injury and fatal risk scenarios separately. In accordance with the findings in the second section, the third section explores the moderating effects of the perceived five dimensions of safety climate. In the fourth section, the principle of information entropy, mean-based statistics and canonical discriminant analysis were used to determine the critical influential factors of risk tolerance assessment for workers and FLMs. For the above four sections, each analysis is conducted for both construction workers and FLMs, and corresponding comparisons are given.

4.1 Risk Tolerance on Safety Risks

Analysis of risk tolerance level is a fundamental aspect of occupational safety management, as highlighted by the fact that occupational accidents lead the panorama of world accidents (Harms-Ringdahl, 2003, Rodrigues et al., 2015a). In this context, all information that can increase the understanding of how construction workers assess their risk tolerance is useful, particularly for construction workers and FLMs because they are the direct participants in conducting construction tasks and confronting safety risks. This section aims to analyse risk tolerance level in construction safety risk scenarios.

4.1.1 Risk Levels in Safety Risk Scenarios

On the basis of the discussion in Section 3.3.1.1, a total of 12 risk scenarios were designed to assess risk tolerance levels, as shown in Table 4.1. For each risk scenario, a risk level (RL), which represents the risk of the frequency of workers suffering an accident with a specific severity in one year, was calculated. The accident number and its severity (number of lost work days) were calculated as follows: N*DL/100, where N corresponds to the accident number, and DL indicates the number of days lost. The accident number refers to accidents that occur in one year.

Table 4.1 Risk scenarios and the referent risk level computed

Items	Scenario descriptions	Risk level
RA1	In 100 workers, each year, 14 workers suffer lower back injury due to fall from a two-metre-high ladder, which requires a 0.5 day time off.	0.07
RA2	In 100 workers, each year, eight workers suffer lower back injury due to fall from a two-metre-high ladder, which requires one week time off.	0.56
RA3	In 100 workers, each year, two workers suffer lower back injury due to fall from a two-metre high ladder, which requires four weeks time off.	0.56
RB1	In 100 workers, each year, 14 workers suffer wrist injury due to disconnected power tools while the tools are not in use, which requires a 0.5 day time off.	0.07
RB2	In 100 workers, each year, eight workers suffer wrist injury due to disconnected power tools while the tools are not in use, which requires one week time off.	0.56
RB3	In 100 workers, each year, two workers suffer wrist injury due to disconnected power tools while the tools are not in use, which requires four weeks time off.	0.56
RC1	In 100 workers, each year, eight workers suffer a leg injury due to slips on sites, which requires one day time off.	0.08

RC2	In 100 workers, each year, one worker suffers a leg injury due to slips on sites, which requires one week time off.	0.07
RC3	In 100 workers, each year, 10 workers suffer a leg injury due to slips on sites, which requires one week time off.	0.70
RM	In 100 workers, each year, five workers suffer mental stress as a result of injury, which requires 18 weeks off.	0.63
RD1	In one million workers, 8 of them die per year.	0.078
RD2	In one million workers, 30 of them die per year.	0.62

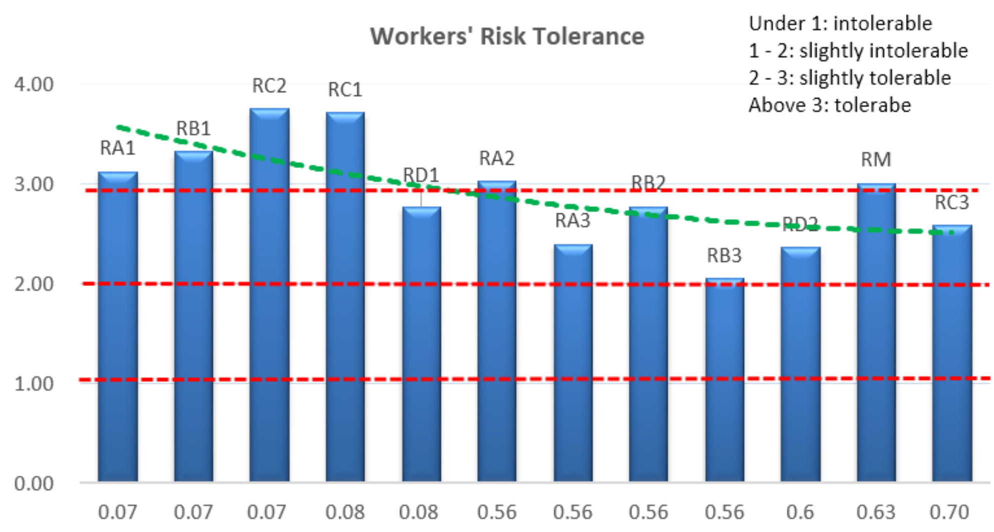
4.1.2 Risk Tolerance Level Analysis

4.1.2.1 Risk tolerance level of construction workers

Figure 4.1 presents the analysis of workers' risks tolerance level for each of the risk scenarios. The risk level was computed while accounting for the number of accident occurrence and the number of days lost, as listed in Table 4.1. And the vertical axis refers to the Likert-scale used to measure risk tolerance. In accordance with Rodrigues et al. (2015a), fatality scenarios were considered to represent a loss of 7,500 workdays.

On the whole, results show that the level of risk tolerance decreased slightly as the risk level of the risk scenario increased. Consequently, construction workers assess lower risk situations as more tolerable and higher risk situations as more intolerable. However, some exceptions were observed. RD1 represents low-frequency fatal scenario, and although it is not the worst scenario that was mathematically computed (RL = 0.08), workers show lower tolerance for it possibly due to the fear of death. Another exception comes in RM (mental stress scenario). Although the computed risk level of mental stress is high (RL = 0.63), workers show higher tolerance for it. One possible reason is that workers may not know much about mental stress because it is not as common as physical injuries.

Interestingly, no scenarios were viewed as definitely intolerable or slightly intolerable. As the direct victims on site, workers regarded all mentioned risk scenarios as acceptable to some extent. The four scenarios with the same risk level (i.e. risk level = 0.56) differ in severity and frequency for both modes of injury (RA3 and RB3 have higher severity). Results show that when severity was higher, the level of risk tolerance tended to be lower (RA2—RA3, $t = 5.557$, $p < 0.001$; RB2—RB3, $t = 6.808$, $p < 0.00$). This conclusion is not surprising given that previous studies indicated that the severity of risk scenarios is significantly related to construction workers' risk perception, such that a high severity corresponds to increased risk perception of the workers towards the scenario (Xia et al., 2017).



Note: N = 192.

Figure 4.1 Workers' risk tolerance level by risk level computed for each scenario

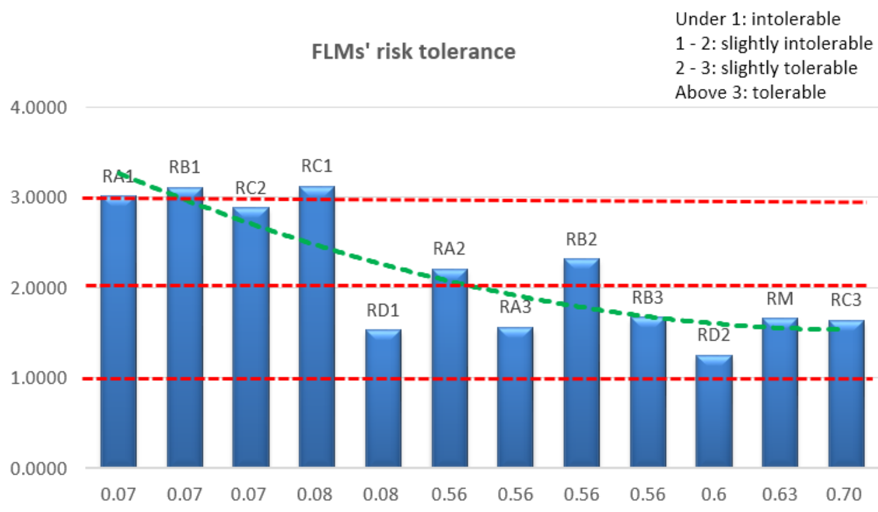
Results of the lower risk scenarios also need attention. In the scenario of RA1 (where RL = 0.07) and scenario of RB1 (where RL = 0.07), the risk tolerance level is lower than the scenario of RC2 (where RL = 0.07) and RC1 (where RL = 0.08), which have higher risk levels. The risk scenarios of RA1 and RB1 represent safety incidents that have one-day time off (small severity), but where the frequency of incidents among every 100 workers is higher and more than double the frequency for RC1 and RC2. For these low-risk level scenarios, incident frequency seems to have more influence on risk tolerance than severity, which differs from scenarios with higher risk levels in which severity tended to play a more important role in risk tolerance level.

When observing scenarios wherein workers show lower risk tolerance levels (for example, RA3, RB3 and RD2), these scenarios were found to feature very severe incident severities, i.e., one month time off and fatal, even though the incident frequencies are not high.

4.1.2.2 Risk tolerance level of FLMs

Figure 4.2 indicates the risk tolerance level of site management personnel. Similar to workers, FLMs' risk tolerance also decreases as the risk level of the scenario increased. However, this trend is much more obvious than that for workers. An exception is found in RD1, which refers to the low-frequency fatal scenario. This observation is the same as that for the workers' risk tolerance level.

With regard to the four scenarios with the same risk level (i.e. risk level = 0.56) and which differ in severity and frequency for both modes of injury (RA3 and RB3 have higher severity), results show that when the severity was higher, the level of risk tolerance tended to be lower (RA2—RA3, $t = 13.97$, $p < 0.001$; RB2-RB3, $t = 12.39$, $p < 0.00$). This risk tolerance pattern is the same as that for construction workers. However, with regard to scenarios of lower risk levels, such as RA1 (where RL = 0.07), RB1 (where RL = 0.07), RC1 (where RL = 0.08) and RC2 (where RL = 0.07), the risk tolerance levels show no significant differences. These findings indicate that if one risk scenario is assessed to have a lower risk level, then FLMs mainly focus on the total risk level rather than the frequency and severity.



Note: N = 164.

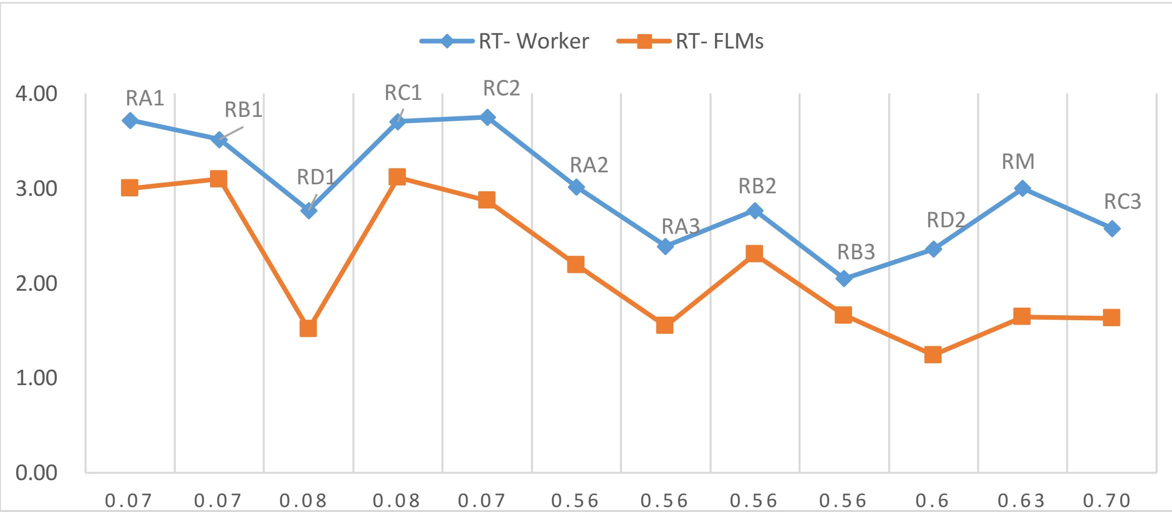
Figure 4.2 FLMs' risk tolerance level by risk level computed for each scenario

4.1.2.3 Comparison of risk tolerance level between construction workers and FLMs

According to the risk tolerance levels shown in Figures 4.1 and 4.2, FLMs evaluate the scenarios as more intolerable. For specific comparison, the differences of risk tolerance levels in each risk scenario between workers and FLMs are calculated, which can be seen in Figures 4.3 and 4.4. Considerable differences exist in mental stress and fatal scenarios. Applying independent t-tests statistically proved these differences, as shown in Table 4.2.

In a mental stress scenario, workers and FLMs showed the biggest difference in risk tolerance level. On average, workers' tolerance is 3.00, which is regarded as tolerable, whereas the figure of FLMs is 1.65, which can be considered slightly intolerable. According to 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 among all other injuries. Although its computed risk level is high, workers still evaluate mental stress as a tolerable risk. Thus, relevant safety training to improve safety awareness of mental injury is required.

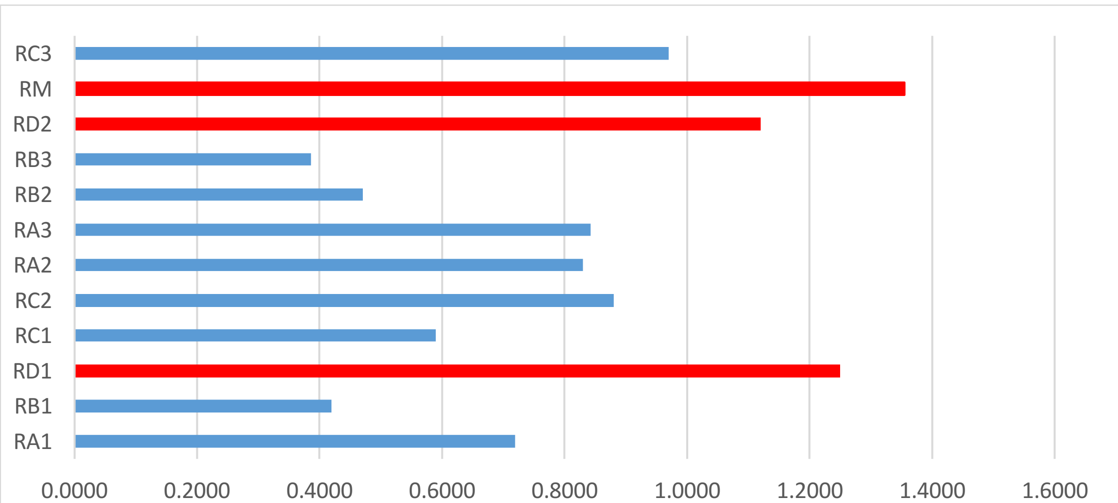
In the two fatal scenarios, the differences between workers and FLMs are also significant. Specifically, the latter evaluates fatal risk as intolerable at around 1.30, while the former evaluates it at above 2.30. The comparison indicates that workers are less sensitive to incidents with serious consequences but which cannot be witnessed and/or heard frequently. Although mental and fatal scenarios showed higher incident severities, workers might believe that they may not suffer these risks due to their lower possibilities. For FLMs, although the possibility of fatal and mental stress is relatively low compared with other physical injuries, their accident severity is much higher no matter for the victims or construction companies. Accordingly, FLMs showed a lower tolerance for these risks.



Note: N (workers) = 192.

N (FLMs) = 164

Figure 4.3 Differences of risk tolerance levels between construction workers and FLMs



Note: N (workers) = 192.

N (FLMs) = 164

Figure 4.4 Differences of risk tolerance patterns between construction workers and FLMs

Table 4.2 Statistical comparison between workers and FLMs

Comparison	**Statistical test**	**Statistical strength**	**Conclusion**	**Difference In sample means**
Total risk tolerance: workers vs FLMs	Independent sample t-test	t = 3.396 P = 0.003	Strong statistical evidence	0.84
Mental disorder tolerance: workers vs FLMs	Independent sample t-test	t = 5.517 P < 0.001	Strong statistical evidence	1.35
Death1 tolerance: workers vs FLMs	Independent sample t-test	t = 4.694 P < 0.001	Strong statistical evidence	1.25
Death2 tolerance: workers vs FLMs	Independent sample t-test	t = 4.645 P < 0.001	Strong statistical evidence	1.12

Note: N (workers) = 192.

N (FLMs) = 164

4.1.3 Discussion

4.1.3.1 Summary of analysis results

Variations in risk tolerance can lead to different risk judgements and diverse safety behaviours (Wang et al., 2016); however, to date, little is known about how construction practitioners evaluate safety risk tolerance in different scenarios with different risk levels and whether frontline workers and FLMs possess the same vision of risk tolerance. This research fills this knowledge gap by revealing frontline workers' and FLMs' risk tolerance levels from three perspectives: (1) risk level, (2) frequency of risk scenarios and (3) consequence of risk scenario severity. Below are several important findings.

(1) In general, scenarios with higher risk levels were assessed as intolerable, whereas scenarios with lower risk levels were regarded as more tolerable. Exceptions appear in the fatal scenario (RD1), where both workers and FLMs show significantly lower tolerance regarding fatal risks compared with other common injury risks.

(2) Workers' risk tolerance level is significantly higher than FLMs'.

(3) For both workers and FLMs, risk tolerance will be influenced more by risk severity rather than the incident frequency in moderate-risk and high-risk scenarios. Specifically, under these scenarios, risk tolerance levels tend to change in line with the variation of risk severities. When the severity of consequences increases, the influence of frequency seems to disappear, and judgements about risk tolerance become mainly dependent on risk severity level.

(4) In scenarios with lower risk levels where the risk severity is small but the frequency of the event is very high, workers' risk tolerance levels tend to be more sensitive to the incident frequency, whereas FLMs' risk tolerance does not show this trend.

(5) Regarding mental stress scenarios, workers and FLMs showed significant differences. Construction workers' risk tolerance is much higher than that of FLMs. Although the consequences of mental stress are more severe than those of common physical injuries, construction workers seem to lack knowledge about mental stress.

4.1.3.2 Theoretical and practical contributions

Firstly, the major contribution of this research to safety risk management literature is its design and proposal of a risk scenario description instrument for assessing safety risk tolerance level. The conventional measurement for assessing risk tolerance is criticised as either not considering risk frequency and risk severity for risk scenarios or overlooking the various risk frequencies and severities for the same risk scenario (see Section 2.3), which as a result, would generate inaccurate risk tolerance level assessment. This research addressed this limitation by incorporating the least, mid and worst risk severity and frequency for assessing risk tolerance levels under different types of safety risks. Although risk frequency and severity have been discussed widely in risk management literature (Xia et al., 2017), this study is the first to introduce them, especially considering their different levels for the same risk type, into a risk tolerance measurement in the construction safety context. Accordingly, in-depth and comprehensive understanding of safety risk tolerance level was offered.

According to Rundmo et al. (2011), the level of risk tolerance can be influenced by the severity of the consequences, and in scenarios where the severity of risk consequences is small, the influence of the consequences is lower. The current research supported this opinion by showing that risk tolerance tends to be influenced more by risk severity rather than incident frequency in moderate-risk and high-risk scenarios. Specifically, under these scenarios, risk tolerance levels tend to change in line with the variation of risk severities. When the severity of consequences increases the influence of frequency appears to disappear, and judgements about risk tolerance are dependent on incident severity level. These findings also expand this knowledge by showing that in scenarios with low risk levels, especially for scenarios where the severity of incidents is small but the frequency of events is high, workers' risk tolerance level becomes sensitive because of the incident frequency.

Secondly, we expanded the understanding of risk tolerance level by considering different types of safety risks. Most prior research focus on the common safety risks identified on construction sites. These risks are used as sources to evaluate construction employees' risk tolerance and perception (Wang et al., 2016, Feng and Wu, 2015). Risks that may lead to fatalities must be given considerable attention. However, a rigorous theoretical articulation and empirical investigation are lacking. Considering the most common safety risks on construction sites, the current research also includes mental injury and fatal risks. For mental injury risks, workers tend to ignore the risk of mental stress, even if such risk is considered as having the most days lost among other common injury risks. Regarding fatal risks, they are treated differently from common injury risks because the risk tolerance is kept at the lowest level regardless of whether such a risk is evaluated as low or high. Thus, academics and practitioners have a duty to consider and analyse fatal risks when assessing and managing construction safety risks.

Thirdly, this research provides empirical evidence for the differences of workers and FLMs' risk tolerance level of safety risks. Several studies indicate that management personnel and frontline workers do not share the same risk perception (Harvey et al., 1999, McDonald et al., 2000, Smallwood and Haupt, 2005, Hallowell, 2010). However, in the construction literature, limited research tests this difference empirically. We found that construction workers and FLMs have different levels of risk tolerance for the surveyed types of safety risks (from common safety to death risks). This statistical evidence not only adds knowledge to the risk management literature but also offers considerable values for safety management practice.

(1) Firstly, these differences pointed out that the health and safety vision of FLMs which is often manifested through safety procedures and standards, are not shared by the workers in the same projects. Such a result is consistent with the findings of Hallowell (2010). Therefore, the safety climate, which refers to a shared understanding of workplace safety issues and serves as a frame of risk judgement, is weak in this selected sample of the construction industry. From this point, an important task is not only to build a positive safety climate but also to facilitate workers' perception of this safety climate. Improving awareness to learn from the shared vision of safety issues from management personnel is critical.

(2) Secondly, the results further indicate that one reason for the high rate of incidents on sites may be workers' high tolerance of the high-frequency and low-severity risk scenarios. The attitude of taking risks for granted may cause them to develop a habit

of not paying attention to safety details and having low safety awareness for low-risk scenarios. Thus, further safety training and risk monitoring should be designed to focus on risk scenarios with high frequency to lessen workers' high risk tolerance.

4.2 Mediating Effect of Risk Perception

Some research has investigated the influence of risk tolerance on pilots' safety behaviour (Hunter, 2002, Ji et al., 2011), which emphasises the important role of risk tolerance in determining individuals' risk judgement. For safety studies in the construction industry, the influence of risk tolerance has not been explored, which constitutes a considerable knowledge gap in construction safety management. The analysis results in Section 4.1 indicated that construction practitioners' risk tolerance is significantly different in common injury and fatal risk scenarios. Current research mainly focuses on the common risks in an occupational setting, such as slip and mechanical injury. The lack of consideration of how employees directly process fatal risk information and how risk judgement influence safety behaviours have not been explored. Therefore, this section aims to explore how risk tolerance influences safety behaviour by examining the mediating effect of risk perception in common injury and fatal risk scenarios.

4.2.1 Reliability and Validity of Questionnaires

Before testing the hypotheses, studies on the reliability and validity of measurement instruments need to be conducted for reliable model testing and theory development (Xiong et al., 2015). Reliability means that the questionnaires are consistent; thus, the questionnaire items belong to one dimension (Flynn et al., 1994). Cronbach's α is the most common measure of scale reliability (Field, 2009), where $\alpha = 0.6$ is the acceptance level. When one questionnaire contains more than one dimension, the internal consistency of each dimension should be tested. Results show that the Cronbach's α for risk perception, risk tolerance and workers' risk behaviour are 0.925, 0.916 and 0.851, respectively, in the construction worker group. Cronbach's α for risk perception, risk tolerance and workers' risk behaviour are 0.896, 0.862 and 0.879, respectively, in the FLM group. These results confirm the internal consistency and reliability of the hypothetical model.

Convergent and discriminant validity tests are two common tests for validity (Xiong et al., 2015). Convergent validity refers to the degree of positive correlation of one manifest variable and other manifest variables within the same construct. Manifest variables within the same construct should share a comparatively high proportion of commonality (Hair Jr et al., 2016). Average variance extracted (AVE) and factor loadings are used to assess convergent and discriminant validity. These two indicators should be respectively 0.50 and 0.50 or higher (Fornell and Larcker, 1981). On the basis of the results of confirmatory factor analysis, the standardised factor loading of all items in workers' measurement model is higher than 0.5, and the AVE values for risk perception, risk tolerance and safety behaviour are 0.59, 0.51 and 0.74, respectively. In FLMs' measurement model, the standardised factor loading of all items in the workers' measurement model is higher than 0.5, and the AVE values for risk perception, risk tolerance and safety behaviour are 0.59, 0.65 and 0.80, respectively. These results indicate good validity of the measurement model in the worker and FLM groups.

However, the goodness of fit of the measurement model does not meet the requirement for acceptance. One possible reason for this result is that the items used in the measurement model have some inner relationships. Items in the measurement model must be adjusted accordingly. Some content-similar items exist in the measurement model of risk perception, risk tolerance and safety support. Takahashi and Nasser (1996) and Nasser et al. (1997) suggested that item parcelling can be applied to mini-scale the measurement where items have similar content to improve the goodness of fit in confirmation factor analysis. Therefore, for risk perception and risk tolerance, the items that belong to the same risk scenarios are parcelled.

After item parcelling, the goodness of fit achieves an acceptable level, as indicated in Tables 4.3 and 4.4. The adjusted measurement scale for each variable can then be used for the next step of hypothesis testing.

Table 4.3 Goodness of fit of the measurement model in the worker group

Goodness of fit measure	Statistics	Fitness criterion	Fit statistics
Absolute fit indices	$\chi2$/df	< 5 acceptable; < 3 good	2.037
	RMR	< 0.05 good	0.05
	RMSEA	< 0.1 acceptable; < 0.08 good	0.074
	GFI	> 0.8 acceptable; > 0.9 good	0.880
	AGFI	> 0.8 acceptable; > 0.9 good	0.825
Incremental fit indices	NFI	> 0.9	0.873
	RFI	> 0.9	0.834
	IFI	> 0.9	0.931
	TLI	> 0.9	0.908
	CFI	> 0.9	0.930
Parsimonious fit indices	PNFI	> 0.5	0.664
	PGFI	> 0.5	0.602

Note: N (workers) = 192.

Table 4.4 Goodness of fit of the measurement model in the FLM group

Goodness of fit measure	Statistics	Fitness criterion	Fit statistics
Absolute fit indices	$\chi2$/df	< 5 acceptable; < 3 good	3.721
	RMR	< 0.05 good	0.035
	RMSEA	< 0.1 acceptable; < 0.08 good	0.094
	GFI	> 0.8 acceptable; > 0.9 good	0.916
	AGFI	> 0.8 acceptable; > 0.9 good	0.767
Incremental fit indices	NFI	> 0.9	0.889
	RFI	> 0.9	0.761
	IFI	> 0.9	0.916
	TLI	> 0.9	0.813
	CFI	> 0.9	0.913
Parsimonious fit indices	PNFI	> 0.5	0.513
	PGFI	> 0.5	0.524

N (FLMs) = 164

4.2.2 Correlation Analysis

After reliability and validity testing, IBM SPSS 23.0 was used to conduct the correlation analysis. Tables 4.5 and 4.6 show the means, standard deviations and correlations for variables of risk tolerance of common injury and fatal risks, risk perception of common injury and fatal risks and safety behaviour of worker and FLM groups.

For construction workers, a significant negative correlation exists between risk tolerance and risk perception in common injury risk scenarios. The risk tolerance of common injury risks is significantly negatively correlated with the perceived common injury risks ($b = -0.510$, $p < 0.001$). A significant inverse correlation exists between risk tolerance of common injury risks and safety behaviour ($b = -0.167$, $p < 0.05$). Also, the correlation between perceived common injury risks and safety behaviour is significantly positively related ($b = 0.273$, $p < 0.001$). The risk tolerance of fatal risks is strongly negatively related to risk perception of fatal risks ($b = -0.569$, $p < 0.001$). Moreover, risk perception of fatal risks is significantly related to safety behaviour ($b = 0.159$, $p < 0.05$), but this correlation is weaker than that in common injury risk scenarios. Also, the correlation between risk tolerance of fatal risks and safety behaviour is significant ($b = -0.092$, $p = 0.006$).

Table 4.5 Analysis of means, standard deviations and bivariate correlations in the worker group

Variable	Mean	Standard Deviation	1	2	3	4	5
Risk tolerance of common injury risks	2.52	0.72	1				
Risk perception of common injury risks	4.02	0.82	-0.510**	1			
Risk tolerance of fatal risks	1.70	0.73	0.276**	-0.244*	1		
Risk perception of	5.05	0.66	-0.221**	0.121	-0.569**	1	

fatal risks								
Safety behaviour	4.43	0.84	-0.167**	0.273**	-0.092**	0.159*	1	

**. Correlation is significant at the 0.01 level (two-tailed).
*. Correlation is significant at the 0.05 level (two-tailed).
N (workers) = 192.

Table 4.6 Analysis of means, standard deviations and bivariate correlations in the FLM group

Variable	Mean	Standard Deviation	1	2	3	4	5
Risk tolerance of common injury risks	2.27	0.83	1				
Risk perception of common injury risks	4.04	1.05	-0.054	1			
Risk tolerance of fatal risks	1.38	0.64	0.334**	-0.074	1		
Risk perception of fatal risks	5.45	0.91	-0.269**	0.408**	-0.439**	1	
Involvement of safety management	3.05	1.71	-0.464**	-0.041	-0.233**	0.283*	1

**. Correlation is significant at the 0.01 level (two-tailed).
*. Correlation is significant at the 0.05 level (two-tailed).
N (FLMs) = 164

For FLMs, no correlation exists between risk tolerance and risk perception ($b = -0.054$, $p = 0.555$) in common injury risk scenarios. Also, the correlation between risk perception and involvement of safety management is insignificant ($b = -0.041$, $p = 0.650$). However, the risk tolerance of common injury risks is significantly associated with the involvement of safety management ($b = -0.464$, $p < 0.000$) which is the same as that in the worker group. The risk tolerance of fatal risks is strongly negatively related to risk perception of fatal risks ($b = -0.439$, $p < 0.001$). Such results are different from scenarios of common injury risks. The correlation between risk tolerance of fatal risks and involvement of safety management is significant ($b = -0.233$, $p < 0.01$). The correlation between the risk perception of fatal risks and involvement of safety management is also significant ($b = 0.283$, $p < 0.01$).

To summarise, the correlation between risk tolerance, risk perception and safety behaviour for construction workers is significant in common injury risk scenarios. However, the correlation between risk tolerance and safety behaviour is insignificant ($b = -0.092$, $p = 0.206$). In the FLM group, the correlation between risk tolerance, risk perception and involvement of safety management is significant in fatal risk scenarios, whereas the correlations between risk tolerance and risk perception ($b = -0.054$, $p = 0.555$) and between risk perception and involvement of safety management ($b = - 0.041$, $p = 0.650$) are insignificant in common injury risk scenarios.

4.2.3 Mediating Analysis

Mediators can be a potential mechanism by which independent variables can produce changes on dependent variables (Baron and Kenny, 1986). Thus, the mediation method allows researchers to investigate whether the empirical evidence is consistent with the mediation model X → M → Y, which indicates that the effect of independent variable X on dependent variable Y is (at least in part) causally mediated by a proposed mediator M (Danner et al., 2015), as shown in Figure 4.5. Path c is called the total effect, which shows the effect of independent variable X on dependent variable Y. Path c' is called the direct effect, which shows the effect of independent variable X on dependent variable Y when mediator variable M is controlled. A comparison of c and c' indicates that several possibilities of mediating effect may occur.

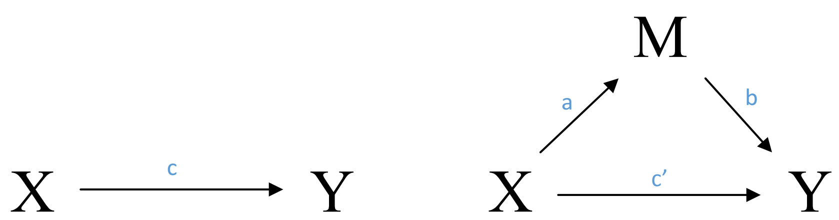


Figure 4.5 Mediating effect

To facilitate the understanding of the mediating effect, Figure 4.6 provides an overview of all possible models of mediating effects with reference to the example of work distress as a potential mediator of the effect of lack of control on alcohol consumption.

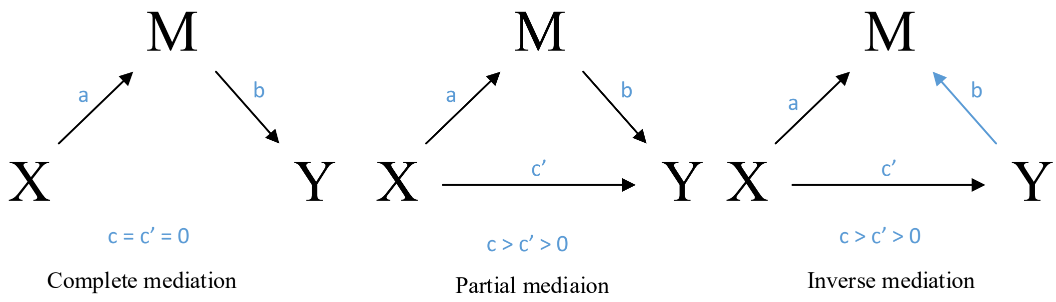


Figure 4.6 Examples of possible mediating effects

(1) Complete mediation (X → M → Y, c' = 0): Lack of control affects people's work distress, which in turn affects their alcohol consumption.

(2) Partial mediation (X → M → Y, X → Y, 0 < c'< c): Lack of control affects people's work distress, which in turn affects their alcohol consumption. Moreover, lack of control affects people's alcohol consumption directly.

(3) Inverse mediation (X → M, X → Y → M, 0 < c'< c): Lack of control affects people's alcohol consumption, which also affects their work distress. Moreover, lack of control affects people's work distress directly.

4.2.4 Hypothesis Testing

This section mainly uses empirical data to confirm the relationships between risk tolerance, risk perception and safety behaviour, as illustrated in Figure 4.7. Hypotheses 1, 2, 3 and 5, 6, 7 are tested in this section.

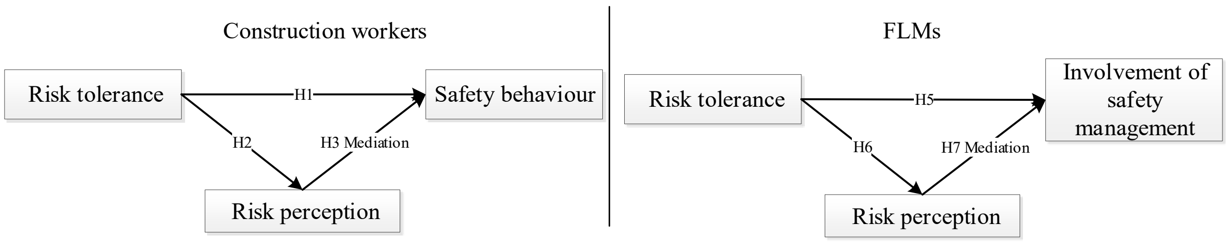


Figure 4.7 Theoretical research model for mediation of risk perception

In this theoretical model, risk perception is hypothesised to have a mediating effect on the relationships between risk tolerance and safety behaviour. To test this mediating effect, procedures described by Baron and Kenny (1986) are followed. Baron and Kenny (1986) suggested that three regression equations must be estimated to examine a mediating effect.

(1) The dependent variable (safety behaviour) is regressed on the independent variable (risk tolerance) to test relationship path c.

(2) The mediator (risk perception) is regressed on the independent variable (risk tolerance) to test relationship path a.

(3) The dependent variable (safety behaviour) is regressed on the independent variable (risk tolerance) and the mediator (risk perception) to test relationship path b and c'.

To establish a mediation, the independent variable (risk tolerance) must affect the dependent variable (safety behaviour) in the first equation. Then, the mediator (risk perception) must affect the dependent variable in the third equation. If these conditions hold, then the effect of the independent variable (risk tolerance) on the dependent variable (safety behaviour) in the third equation must be less in the third equation than in the second.

4.2.4.1 Mediating effect test in construction worker group

To test Hypotheses 1–3, models of multiple linear regression are adopted using IBM SPSS 23. Tables 4.7 and 4.8 show the results. These mediating effects are tested on common injury and fatal risk scenarios.

Common injury risk scenarios

- In the first step, safety behaviour is regressed on risk tolerance. Results show that risk tolerance is significantly negatively related to safety behaviour (B = -0.196, $p < 0.05$).
- In the second step, risk perception is regressed on risk tolerance. Results show that risk tolerance is significantly negatively related to risk perception (B = -0.587, $p < 0.001$).
- In the third step, safety behaviour is regressed on risk tolerance and risk perception. Figure 4.8 shows that when risk perception is controlled, the influence of risk tolerance on safety behaviour is no longer significant (B = -0.045, p = 0.638).

Table 4.7 Mediating of risk perception in common injury risk scenarios—worker group

Step	Path	B	SE	t	p
Equation 1: safety behaviour regressed on the risk tolerance of common injury risks	c	-0.196	0.084	-2.342	0.020
Equation 2: risk perception of common risks regressed on the risk tolerance of common injury risks	a	-0.587	0.072	-8.180	0.000
Equation 3: safety behaviour regressed on the risk tolerance of common injury risks and risk perception of common injury risks	b	0.257	0.083	3.111	0.002
	c’	-0.045	0.095	-0.472	0.638

Note: N = 192.

Table entries represent standardised parameter estimates with standard errors in parentheses.

Fatal risk scenarios

- In the first step, safety behaviour is regressed on risk tolerance. Results show that risk tolerance is significantly related to safety behaviour (B = -0.105, p = 0.006).
- In the second step, risk perception is regressed on risk tolerance. Results show that risk tolerance is significantly negatively related to risk perception (B = -0.519, p = 0.071).

- In the third step, safety behaviour is regressed on risk tolerance and risk perception. Figure 4.8 shows that when risk perception is controlled, the influence of risk tolerance on safety behaviour is still insignificant (B = -0.002, p = 0.988).

Table 4.8 Mediating of risk perception in fatal risk scenarios—worker group

Step	Path	B	SE	t	p
Equation 1: safety behaviour regressed on the risk tolerance of fatal risks	c	-0.105	0.083	-1.269	0.006
Equation 2: risk perception of fatal risks regressed on the risk tolerance of fatal risks	a	-0.519	0.054	-9.543	0.071
Equation 3: safety behaviour regressed on the risk tolerance and risk perception of fatal risks	b	0.200	0.110	1.871	0.000
	c'	-0.002	0.100	-0.016	0.988

Note: N = 192.

Table entries represent standardised parameter estimates with standard errors in parentheses.

Figure 4.8 Test results of Hypotheses 1–3

To summarise, the model demonstrated by the current sample is illustrated in Figure 4.8. Hypothesis 1, which proposed that risk tolerance can influence safety behaviour negatively and directly, is fully supported in this study. This relationship is significant in fatal and common injury risk scenarios. Hypothesis 2, which proposed that risk tolerance is associated with risk perception negatively, is partially validated in this research. This relationship is strong and significant in common injury risk scenarios (B = -0.587, p < 0.000) but insignificant in fatal risk scenarios (B = -0.519, p = 0.071). Hypothesis 3, which proposed that risk perception mediates the relationship between workers' risk tolerance and safety behaviour, is partially supported in this study. Risk perception can fully mediate the relationship between risk tolerance and safety behaviour in common injury risk scenarios. However, this relationship is not validated in fatal risk scenarios.

4.2.4.2 Mediating effect test in the FLM Group

To test Hypotheses 5–7, multiple linear regression models are adopted using IBM SPSS 23. These mediation effects are tested on common injury and fatal risk scenarios on site. Tables 4.9 and 4.10 present the results.

Common injury risk scenarios

(a) In the first step, the involvement of safety management is regressed on risk tolerance. Results show that risk tolerance is significantly negatively related to the involvement of safety management (B = -0.957, p < 0.001).

(b) In the second step, risk perception is regressed on risk tolerance. Results show that risk tolerance is insignificantly negatively related to risk perception (B = -0.068, p = 0.555).

(c) In the third step, the involvement of safety management is regressed on risk tolerance and risk perception. Figure 4.7 shows that when risk perception is controlled, the influence of risk tolerance on the involvement of safety management is still significant (B = -0.964, p < 0.000).

Fatal risk scenarios

- In the first step, the involvement of safety management is regressed on risk tolerance. Results show that risk tolerance is significantly negatively related to the involvement of safety management (B = -0.629, p = 0.009).

- In the second step, risk perception is regressed on risk tolerance. Results show that risk tolerance is significantly negatively related to risk perception (B = -0.628, p < 0.001).
- In the third step, the involvement of safety management is regressed on risk tolerance and risk perception. Figure 4.9 shows that when risk perception is controlled, the influence of risk tolerance on the involvement of safety management is still insignificant (B = -0.364, p = 0.163).

Table 4.9 Mediating of risk perception in common injury risk scenarios–FLM group

Step	Path	B	SE	Β	t	p
Equation 1: involvement of safety management regressed on the risk tolerance of common injury risks	c	-0.957	0.165	-0.464	-5.786	0.000
Equation 2: risk perception of common risks regressed on the risk tolerance of common injury risks	a	-0.068	0.114	-0.054	-0.592	0.555
Equation 3: involvement of safety management regressed on the risk tolerance and risk perception of common injury risks	b	-0.108	0.131	-0.066	-0.823	0.412
	c’	-0.964	0.166	-0.468	-5.814	0.000

Note: N = 164;

Table entries represent standardised parameter estimates with standard errors in parentheses.

Table 4.10 Mediating of risk perception in fatal risk scenarios–FLM group

Step	Path	B	SE	Β	t	p
Equation 1: involvement of safety management regressed on the risk tolerance of fatal risks	c	-0.629	0.238	-0.233	-2.650	0.009
Equation 2: risk perception of fatal risks regressed on the risk tolerance of fatal risks	a	-0.628	0.116	-0.439	-5.401	0.000
Equation 3: involvement of safety management regressed on the risk tolerance and risk perception of fatal risks	b	0.422	0.182	0.224	2.324	0.022
	c’	-0.364	0.260	-0.135	-1.402	0.163

Note: N = 164;

Table entries represent standardised parameter estimates with standard errors in parentheses.

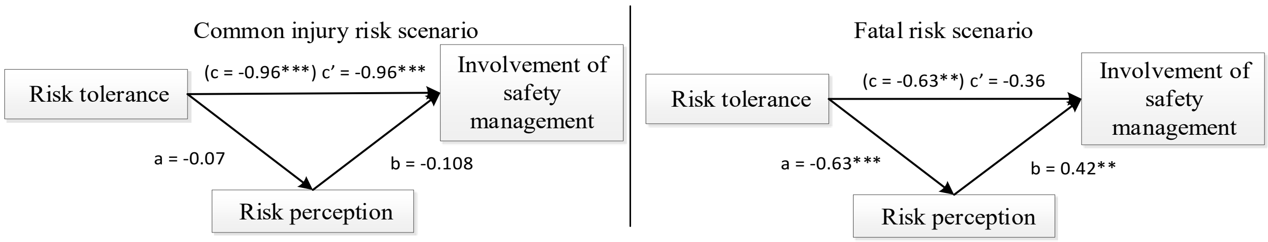


Figure 4.9 Test results of Hypotheses 5–7

To summarise, the models demonstrated by the current sample are illustrated in Figure 4.9, which shows the hypotheses testing results for construction workers and FLMs, respectively.

Hypothesis 5, which proposed that FLMs' risk tolerance can influence the involvement of safety management negatively and directly, is fully supported in this study. This relationship is significant in common injury and fatal risk scenarios. Hypothesis 6, which proposed that risk tolerance is associated with risk perception negatively, is partially validated in this research. This relationship is strong and significant in fatal risk scenarios, whereas it is insignificant in common injury risk scenarios. Hypothesis 7, which proposed that FLMs' risk perception mediates the relationship between their risk tolerance and involvement of safety management, is partially supported in this study. This mediating effect is validated in fatal risk scenarios but not in common injury risk scenarios.

4.2.5 Discussion

4.2.5.1 Summary of Analysis Results

This section mainly explores the relationships between risk tolerance, risk perception and safety behaviour (involvement of safety management) among workers and FLMs in common injury and fatal risk scenarios in the construction industry. Table 4.11 presents the results.

(1) Hypotheses 1 and 5 are fully supported in this research. The risk tolerance of workers and FLMs is negatively associated with safety behaviour in common injury and fatal risk scenarios. Therefore, no matter the safety risks that workers and FLMs are confronted with, a high risk tolerance corresponds to more possibilities of exhibiting unsafe behaviours.

(2) Hypotheses 2 and 6 are partially supported in this research. The risk tolerance of workers is negatively associated with risk perception only in common injury risk scenarios. For FLMs, the negative relationship between risk tolerance and risk perception is validated in fatal risk scenarios only.

(3) Hypotheses 3 and 7 are also partially validated. When considering common injury risks for workers, risk perception can fully mediate the relationship between risk tolerance and safety behaviour. Thus, risk tolerance has an indirect effect on safety behaviour through influencing risk perception. For FLMs, Hypothesis 7 is supported in fatal risk scenarios. When dealing with such risks, FLMs' risk tolerance can influence their safety behaviour by affecting risk perception.

(4) When considering the fatal risk scenarios for workers, the influence of risk tolerance on safety behaviour is almost zero, and the influence of risk tolerance on risk perception is insignificant. Only the effect of risk perception on safety behaviour is shown as strong and significant.

(5) When considering common injury risk scenarios for FLMs, the relationship between risk tolerance and risk perception and between risk perception and involvement of safety management are weak and insignificant. Only the influence of risk tolerance on the involvement of safety management is supported as strong and significant.

These findings not only reveal the relationship between risk tolerance, risk perception and safety behaviour in workers and FLMs but also indicate that different risk behaviour patterns exist when dealing with common injury and fatal risk scenarios. Objective risk judgement is important because it can help avoid potential risk behaviours. However, current studies mainly focus on exploring how construction workers assess safety risks based on the common safety risks on site, such as falling, slipping and mechanical injury. Few studies clearly focus on fatal risks and the differences of risk judgement between common injury and fatal risks. This research fills this knowledge gap by revealing frontline workers' and FLMs' risk behaviour patterns from three perspectives: (1) different risk scenarios: common injury and fatal risks, (2) mediating effect of risk perception on relationship between risk tolerance and safety behaviour and (3) the difference of workers and FLMs' risk behaviour patterns.

4.2.5.2 Theoretical and Practical Contribution

Firstly, our results expand the safety behaviour literature by adding knowledge about the influence mechanism of risk tolerance in the field of construction safety. Most prior research in the domain of construction safety focuses on explaining unsafe behaviours from the perspectives of safety knowledge, working environment, equipment and material condition and production pressure (Han et al., 2014, Rahman et al., 2017, Whiteoak and Mohamed, 2016, Wang et al., 2015a, Fang et al., 2015a). Therefore, a rigorous theoretical articulation and empirical investigation of risk tolerance on safety behaviour is lacking. Risk tolerance has become an important studying variable in personality research fields associated with occupational health and safety in recent years (Hunter, 2002, Rodrigues et al., 2015a) (Pauley et al., 2008). The current study focuses on the effect of risk tolerance and safety behaviour on workers, as well as FLMs' safety involvement, and finds that risk tolerance does have a negative influence on safety behaviour. This relationship can be mediated by risk perception to a certain degree. For scenarios where workers make risk judgements under common injury risks and FLMs make risk judgements under fatal risks, risk tolerance affect safety behaviour indirectly through affecting risk perception. However, the results of this study do not demonstrate a direct influence of risk tolerance on safety behaviour, indicating that a part of the effects of risk perception on safety behaviour comes from the contribution of risk tolerance. Therefore, risk tolerance is considered an exogenous variable that influences risk perception and, in turn, affects safety behaviour in the causal relationship. The positive influence of risk perception on safety behaviour has been acknowledged in many studies (Zou and Zhang, 2009, Chen and Jin, 2015, Gürcanli et al., 2015). If the negative influence of risk tolerance on risk perception cannot be effectively controlled, then construction employees with a high risk tolerance are likely to behave unsafely. Thus, the importance of understanding, monitoring and controlling risk tolerance and risk perception is justified and expanded to safety management success in terms of reducing unsafe behaviours on construction sites.

Secondly, we elaborated the risk judgement in construction safety by focusing on two dimensions: (1) employee – workers and FLMs and (2) risk type – common injury and fatal risks. Safety management emphasises that workers and FLMs are the most important groups in construction projects, and they may confront and must deal with the same safety risks in construction sites (Hallowell, 2010). However, little has been mentioned regarding the risk behaviour differences of these two groups. Also, prior research is mainly conducted under the common safety risk scenarios. Differences in risk behaviour under common injury and fatal risks are not considered. On the basis of the results of the analysis of risk tolerance level, workers and FLMs show particular differences considering the two types of risks. Thus, this research utilises the same safety risk scenarios to elaborate the risk behaviour analysis in worker and FLM groups. We also conducted this analysis under common injury and fatal risk scenarios to investigate risk behaivour patterns under different risk scenarios. By doing so, we could advance the understanding of the differences of safety risk behaviours between workers and FLMs, as well as the differences under common injury and fatal risks.

With regard to the scenarios of workers considering fatal risks, the assessment of risk tolerance shows no effect (B = -0.002) on safety behaviour, whereas the perception of risks has a significantly positive influence on safety behaviour (B = 0.2***). Thus, when considering safety risks that may have possibilities for fatalities, workers do not behave unsafely due to their high risk tolerability. This risk behaviour pattern is different from workers' risk behaviours in the common injury risk scenarios, in which risk tolerance can decide safety behaviour indirectly. If workers have high risk tolerance, then they perceive that the risks are not that serious and have a high tendency to behave unsafely. This difference reveals that construction workers have different risk behaviour patterns when confronted with different risk scenarios, especially when the scenarios vary in terms of severity. Two reasons can explain this condition: (1) Workers are sensitive to risk severity when perceiving safety risks, in which risk severity has more effect than the probability (Xia et al., 2017). Thus, they show different risk thoughts when the perceived severity is different. (2) Workers do not take risks that are of high severity and are life-threateaning. This result implies that safety management effort should be exerted when monitoring, regulating and educating common and non-severity risks on sites. Also, improving the level of risk perception should be the safety training focus.

With regard to the scenarios of FLMs considering common injury risks, risk tolerance is the only variable that can affect FLMs' involvement in safety management whether or not risk perception is considered. Also, the effect of risk tolerance on the involvement of safety management is close to 1, where B = -0.96**. Therefore, risk tolerance has a strong and significant influence on FLMs' involvement of safety management. This result indicates that when FLMs consider risks, especially the common ones that do not lead to serious injuries and fatalities, their risk perception does not affect the involvement of safety management, whereas their risk tolerance plays an important role. FLMs are more sensitive to risk tolerance than perceived risk when dealing with risks of moderate severity. The minimal effect of risk perception may be due to the clear understanding of FLMs of these risks, and they know that no serious injuries can occur. Thus, their involvement in safety management does not need to rely on the assessment results. Hallowell (2010) mentioned that site management personnel have a shallow level of risk perception regarding low serious injuries, such as temp discomfort, temp pain and minor first aid. Given that construction workers are not the direct victims on site, these low injuries are not their first concern. The possible explanation for the strong influence of risk tolerance is that risk tolerance is a criterion for resource allocation. From the perspective of risk management, resource distribution strategies can be applied to risks that can be ranked by certain tolerable lines and, accordingly, different risk treatments (Kwak and LaPlace, 2005). Lehmann et al. (2009) pointed out that risk tolerance can be used in detailed planning and decision making process regarding specific tasks/events for organisations. Therefore, risk tolerance is also considered in allocating resources to certain risks, as well as balancing and optimising such resources and project plans. FLMs must understand the specific limits of organisations, such as company expectations, process constraints, compliance goals, product quality requirements and safety regulations. Thus, common injury FLMs may consider project managers more than risk management because the main work focus is different under common injury risk scenarios. Thus, FLMs' involvement in safety management may be influenced by their assessment of risk tolerance.

The relationship between risk judgement and safety behaviour is not straightforward. An evident explanation of why employees appear to take risks may simply be that they have poor knowledge of the hazards involved and an inaccurate perception of risks. Hence, they may not realise that what they are doing is unsafe (Rundmo, 2001). However, this idea offers only a partial explanation because unsafe behaviours have often been observed even if the risks are accurately perceived (Flin et al., 2000). This section reveals and provides evidence of how construction workers and FLMs conduct risk judgement in common injury and fatal risks, which can further explain why construction employees behave unsafely. In summary, construction workers view common injury risks, which are common and low severity risks on site, as commonplace. For everyday activities, workers do not consider the risks per se but whether their actions are successful or 'tolerable' (Ayres et al., 1998, Bohm and Harris, 2010). Thus, the assessment of risk tolerance affects their decision to behave safely or not. However, the tolerability of risk is no longer important for risks with possible fatalities given that no one takes risks of fatalities anymore. When considering the common injury risks on site, FLMs are aware that these risks cannot be completely eliminated, and no serious consequences may occur. FLMs' work focus may be the efficiency of project plan and resource allocation. Therefore, a high-sensitivity risk tolerance occurs.

These results expand the current knowledge of construction employees' risk judgement and how this risk information processing influences safety behaviour. For construction practice, safety management should not merely focus on workers; FLMs also need attention. Moreover, risk management plans should be designed considering all possible risks, including, common injury and fatal risks.

Table 4.11 Summary of test results of Hypotheses 1–3 and 5 --7

Proposed relationship		**Scenario of common injury risk**		**Scenario of fatal risk**	
Relationship type	Specific relationship	Construction worker	FLM	Construction worker	FLM
Direct	Risk tolerance → Safety behaviour	c = -0.20*** **(yes)**	c = -0.96*** **(yes)**	c = -0.11** **(yes)**	c = -0.63** **(yes)**
	Risk tolerance → Risk perception	a = -0.59*** **(yes)**	a = -0.07 **(no)**	a = -0.52 **(no)**	a = -0.63*** **(yes)**
Mediation	Risk perception ↗ ↘ Risk tolerance → Safety behaviour	c' = -0.045 c' not sig **(yes)**	c' = - 0.96*** c' = c **(no)**	c' = -0.002 c, c' not sig **(no)** **b = 0.28*** **	c' = -0.36 c' not sig **(yes)**

Note: N (construction worker) = 192; N (FLMs) = 164.
. Significant at the 0.01 level; *. Significant at the 0.001 level
Using safety behaviour represents involvement of safety management for FLMs

4.3 Moderating Effect of Perceived Safety Climate

Perceived safety climate provides workers and FLMs with cues to the extent where safety is prioritised and what behaviours and outcomes can be reinforced or punished. When they conduct risk-related activities, their perceived safety climate sends a message regarding whether or not safety is critical. Then, relevant risk thoughts and behaviours are determined. Thus, testing of how perceived safety climate can influence construction practitioners' risk judgement is necessary.

4.3.1 Specified Hypotheses for the Moderating Effect of Perceived Safety Climate

This section mainly provides empirical evidence for the moderating role of perceived safety climate in construction practitioners' risk judgement. On the basis of the results analysed in Section 4.2, two different relationships between risk tolerance, risk perception and safety behaviour were revealed for workers and FLMs, respectively. When construction workers deal with common injury risks, risk tolerance influences safety behaviour by having a negative effect on risk perception. In fatal risk scenarios, their risk tolerance has no effect on their safety behaviours. Instead, their risk perception can influence their safety behaviours. When FLMs deal with common injury safety risks, their risk tolerance can influence their safety management involvement directly and negatively, whereas when dealing with fatal risks, their safety management involvement can be influenced indirectly by risk tolerance. Thus, on the basis of these identified risk behaviour patterns, the moderating effect of perceived safety climate is tested. Figure 4.10 shows the theoretical research model. Hypotheses 4 and 8 are specified as follows:

Hypothesis 4-1. When construction workers deal with common injury safety risks, their perceived safety climate moderates the negative correlation between risk tolerance and risk perception. This correlation is weak when a positive safety climate is perceived.

Specific sub-hypotheses of this hypothesis include safety attitude of top management (4-1a), safety attitude of immediate supervisors (4-1b), communication with supervisors (4-1c), co-workers' influence (4-1d) and safety support (4-1e).

Hypothesis 4-2. When construction workers deal with fatal risks, their perceived safety climate moderates the positive correlation between risk perception and safety behaviour. This correlation is strong when a positive safety climate is perceived. Specific sub-hypotheses of this hypothesis include safety attitude of top management (4-2a), safety attitude of immediate supervisors (4-2b), communication with supervisors (4-2c), co-workers' influence (4-2d) and safety support (4-2e).

Hypothesis 8-1. When FLMs deal with common injury safety risks, their perceived safety climate moderates the negative correlation between risk tolerance and involvement of safety management. This correlation is weak when a positive safety climate is perceived. Specific sub-hypotheses of this hypothesis include safety attitude of top management (8-1a), safety attitude of immediate supervisors (8-1b), communication with supervisors (8-1c), co-workers' influence (8-1d) and safety support (8-1e).

Hypothesis 8-2. When FLMs deal with fatal safety risks, their perceived safety climate moderates the negative correlation between risk tolerance and risk perception. This correlation is weak when a positive safety climate is perceived. Specific sub-hypotheses of this hypothesis include safety attitude of top management (8-2a), safety attitude of immediate supervisors (8-2b), communication with supervisors (8-2c), co-workers' influence (8-2d) and safety support (8-2e).

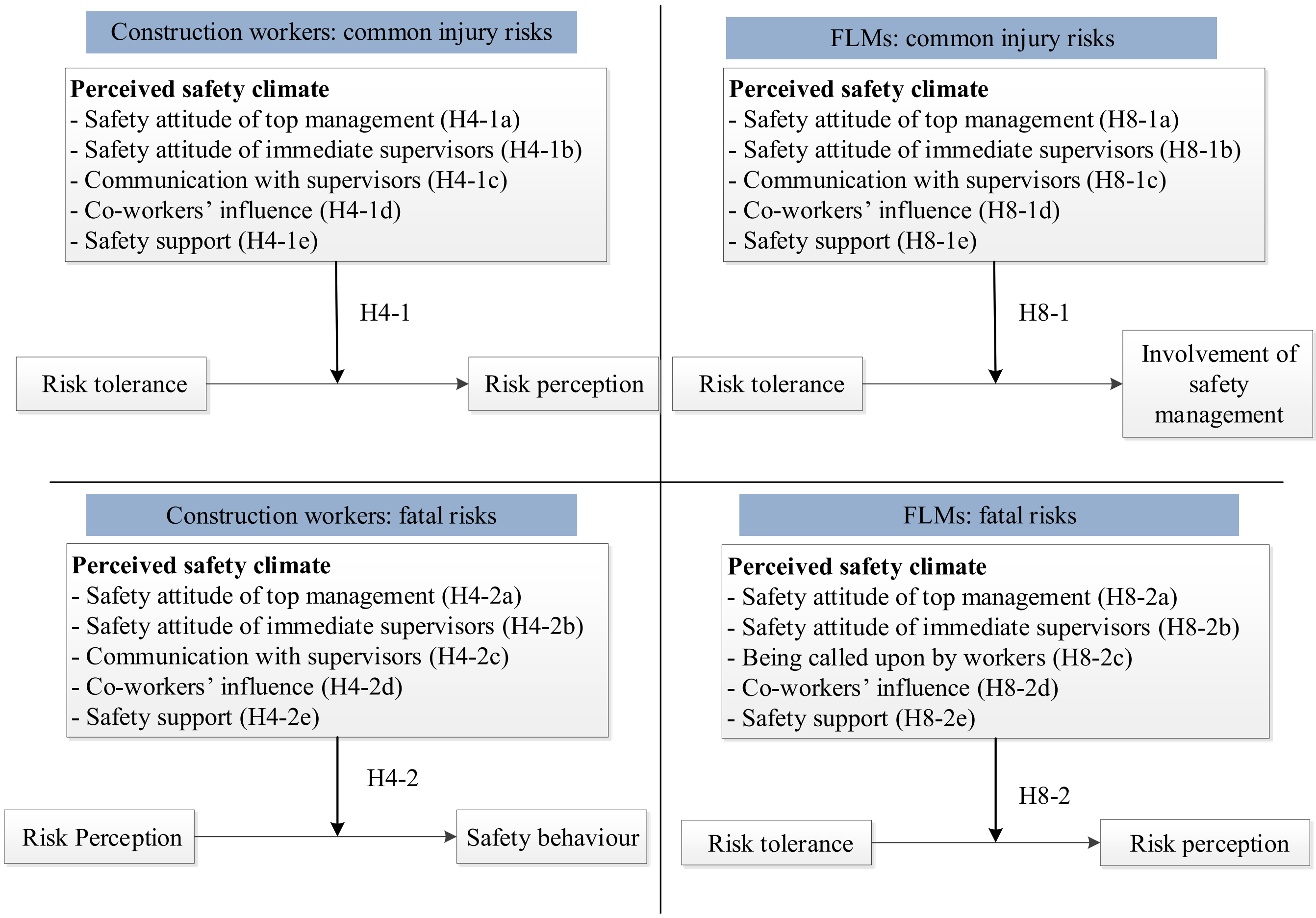


Figure 4.10 Theoretical research model for the moderating effect of perceived safety climate

4.3.2 Analysis Strategy

We use IBM SPSS 23.0 and Mplus 7.11 to analyse the reliability and validity of the measures of study variables. All proposed hypotheses are tested using Mplus 7.11, where regression models are established for moderation analyses.

In general terms, a moderator is a qualitative (e.g. sex, race, class) or quantitative (e.g. level of reward) variable that affects the direction and/or strength of the relation between independent or predictor variables and dependent or criterion variables (Baron and Kenny, 1986). Moderators indicate when or under what conditions effects can be expected. The moderator may increase or decrease the strength of a relationship or change its direction (Baron and Kenny, 1986). The key to evaluating whether a moderating effect exists is to assess the significance of path c, which shows the interaction effect of independent variable X and moderate variable M, as shown in Figure 4.11.

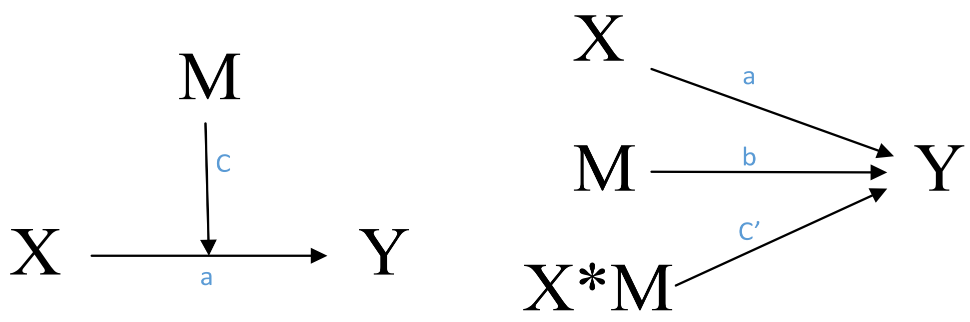


Figure 4.11 Moderating effect

Specifically within a correlational analysis framework, the moderator is a third variable that affects the zero-order correlation between two other variables or the value of the slope of dependent variables on independent variables. In analysis of variance terms, a basic moderating effect can be represented as an interaction between a focal independent variable and a factor that specifies the appropriate conditions for its operation (Baron and Kenny, 1986). For example, prior research has suggested the main effect of social support on quality of life. However, Cohen and Willis (1985) demonstrated that the relationship between social support and quality of life depends on individuals' stress level. People who experience too much stress but have good social support show better outcomes (few symptoms of depression, anxiety and fatigue) than those with low social support (Cohen and Wills, 1985).

4.3.3 Reliability and Validity of the Safety Climate Questionnaire

The reliability and validity of safety climate questionnaire are examined before further analysis and hypothesis testing. A literature review indicates that safety climate has five dimensions, namely, safety attitude of top management, safety attitude of immediate supervisors, co-workers' influence, communication with supervisors/being called upon by workers and safety support. These dimensions are considered in this research. No instrument for safety support measurement is available in the construction management literature. Therefore, a reliability and validity instrument must be developed first.

4.3.3.1 Confirmation of the Component of Safety Support

On the basis of a literature review and interviews with construction safety experts, nine items (shown as SS01–SS09 in the questionnaire) were designed to represent safety support as follows:

1. If I were injured at work, I would not worry about medical costs because the insurance I get through my employer would cover them.
2. If I were injured at work and needed three weeks off, the weekly payment I would receive during time off would cover my basic living expenses.
3. If I were injured at work, my employer would do what could be done to support me.
4. If I were injured at work, my employer would provide enough information about my rights and responsibilities.
5. My employer would treat me fairly during the claim process.
6. My employer would treat me fairly after the claim process.
7. We have sufficient first-aid materials at our site.
8. I am happy with my current income from construction work.
9. I feel my job is secure.

A two-step analysis method derived from Sunindijo and Zou (2013) was used to confirm the components of safety support. Firstly, an item analysis was conducted to evaluate the nine items that were initially identified, and only those with the highest corrected item-total correlations (CITI) (0.40 or greater) were retained because these items provided the best representations of the construct (Sunindijo and Zou, 2013). In the construction worker group, items 07 and 09 were excluded, whereas in the FLM group, items 01, 07 and 08 were excluded.

Secondly, factor analysis using a principal axis method and varimax rotation was performed on the remaining seven items to determine their factor structures. The Kaiser–Meyer–Olkin measure of sampling adequacy was 0.858 and 0.711 in the worker and FLM groups, respectively. Bartlett's test of sphericity for each group was significant ($p < 0.000$), indicating that factor analysis was suitable for analysing the data. Tables 4.12 and 4.13 summarise the results of factor analysis for the worker and FLM groups, respectively.

On the basis of the eigenvalue (>1) and scree plot of the factor analysis, one component of safety support was extracted and accounted for 71.273% of the variance in the construction worker group. Similarly, one component of safety support, which accounted for 76.414% of the total variance, was extracted in the FLM group. Thirdly, the reliability and validity of the four dimensions of safety climate were tested.

Table 4.12 Factor analysis of safety support in the worker group

No.	Item	Safety support
SS03	If I were injured at work, my employer would always do what could be done to support me.	0.916
SS05	My employer would treat me fairly during the claim process.	0.923
SS06	My employer would treat me fairly after the claim process.	0.908
SS04	If I were injured at work, my employer would always provide enough information about my rights and responsibilities.	0.872
SS02	If I were injured at work and needed three weeks off, the weekly payment during time off would cover my basic living expenses.	0.824
SS08	I am happy with my income from construction work.	0.795

SS01	If I were injured at work, I would not be worried about medical costs because the insurance I get through my employer would cover them.	0.633
	Eigenvalue	4.970
	Percentage of variance explained	71.004
	Cumulative percentage of variance explained	71.004
	Coefficient alpha reliability estimates	0.929

Table 4.13 Factor analysis of safety support for FLM group

No.	Item	Safety support
SS06	My employer would treat me fairly after the claim process.	0.897
SS05	My employer would treat me fairly during the claim process.	0.863
SS04	If I were injured at work, my employer would always provide enough information on my rights and responsibilities.	0.735
SS02	If I were injured at work and needed three weeks off, the weekly payment during time off would cover my basic living expenses.	0.725
SS03	If I were injured at work, my employer would always do what could be done to support me.	0.688
SS09	I feel my job is secure.	0.676
	Eigenvalue	4.585
	Percentage of variance explained	76.415
	Cumulative percentage of variance explained	76.414
	Coefficient alpha reliability estimates	0.810

4.3.3.2 Analysis of the Reliability and Validity of Measurement Scale

Before testing the moderating effect, studies need to be conducted on the reliability and validity of the measurement instruments for reliable model testing and theory development (Xiong et al., 2015). Reliability means that the questionnaires are consistent; thus, the questionnaire items belong to one dimension (Flynn et al., 1994). Cronbach's α is the most common measure of scale reliability (Field, 2009), where α = 0.6 is the acceptance level. When one questionnaire contains more than one dimension, the internal consistency of each dimension should be tested.

In the construction worker group, the Cronbach's α for the five safety climate dimensions—safety attitude of top management, safety attitude of immediate supervisors, co-workers' influence, communication between workers and supervisors and safety support—are 0.917, 0.892, 0.943, 0.766 and 0.930, respectively. The Cronbach's α in FLM group are 0.938, 0.812, 0.879, 0.811 and 0.810. These results indicate and confirm that the applied questionnaire of safety climate has very good reliability.

Convergent and discriminant validity tests are two common tests for validity (Xiong et al., 2015). Convergent validity refers to the degree of positive correlation of one manifest variable and other manifest variables within the same construct. Manifest variables within the same construct should share a comparatively high proportion of commonality (Hair Jr et al., 2016). AVE and factor loadings are used to assess convergent and discriminant validity. These two indicators should be respectively 0.50 and 0.50 or higher (Fornell and Larcker, 1981).

In the construction worker group, the standardised factor loading of all items in the safety climate measurement model is higher than 0.5, and the AVE value for safety attitude of top management, safety attitude of immediate supervisors, co-workers' influence, communication with supervisors and safety support are 0.78, 0.53, 0.85, 0.48 and 0.64, respectively. This confirmatory factor analysis yields an acceptable fit, where $\chi 2/df = 1.898$, $p < 0.000$, RMR = 0.098, CFI = 0.973 and RMSEA = 0.069. In the FLM group, the standardised factor loading of all items in the safety climate measurement model is higher than 0.5, and the AVE value for safety attitude of top management, safety attitude of immediate supervisors, co-workers' influence, being called upon by workers on safety issues and safety support are 0.50, 0.48, 0.80, 0.57 and 0.54, respectively. These results indicate the good validity of the employed safety climate questionnaire. This confirmatory factor analysis yields an acceptable fit, where $\chi2/df = 1.994$, $p < 0.000$, RMR = 0.066, CFI = 0.925 and RMSEA = 0.090. Therefore, the four dimensions of safety climate have sufficiently district factors.

4.3.4 Perceived Safety Climate in Worker and FLM Groups

Table 4.14 presents the levels of perceived safety climate. FLMs perceive a more positive safety climate than workers. The average score of each dimension of safety climate evaluated by FLMs is higher than the figure given by workers. The biggest difference comes from the dimension of safety attitude of top management, in which the average score of workers is 4.1906, whereas that of FLMs is 5.4563. Thus, safety attitude of top management may exert different influences on workers and FLMs' safety perception. Further evidence of each dimension's influence on risk judgement is provided below.

Table 4.14 Levels of perceived safety climate in worker and FLM groups

No.	Item	Worker average	FLM average	Difference
Dimension 1	Safety attitude of top management	4.1906	5.4563	1.2657
Dimension 2	Safety attitude of immediate supervisors	4.1964	5.1244	0.9280
Dimension 3	Communication with supervisors/workers	4.3542	5.0027	0.6485
Dimension 4	Co-workers' influence	3.8229	3.8871	0.0642
Dimension 5	Safety support	3.6094	4.4624	0.8530

Safety climate:
1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = slightly agree, 5 = agree, 6 = strongly agree

4.3.5 Hypothesis Testing

4.3.5.1 Moderating effect test

To test the moderating effects proposed in Hypotheses 4-1, 4-2, 8-1 and 8-2, four regression models were established in Mplus 7.11. Three steps were followed to create each regression model. To test Hypothesis 4-1, step one treated risk perception as a dependent variable, and the selected control variables were treated as independent variables. Step two added risk tolerance and five perceived safety climate dimensions to step one as independent variables. Step three added the interaction effects between risk tolerance and each perceived dimension of safety climate as independent variables. On the basis of these three steps, four multiple regression models were built to test Hypotheses 4-1, 4-2, 8-1 and 8-2.

Table 4.15 shows the moderating effect results of Hypothesis 4-1. The moderating effect of co-workers' influence was tested as insignificant. The other four dimensions of perceived safety climate showed a significant moderating effect, but the regression coefficients were negative, in which: H4-1a: $B = -0.12$, $P < 0.05$; H4-1b: $B = -0.18$, $P < 0.05$; H4-1c: $B = -0.20$, $P < 0.05$ and H4-1e: $B = -0.16$, $P < 0.01$. Therefore, the relationship between risk tolerance and risk perception could be negatively moderated by safety attitude of top management, safety attitude of immediate supervisors, communication with supervisors and safety support. In other words, the negative relationship between risk tolerance and risk perception could be strengthened if a positive safety climate was perceived. Thus, Hypothesis 4-1 was rejected by the current data.

Table 4.16 shows the results of Hypothesis 4-2. The interaction coefficients of the five dimensions of perceived safety climate were insignificant. Thus, Hypothesis 4-2 was rejected by the current data.

Table 4.17 shows the results of Hypothesis 8-1. The interaction coefficients of the five dimensions of perceived safety climate were insignificant. Therefore, Hypothesis 8-1 was rejected by the current data.

Table 4.18 reveals that four dimensions of perceived safety climate showed significant and positive moderating effects, in which: H8-2a: $B = 1.60$, $P < 0.001$; H8-2b: $B = 0.46$, $P <$

0.001; H8-2c: B = 0.63, P < 0.001 and H8-2e: B = 0.43, P < 0.001. These results indicated that the relationship between risk tolerance and risk perception could be positively moderated by safety attitude of top management, safety attitude of immediate supervisors, communication with supervisors and safety support. In other words, the negative relationship between risk tolerance and risk perception could weaken if a positive safety climate was perceived. Hypothesis 8-2d had not been tested as significant. Thus, this hypothesis was partially proved.

Table 4.15 Moderating effect test of Hypothesis 4-1

Predictor variable	**Step 1**	**Step 2**	**Step 3**
	Dependent variable: **risk perception**		
Controlled variable			
Age	0.07**	0.03**	0.02
Experience	-0.08**	-0.70**	-0.75*
Independent variable			
Risk tolerance (RT)		-0.54***	-0.006
Moderation variable			
Safety attitude of top management (SATM)		0.06	0.35*
Safety attitude of immediate supervisor (SAIS)		0.09***	0.53***
Communication with supervisor (CS)		0.15**	0.59*
Co-workers' influence (CI)		0.18	0.34
Safety support (SS)		0.31	0.40*
Interaction effect			
RT*SATM (Hypothesis 4-1a)			-0.12*
RT*SAIS (Hypothesis 4-1b)			-0.18*
RT*CS (Hypothesis 4-1c)			-0.20*
RT*CI (Hypothesis 4-1d)			-0.18
RT*SS (Hypothesis 4-1e)			-0.16**

Note: N = 192.

Table entries represent standardised parameter estimates with standard errors in parentheses.

***. Estimate is significant at the .001 level (two-tailed).

**. Estimate is significant at the .01 level (two-tailed).

*. Estimate is significant at the .05 level (two-tailed).

Table 4.16 Moderating effect test of Hypothesis 4-2

Predictor variable	Step 1	Step 2	Step 3
		Dependent variable: **safety behaviour**	
Controlled variable			
Age	0.07**	0.03**	0.02
Experience	-0.08**	-0.70**	-0.75*
Independent variable			
Risk perception (RP)		-0.54***	-0.006
Moderation variable			
Safety attitude of top management (SATM)		0.06	0.35*
Safety attitude of immediate supervisor (SAIS)		0.19***	0.33***
Communication with supervisor (CS)		0.35**	0.69*
Co-workers' influence (CI)		0.20	0.24
Safety support (SS)		0.37	0.40
Interaction effect			
RP*SATM (Hypothesis 4-2a)			0.18
RP*SAIS (Hypothesis 4-2b)			0.24
RP*CS (Hypothesis 4-2c)			0.30
RP*CI (Hypothesis 4-2d)			0.18
RP*SS (Hypothesis 4-2e)			0.33

Note: N = 192.

Table entries represent standardised parameter estimates with standard errors in parentheses.

***. Estimate is significant at the .001 level (two-tailed).

**. Estimate is significant at the .01 level (two-tailed).

*. Estimate is significant at the .05 level (two-tailed).

Table 4.17 Moderating effect test of Hypothesis 8-1

Predictor variable	Step 1	Step 2	Step 3
	Dependent variable: **involvement of safety management**		
Controlled variable			

Age	0.21**	0.17**	0.02
Experience	-0.08**	-0.71**	-0.72*
Independent variable			
RT		-0.54***	-0.006
Moderation variable			
Safety attitude of top management (SATM)		0.06	0.35*
Safety attitude of immediate supervisor (SAIS)		0.21**	0.33***
Communication with supervisor (CS)		0.35**	0.54*
Co-workers' influence (CI)		0.22	0.37
Safety support (SS)		0.11	0.14
Interaction effect			
RT*SATM (Hypothesis 8-1a)			0.40
RT*SAIS (Hypothesis 8-1b)			0.21
RT*CW (Hypothesis 8-1c)			0.33
RT*CI (Hypothesis 8-1d)			0.15
RT*SS (Hypothesis 8-1e)			0.20

Note: N = 164.

Table entries represent standardised parameter estimates with standard errors in parentheses.

***. Estimate is significant at the .001 level (two-tailed).

**. Estimate is significant at the .01 level (two-tailed).

*. Estimate is significant at the .05 level (two-tailed).

Table 4.18 Moderating effect test of Hypothesis 8-2

Predictor variable	Step 1	Step 2	Step 3
	Dependent variable: **risk perception**		
Controlled variable			
Age	0.27**	0.17**	0.02
Experience	-0.08**	-0.70**	-0.75*
Independent variable			
RT		-0.53***	-4.01***
Moderation variable			

Safety attitude of top management (SATM)	0.31	-1.78**
Safety attitude of immediate supervisor (SAIS)	0.48***	-0.11
Communication with supervisor (CS)	0.23	-0.58
Co-workers' influence (CI)	0.18	0.34
Safety support (SS)	0.03	-0.73**
Interaction effect		
RT*SATM (Hypothesis 8-2a)		1.60***
RT*SAIS (Hypothesis 8-2b)		0.46***
RT*CW (Hypothesis 8-2c)		0.63***
RT*CI (Hypothesis 8-2d)		0.30
RT*SS (Hypothesis 8-2e)		0.43***

Note: N = 164.

Table entries represent standardised parameter estimates with standard errors in parentheses.

***. Estimate is significant at the .001 level (two-tailed).

**. Estimate is significant at the .01 level (two-tailed).

*. Estimate is significant at the .05 level (two-tailed).

4.3.5.2 Further explanation of the significant moderating effects

Eight moderating effects are tested as significant by the data. To further understand these moderation effects, they are plotted based on their regression coefficient. The score of each significant coefficient is divided into three groups: high (M + 1SD), mean (M) and low (M - 1SD). Figure 4.12 illustrates the moderating effects identified in the worker group, and Figure 4.13 illustrates the moderating effects identified in the FLM group.

Figure 4.12(1) shows that the slope of high safety attitude of top management is evidently higher than that of the mean and low safety attitude of top management. In general, an environment with high safety attitude of top management increases the negative effects of risk tolerance on risk perception. When workers have a high risk tolerance, with an environment of positive safety attitude of top management, their risk perception decreases.

However, the moderating effect is the opposite with low risk tolerance. Figure 4.12(2) shows that the slope of high safety attitude of immediate supervisors is evidently higher than that of mean and low safety attitude of immediate supervisors. In general, an environment with high safety attitude of immediate supervisors increases the negative effects of risk tolerance on risk perception. When workers have a high risk tolerance, with an environment where supervisors have a positive safety attitude, their risk perception decreases. However, the moderating effect is the opposite with low risk tolerance. Figure 4.12(3) provides further understanding of the three levels of communication as a moderator variable on the result. The slope of high communication is evidently higher than that of mean and low communication. Therefore, high communication increases the negative effect of risk tolerance on risk perception. When workers have low risk tolerance, their risk perception improves with increasing communication. However, the moderation effect is the opposite with high risk tolerance. Figure 4.12(4) shows that the slope of high safety support is evidently higher than that of mean and low safety support. In general, an environment with high safety support increases the negative effects of risk tolerance on risk perception. When workers have high risk tolerance, with an environment of good safety support, their risk perception decreases. However, the moderating effect is the opposite with low risk tolerance.

The slope of low safety attitude of top management in the FLM group is evidently higher than that of mean and high safety attitude of top management. In general, an environment with high supervision decreases the negative effects of risk tolerance on risk perception. When FLMs have high risk tolerance, their risk perception increases with an environment where top management has a high safety attitude. Figure 4.13(2) shows that the slope of low safety attitude of immediate supervisors is evidently higher than that of mean and high safety attitude of immediate supervisors. In general, an environment with a high level of positive safety attitude of immediate supervisors can weaken the negative effects of risk tolerance on risk perception. When FLMs have high risk tolerance, their risk perception increases with an environment where supervisors have a positive safety attitude. Figure 4.13(3) provides further understanding of the three levels of communication with workers as a moderator variable on the result. The slope of high communication with workers is evidently lower than that of mean and low communication with workers. Therefore, high communication with workers decreases the negative effect of risk tolerance on risk perception. When FLMs have a certain risk tolerance, their risk perception improves with increasing communication with workers. Figure 4.13(4) shows that the slope of high safety support is evidently lower than that of mean and low safety support. In general, an environment with a high level of safety support decreases the negative effects of risk tolerance on risk perception. When FLMs have a certain level of risk tolerance, their risk perception increases with an environment of better safety support.

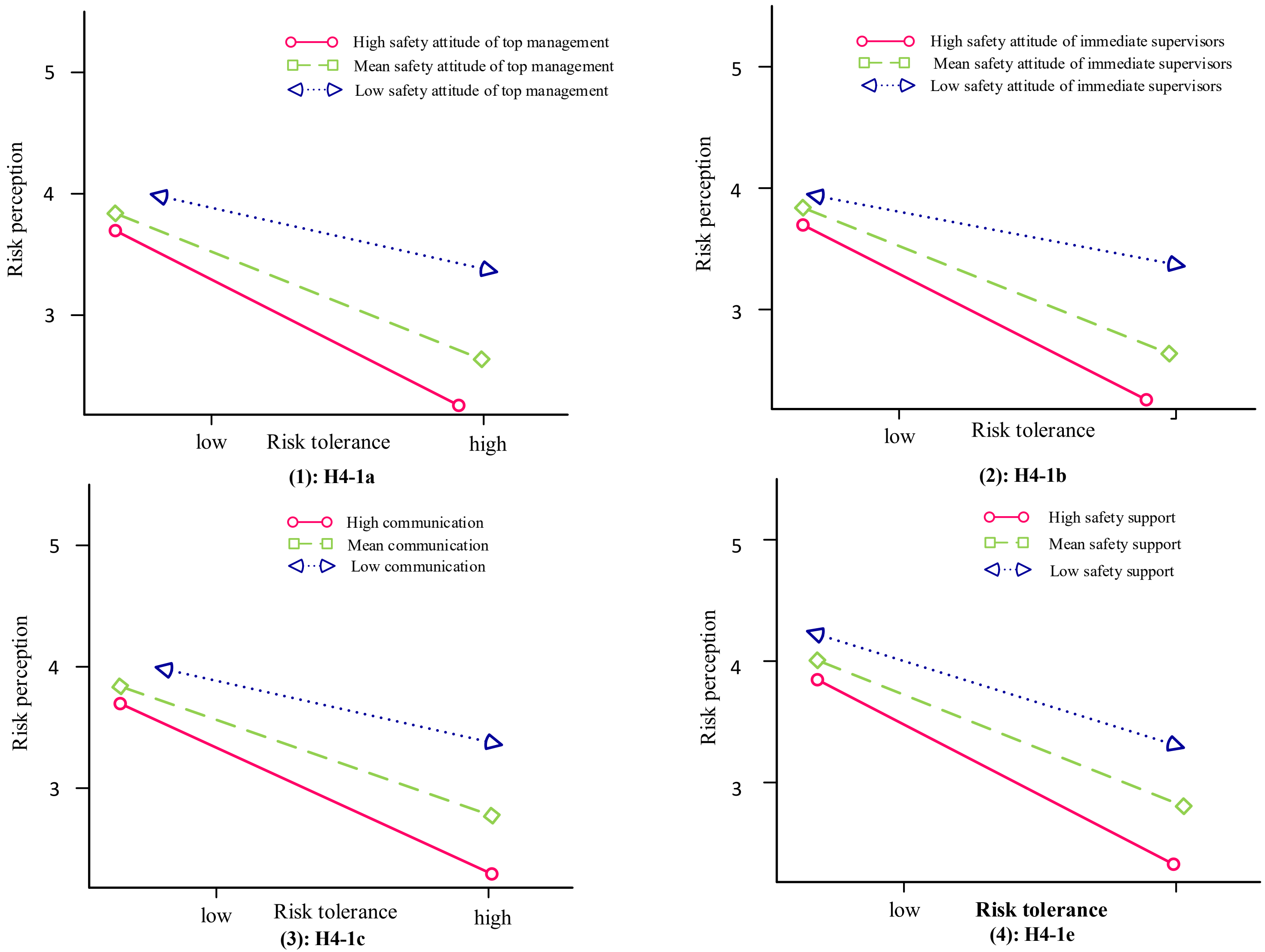


Figure 4.12 Moderating effects of perceived safety climate in the worker group (Hypothesis 4-1)

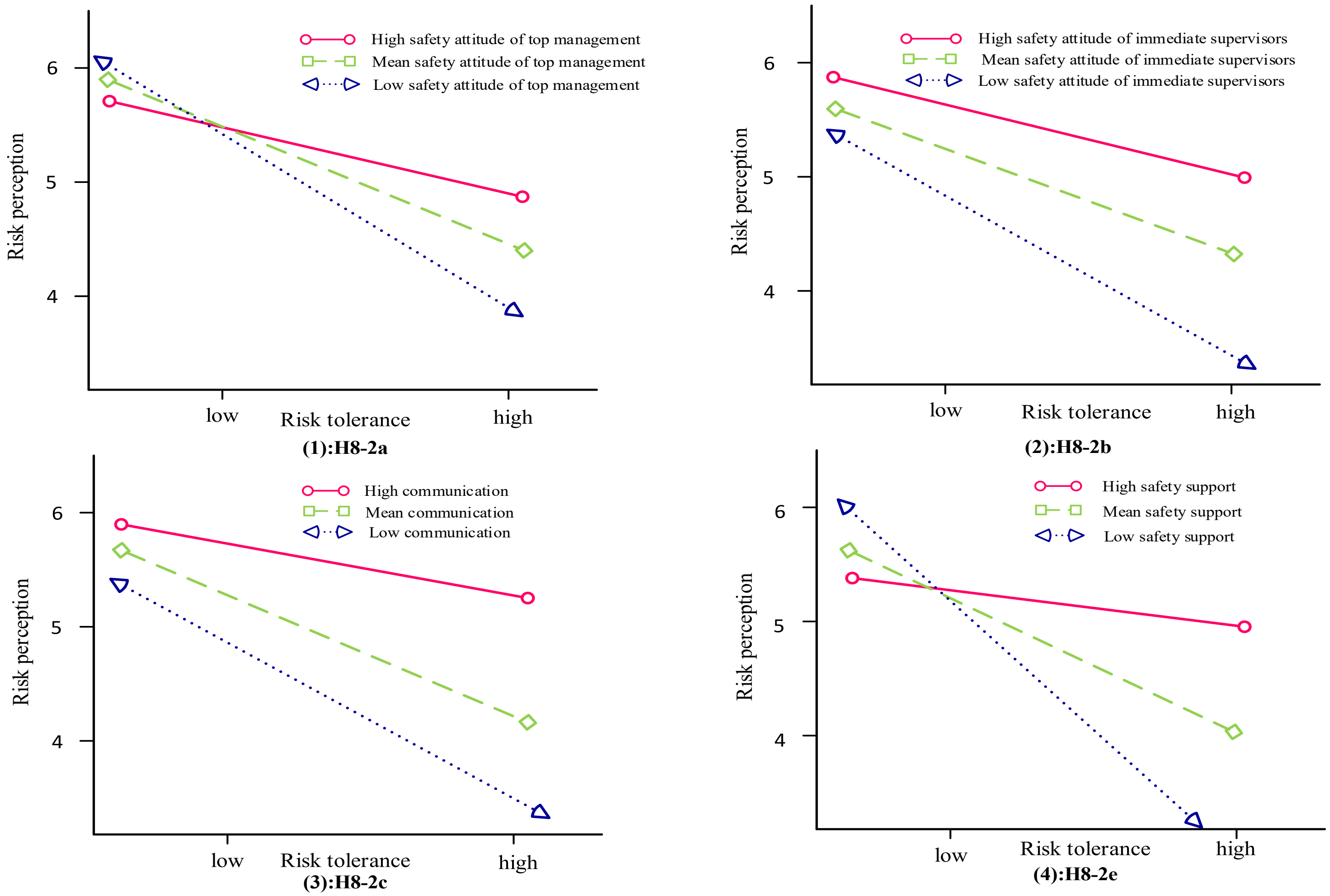


Figure 4.13 Moderating effects of perceived safety climate in the FLM group (Hypothesis 8-2)

4.3.6 Discussion

4.3.6.1 Summary of analysis results

The proposed moderation hypotheses are partially supported. On the basis of the above analysis, the major findings are as follows:

(1) Hypothesis 4-1 is rejected by the data because the moderating effect is the opposite of what is hypothesised. When construction workers confront common injury risks during construction tasks, the negative relationship between risk tolerance and risk perception is negatively moderated by perceived safety attitude of top management (H4-1a), safety attitude of immediate supervisors (H4-1b), communication with supervisors (H4-1c) and safety support (H4-1e). Specifically, when workers perceive a positive safety attitude of top management, safety attitude of immediate supervisors, communication with supervisors and safety support, they tend to have a low perception of risks, which increases the probability of behaving unsafely.

(2) Hypotheses 4-2 and 8-1 are not supported by the collected data.

(3) Hypothesis 8-2 is partially supported by the data because four sub-hypotheses are also supported. When FLMs confront fatal risks during construction tasks, the relationship between risk tolerance and risk perception is positively moderated by the perceived top management attitude (H8-2a), immediate supervisors (8-2b), communication with workers (H8-2c) and safety support (H8-2e), that is, when they perceive a higher level of safety attitude from top and immediate management, communication with workers and safety support, they tend to have a high perception of risks, which decreases the probability of behaving unsafely.

(4) Two evident differences between workers and FLMs are noticed. Firstly, the reaction of perceived positive safety climate between workers and FLMs is different. The negative effect of risk tolerance on risk perception in FLM group

weakens but strengthens in the worker group. Secondly, on the basis of the interaction coefficients, the most important safety climate in the worker group is the communication with supervisors, whereas the most important safety climate for FLMs is the safety attitude of top management and communication with workers comes second.

4.3.6.2 Theoretical and practical contribution

Safety climate serves as a shared understanding of workplace safety issues, thereby guiding normative and adaptive work behaviours by providing cues regarding expected contingencies in behaviour outcomes (Schneider, 1975, Zohar, 1980, DeJoy, 1994). Thus, the following questions arise: (1) How do these shared safety values shape construction practitioners' risk behaviours? (2) How do construction practitioners perceive and respond to these shared safety issues? (3) In the process of safety climate shaping safety behaviours, do differences exist between the frontline workers and FLMs? Findings of this section can contribute to further understanding of these questions.

Firstly, the results of the moderating effect of perceived safety climate enriches the literature on how safety climate affects safety behaviour. In the field of safety management in construction projects, despite the considerable wide attention on safety climate, an in-depth analysis of how this climate moderates risk judgement process is lacking, especially the moderation extent of each safety climate. This study fills this knowledge gap by revealing the moderating effects of the five dimensions of safety climate on workers and FLMs' risk judgement, including top management safety attitude, immediate supervisors' safety attitude, communication with workers (supervisors), co-workers' influence and safety support. The dimension of safety support is found to play different moderating roles in the worker and FLM groups. The dimension of attitude of top management toward safety has the smallest moderating effect between risk tolerance and risk perception ($B = -0.12$, $P < 0.05$) among construction workers, whereas this dimension has the greatest moderating effect among FLMs. This difference can be explained by the work relationships with immediate supervisors and top management. Immediate supervisors provide direct management for workers, engaging in frequent contact with workers more than the upper management. Thus, close personal relationships with workers are built with immediate supervisors. Also, immediate supervisors have more power than the upper management because the latter can only monitor workers indirectly and infrequently (Ellemers et al., 2004, de Waal et al., 2015). Moreover, immediate supervisors have more specific options to sanction or reward workers' daily work activities than the upper management because of these supervisors' unique position in construction organisations. Similarly, workers are highly dependent on their immediate supervisors for gaining certain resources, such as promotions or incentives (Hillman and Dalziel, 2003). This close and direct relationship between workers and immediate supervisors influences workers with the safety values shared by immediate supervisors. Therefore, workers not only perceive safety climate conveyed from the upper management but are also sensitive to their immediate supervisory environment.

Contrary to workers' responses, the dimension of the attitude of top management, rather than the immediate supervisors, towards safety has the largest moderating effect among the dimensions of safety climate ($B = 1.60$. $p < 0.001$). One possible explanation is that FLMs' immediate supervisors or line managers not only focus on safety. FLMs in construction project teams have the most important role in keeping the workplace safe because they are the head of construction sites (Kouabenan et al., 2015). However, line managers care about multiple aspects of projects, such as project progress, logistics and stakeholders' requirement. Thus, FLMs may perceive fewer safety values shared by their line managers than the values workers perceive from their immediate supervisors. Safety is also the highest priority and the core value among the participating construction organisations. The top management may mention, discuss and emphasise safety more than FLMs' line managers. This different work focus decides whether FLMs perceive more safety values conveyed from the upper management than their line managers.

For safety management practice, these results illuminate the design and implementation of safety climate. Different dimensions of safety climate have different levels of moderating effect, and the importance of these dimensions is distinct for workers and FLMs. Thus, tailored designs of safety climate for workers and FLMs are efficient for safety management.

Secondly, the findings expand the knowledge of how construction practitioners respond to the perceived safety climate. The positive effect of safety climate on safety management has been proven by some studies (e.g. Cooper and Phillips, 2004; Seo, 2005; Tucker et al., 2008; Mullen, 2005; Arezes and Miguel, 2005; Mearns and Yule, 2009). However, applying this positive effect of safety climate is questionable without considering individuals' personality. Findings of this research reveal that a positive safety climate can increase FLMs' risk perception, which is consistent with current research. However, the perceived positive safety climate may decrease workers' risk perception if they have a strong willingness to tolerate safety risks. One possible explanation for this situation is that construction workers who score high on willingness to tolerate risks are thought to accept a great level of risks in pursuit of their goals. In this context, workers are thought to be fearless (Rodrigues et al., 2015b) and/or easily support hazardous attitudes, such as being macho, believing in good luck, belief in their invulnerability and being impulsive and anti-authoritarian (Ji et al., 2011). These emotions and attitudes may manifest in construction safety behaviours, such as finishing tasks quickly, ignoring supervisors' advice, believing only themselves and thinking that accidents can never happen to them. Hence, they may underestimate the likelihood and severity of safety risks. Another possible explanation can be conducted from the perspective of risk compensation theory (Peltzman, 1975) applied to construction workers' activities. Construction workers may behave in a less cautious way than usual when they feel ‘safe’ or protected (Feng and Wu, 2015, Stromme, 2004). Thus, when workers perceive an advanced safety climate, a misconception of ‘everyone cares about safety; thus, the working environment is safe’ is considered. As a result, workers may be less sensitive to potential safety risks than usual.

These findings are of great significance theoretically and practically. Few studies have considered the role of safety climate together with people’s personality in safety management. The same safety intervention may exert different effects for people with different attitudes and personalities because risk judgement is usually conducted in a subjective and emotional way (Xia et al., 2017). This research, considering the effect of safety climate together with workers’ risk tolerance, indicates the importance of workers’ tolerability of safety risks. Moreover, high risk tolerance may break and reverse the positive effect of safety climate. Thus, designing and providing tailored safety training for construction workers with different risk tolerance may be helpful to ensure objective risk judgements.

4.4 Critical Influential Factors of Safety Risk Tolerance

Section 2.6 mentions that the research mainly focuses on qualitatively identifying the influential factors of risk tolerance, which are difficult to distinguish. Also, no detailed research of this topic is available in the construction safety field, especially a comparison between workers and FLMs. This missing information creates challenges for comprehensive risk management given that workers and FLMs are important contributors in construction projects. Thus, this section aims to (1) identify the critical influential factors of safety risk tolerance for workers and FLMs and (2) compare the difference of influential factors between these two groups.

4.4.1 Analysis Strategy

Several statistical methods are applied to analyse the data collected through interviews and questionnaire surveys. All analyses are conducted by using IBM SPSS Statistics 23. Figure 4.14 shows the analysis method.

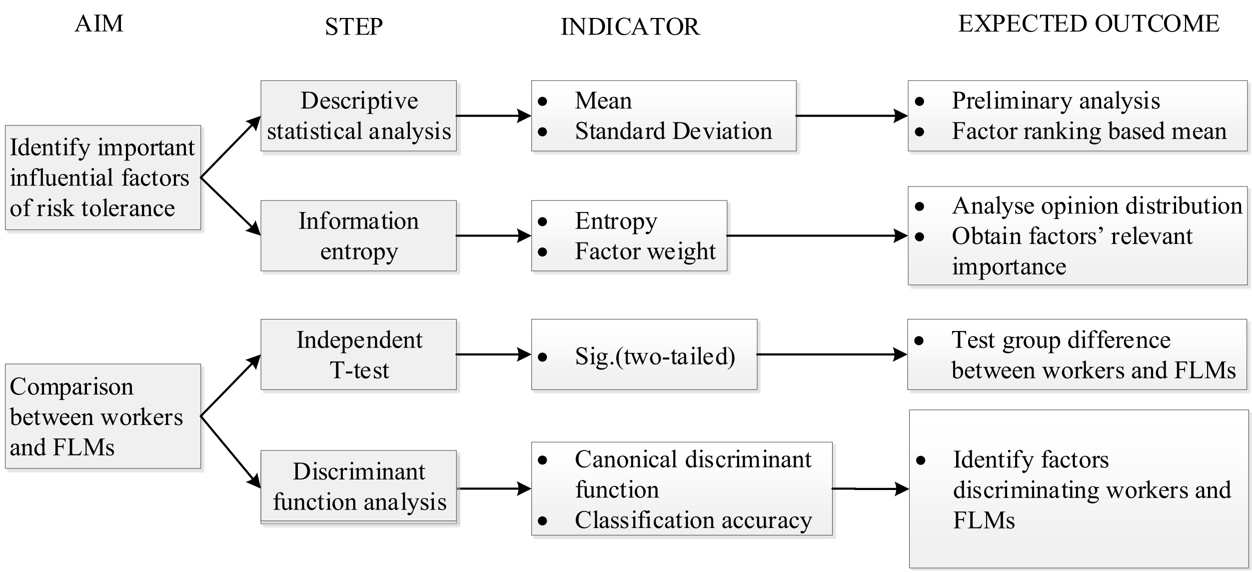


Figure 4.14 Research framework and process

The first aim is to identify the critical factors for each group. According to descriptive statistical analysis, the mean value of each factor can be calculated. Then, a preliminary factor ranking that presents the participants' general opinion is obtained. However, the importance of each factor cannot be determined only by the average opinion given the existence of subjective bias. Thus, an objective method for determining the relevant importance of each factor should be applied.

The entropy method initially appeared in thermodynamics and was then introduced by Shannon (1948) into information theory. This method has recently been widely used in social science, engineering, economy and finance as an objective way to determine weight (Zou et al., 2006b, Hung and Chen, 2009, Li and Jiang, 2017, Hsu and Hsu, 2008). The basic idea of information theory is the more you know about a topic, the less new information you can obtain about it. If an event is probable and it happens, then little information is revealed that it actually happened. Inversely, if the event is improbable, then further information shows that the event happened. Therefore, information content is a function of the inverse of the probability of the event (1/p). Entropy is the measurement of the disorder degree of a system (Kullback, 1997, Li and Jiang, 2017), whereas in information theory, entropy is a measure of unpredictability of a state or equivalently, of its average information content. When the difference of values among the evaluating objects on the same indicator is high, the entropy is small, illustrating that people have similar opinions about the indicator and representing that it provides useful information. Then, the weight of this indicator should be set correspondingly high. By contrast, if the difference of people's evaluation on one indicator is small, then the entropy is high and the relative weight is small (Qiu, 2002, Zou et al., 2006b). In summary, entropy is a measure that uses probability theory to measure the uncertainty of information. More dispersive data correspond to increased uncertainty and less information contained. Equation 4-1 is used to calculate entropy.

$$\mathrm{e} = -\mathrm{k}\sum_{i=1}^{m} p_i \ln p_i \tag{4-1}$$

In Equation 4-1, p_i represents the distribution of participants' opinion on each scale (from 1 to 5). The advantage of using entropy rather than variance to show the discreteness of participants' opinion is that the bias caused by an extreme value is avoided given that the variance related to the scale and entropy values is related only to the opinion distribution on each scale. Another advantage of using entropy is that from the perspective of information theory, entropy conveys the message of the relevant importance of each factor. A high entropy corresponds to increased inconsistency of people's opinion and less importance of the factor.

When $p_i = \frac{1}{k}$, e = 1, e reaches the maximum. Under this situation, people have dispersive opinions about the factor, which means people are not quite sure about it. Thus, less entropy of the indicators corresponds to more consistency of the opinions individuals have about it. In this situation, further information can be provided to assess the tolerance of safety risk. Assuming *m* entropy indicators and *n* evaluation levels exist, Table 4.19 shows the steps to calculate entropy.

Table 4.19 Calculation steps of entropy

Calculation step	Equation
Step 1: Calculate the proportion of each indicator	$p_{Aij} = \frac{x_{Aij}}{\sum_{j=1}^{5} x_{Aij}}$, (i = 1, 2, …, 28)
Step 2: Calculate the entropy of each indicator	$e_{Ai} = -\frac{1}{\ln 5}\sum_{j=1}^{5} p_{Aij} \ln p_{Aij}$, (i = 1, 2, …, 28), where $k_A = \frac{1}{\ln 5}$
Step 3: Calculate the variation coefficient of each indicator	$g_{Ai} = 1 - e_{Ai}$
Step 4: Calculate the entropy weight of each indicator	$\omega_{Ai} = \frac{g_{Ai}}{\sum_{i=1}^{28} g_{Ai}}$

On the basis of the factor mean and entropy weight, the relative importance of each influential factor of risk tolerance can be decided in the worker and FLM groups. Then, the difference between these two groups is analysed. Firstly, an independent t-test is conducted to test the statistical difference of each factor between these two groups. Then, discriminant function analysis (DFA) is applied to discover which factors discriminate risk tolerance between workers and FLMs. DFA indicates how well treatment groups differ from each other. On the basis of the idea of classification, DFA seeks out a linear function of variables for each treatment group that maximises the differences between them, as shown in Equation 4-2.

$$\boldsymbol{s_i = c_i + w_{i1} * x_1 + w_{i2} * x_2 + \cdots + w_{im} * x_m} \qquad (4\text{-}2)$$

where i represents the respective groups, and numbers 1, 2, … and m represent the m variables. c_i refers to the constant for group i, and w_{ij} is the ponderation factors of variable j for group i. s_i is the classification value. In DFA, the factorial scores can be calculated for each observation, thereby providing an integrated metric that reflects the changes in the tested variables. Large factorial weights (absolute value) correspond to the great contribution of variables to the discriminant function.

4.4.2 Influential Factors of Risk Tolerance

On basis of the results of the literature review and interviews, a list of 28 factors is obtained, which forms the main basis for the questionnaire design. All factors are tabulated in Table 4.20 with detailed descriptions.

Table 4.20 Influential factors of risk tolerance

No.	Factor	Description
F01	Working experience	Rich working experience makes workers familiar with potential risks in projects, thus likely reduce risk-taking behaviour (Sung and Hanna, 1996).
F02	Familiarity with task	This factor occurs when workers have completed tasks successfully multiple times and have the skill to complete them successfully without thinking—a state referred to as 'unconsciously competent'. Research shows that workers in this state can become unaware of the potential hazards. This autopilot complacency occurs without workers having to

		refocus or refresh, thus creating a blind spot to potential hazards (Occupational Safety, 2015; Rodrigues et al., 2011).
F03	Control of safety risk	Workers with high capability to control safety risks may underestimate safety risks (Occupational Safety, 2015).
F04	Knowledge of risk management	If individuals have a clear understanding of their risk management policy, then they are careful about their behaviours (Cordell, 2002; Grable, 2000; Grable and Joo, 2004; Rodrigues et al., 2011).
F05	Safety knowledge	With safety knowledge, workers understand the seriousness of risk-taking in construction projects. Thus, low risk tolerance may happen (Pohjola, 2003).
F06	Emotion	This factor refers to whether workers are happy or not. Sometimes, working with anger or sadness may result in irrational risk decision making (Segal et al., 2005).
F07	Belief in good luck	If individuals believe they are always lucky, then they have high risk tolerance because they may believe they can never encounter unsafe situations.
F08	Voluntary action at work	When exposure to risk is considered a voluntary action and part of an action where employees are in control, the associated risks are easily accepted. Formalised work planning built around solid and specific procedures creates structures. Structured and regimented work routines reduce the sense that activities are voluntary. Such structures reduce employees' acceptance of risk (Occupational Safety, 2015).
F09	Emphasis on safety	This factor refers to how much workers realise and emphasise their safety.
F10	Work ability	This factor refers to workers' ability to analyse and judge problems according to their own knowledge and experience. This ability plays an important role within the process of risk tolerance assessment.
F11	Confidence in rescue	As surprising as it may sound, employees may consciously or subconsciously expose themselves to risk thinking that the emergency response plan should be implemented if something goes wrong. Employees' participation in emergency response training and practice drills or scenarios needs to reinforce the idea that the protective system

		may fail and that rescue only reduces the severity of impact and does not prevent the incident from happening (Occupational Safety, 2015).
F12	Role model of accepting risk	When employees' supervisor or manager takes shortcuts or intentionally takes on risks, the behaviour is normalised. Supervisors and managers who are the leaders who 'walk the talk' must be involved in ongoing training. Training programming must include a discussion of normalisation of risks and how to prevent them (Occupational Safety, 2015).
F13	Regulators' safety attitude	Regulators' safety attitude decides the safety procedures' implementation on site as one part of safety climate. Safety attitude can influence workers' assessment of risk tolerance.
F14	Communication with supervisors	An effective and trustworthy communication with supervisors can help strengthen the understanding of safety risks. Thus, objective risk tolerance can be achieved (Kemp, 1991).
F15	Occupational Health and Safety (OHS) regulation	Clear and specific safety regulations help workers realise the punishments against safety regulation. Then, their risk tolerance lessens.
F16	Peers' behaviour	The effect of peers' behaviour refers to workers doing the same things as their peer workers. If other workers complete work early by taking risks, then individuals' risk tolerance is enhanced to take the same risks.
F17	Managers' safety attitude	Immediate supervisors' safety attitude affects workers' safety risk tolerance (Wong et al., 2016).
F18	Supervision from top-level managers	Supervision from governments or supervisors may lessen workers' willingness to take risks. Then, their risk tolerance also lessens.
F19	Personal reputation	People care about their reputation. If they are known to have high risk tolerance and like taking risks, then finding an employer is difficult for them.
F20	Potential gain of profit from risk action	The implications of taking shortcuts must be a part of every training and refresher training programme. Strong messaging must come from senior leadership. It should also be incorporated into regular communication or refresher training to create a strong connection between senior leaders' message and the need to follow the procedures (Occupational Safety, 2015).

F21	Employers' reputation	If employers have a good safety reputation, then employees can be influenced by good safety climate. Moreover, risk tolerance is lessened.
F22	Production stress	If workers work under high pressure, then they have no time to think how to behave safely. They only want to finish work as soon as possible.
F23	Little time to assess confronting risk	In some abrupt cases, quick response and decision making are required because little time is left for thorough discussion and consideration. Thus, workers' risk tolerance varies depending on the time permitted for making decisions.
F24	Completeness of relevant project information	Relevant project information is critical in making the right decisions. Many risk assessments are conducted concerning the limited available data of historical accidents, but other considerations are ignored (Fung et al., 2012).
F25	Visibility of project	If projects are visible, then people behave safely (Kwak and LaPlace, 2005).
F26	Confidence in equipment	Overconfidence occurs when workers place excessive or unwarranted trust that equipment or tools always perform exactly as designed. When workers become familiar with particular tools and equipment and have not experienced any failures, workers can become overly trusting that such equipment or tools can never fail. This situation can occur with simple equipment such as hand tools or complex systems such as computer controls (Occupational Safety, 2015).
F27	Family responsibility	Family responsibility can help individuals realise that they have a family to take care of. Thus, they cannot take safety risks.
F28	Insurance coverage	Insurance coverage represents potential safety support, especially for employees who suffer from injuries on site (interview).

4.4.3 Results

4.4.3.1 Critical influential factors of risk tolerance for workers and FLMs

This section identifies the important factors that affect workers and FLMs' safety risk tolerance. The mean and entropy methods of each factor are derived from the total sample to determine factor importance. Factors with high mean values indicate that participants believe they are relevant to risk tolerance. Table 4.21 shows the ranking results of these factors. Table 4.22 lists the results for entropy calculation.

Table 4.21 Ranking results by mean calculation

No.	Factor	Worker			FLM		
		Mean	SD	Ranking	Mean	SD	Ranking
F01	Work experience	3.8750	.80248	4	4.1935	.69467	1
F02	Familiarity with task	3.7813	.96214	6	4.0161	.68650	2
F03	Control of safety risk	3.6563	1.05183	10	3.7581	.85892	7
F04	Knowledge of risk management	3.9688	.86772	2	3.8226	.87465	6
F05	Safety knowledge	4.0938	.88120	1	4.0000	.72134	3
F06	Emotion	3.0625	1.20046	25	2.8871	1.28916	23
F07	Belief in good luck	2.3281	1.24136	28	1.5645	1.01406	28
F08	Voluntary action at work	3.2500	1.20209	20	2.9792	.97310	20
F09	Emphasis on safety	3.7813	1.14135	7	3.9677	.93648	5
F10	Work ability	3.9219	.79865	3	3.6935	.75630	8
F11	Confidence in rescue	3.6250	1.08536	12	3.4355	1.02997	11
F12	Role model of accepting risk	3.2031	1.13737	21	3.0208	1.22241	18
F13	Regulators' safety attitude	3.7813	1.05556	8	3.3710	.90588	13
F14	Communication with supervisors	3.4531	.98570	16	3.5484	.85876	10
F15	OHS regulation	3.8594	1.20036	5	3.6290	.86924	9
F16	Peers' behaviour	3.3750	1.11393	17	3.2581	1.18164	15
F17	Managers' safety attitude	3.7656	1.01417	9	3.9839	1.04363	4
F18	Supervision from top-level managers	3.1875	1.03157	22	3.0645	1.06490	17
F19	Personal reputation	3.1302	1.35319	23	2.8226	1.26907	25
F20	Potential gain of profit from risk action	2.8750	1.08536	26	2.2742	.86803	26
F21	Employers' reputation	3.0625	1.28880	24	2.8710	1.05897	24
F22	Production stress	3.6094	1.04281	13	3.3065	.99737	14
F23	Little time to assess confronting risk	3.3594	1.00835	18	2.9355	.96897	22
F24	Completeness of relevant project information	3.2813	.97833	19	2.9677	.98720	21
F25	Visibility of project	3.5313	1.13445	15	3.0161	.94554	19
F26	Confidence in equipment	3.6406	1.11205	11	3.3871	.96026	12
F27	Family responsibility	3.5781	1.33583	14	3.1452	1.32330	16

F28	Insurance coverage	2.5938	1.40365	27	1.8548	1.07970	27

*N = 192 in worker group
*N = 164 in FLM group
*average of mean value in worker group = 3.2419
*average of mean value in FLM group = 3.4510

Table 4.22 Ranking result by entropy weight calculation

No.	Factor	Worker			FLM		
		Entropy	Weight	Factor ranking - weight	Entropy	Weight	Factor ranking - weight
F01	Work experience	0.744861	0.137975	2	0.627993	0.148139	2
F02	Familiarity with task	0.770943	0.12387	4	0.644509	0.141562	3
F03	Control of safety risk	0.861997	0.07463	15	0.792283	0.082716	13
F04	Knowledge of risk management	0.775127	0.121607	5	0.76534	0.093445	10
F05	Safety knowledge	0.738602	0.141359	1	0.706641	0.11682	4
F06	Emotion	0.928303	0.038773	24	0.948569	0.02048	28
F07	Belief in good luck	0.872679	0.068853	18	0.609836	0.155369	1
F08	Voluntary action at work	0.945299	0.029582	26	0.821599	0.071042	16
F09	Emphasis on safety	0.850167	0.081027	11	0.76185	0.094835	8
F10	Work ability	0.740307	0.140437	3	0.721049	0.111083	5
F11	Confidence in rescue	0.86246	0.074379	16	0.870038	0.051753	21
F12	Role model of accepting risk	0.907	0.050293	21	0.935845	0.025547	26
F13	Regulators’ safety attitude	0.861045	0.075144	14	0.742379	0.102589	7
F14	Communication with supervisors	0.82575	0.094231	6	0.765655	0.09332	11
F15	OHS regulation	0.849265	0.081515	10	0.728413	0.10815	6
F16	Peers’ behaviour	0.908064	0.049718	22	0.916428	0.03328	24
F17	Managers’ safety attitude	0.831133	0.09132	8	0.792932	0.082458	14
F18	Supervision from top-level managers	0.874634	0.067796	19	0.896768	0.041108	22
F19	Personal reputation	0.984578	0.00834	28	0.93914	0.024235	28
F20	Potential gain of profit from risk action	0.910847	0.048212	23	0.794531	0.081821	15
F21	Employers’ reputation	0.928691	0.038562	25	0.902686	0.038752	23
F22	Production stress	0.864083	0.073502	17	0.845741	0.061428	18

F23	Little time to assess confronting risk	0.858821	0.076347	13	0.847309	0.060804	19
F24	Completeness of relevant project information	0.847417	0.082514	9	0.847811	0.060604	20
F25	Visibility of project	0.827562	0.093251	7	0.834793	0.065788	17
F26	Confidence in equipment	0.854856	0.078492	12	0.779307	0.087883	12
F27	Family responsibility	0.906891	0.050352	20	0.934174	0.026213	25
F28	Insurance coverage	0.965047	0.018902	27	0.764189	0.093904	9

*N = 192 in worker group
*N = 164 in FLM group

The critical influential factors of risk tolerance need to be decided based on the integrated results of mean and entropy analyses. On the basis of the introduction, a high mean corresponds to an increased perception of the factors' importance by the participants. Moreover, a high entropy weight corresponds to great consistency of people's opinions. Thus, people are more confident about the factors' influence and the corresponding mean value is reliable. If factors have top factor ranking based on mean and high entropy weight, then they can be identified as the relative important and influential factors of risk tolerance. However, if factors have low entropy weight, then participants have inconsistent opinions about the factors' influence. Table 4.23 shows how to classify risk tolerance's influential factors based on mean and entropy.

Table 4.23 Classification of risk tolerance influential factors

Indicator	Explanation
Mean is high **Entropy weight is high**	• The most influential factors of risk tolerance
Entropy weight is low	• Participants have dispersive opinions

Table 4.24 presents the factor ranking based on these two methods. Accordingly, rules for selecting the most critical influential factors for each group are (1) the factor ranking based

on mean should be high, (2) the factor ranking based on entropy weight should be high and (3) the ranking difference between the first two should be low. On the basis of these rules, the critical factors for worker and FLM groups are identified and highlighted by green in Table 4.24. Construction workers' working experience, familiarity with the task, knowledge of risk management, safety knowledge and work ability are identified as the top five factors which workers believe have strong influences on their risk tolerance. FLMs' working experience, familiarity with task, safety knowledge, work ability and emphasis on safety are the top five factors that FLMs believe have important influences on their risk tolerance. Figure 4.15 shows the opinion distribution of these factors. Participants' opinions have a different distribution. Rare opinions are placed in levels 1 and 2, whereas other opinions are placed in high levels, such as 3, 4 and 5.

Table 4.24 Factor ranking results

No.	Factor	Worker			FLM		
		Factor ranking - mean	**Factor ranking - weight**	**Ranking difference (ABS)**	**Factor ranking - mean**	**Factor ranking - weight**	**Ranking difference (ABS)**
F01	Work experience	4	2	2	1	2	1
F02	Familiarity with task	6	4	2	2	3	1
F03	Control of safety risk	10	15	5	7	13	6
F04	Knowledge of risk management	2	5	3	6	10	4
F05	Safety knowledge	1	1	0	3	4	1
F06	Emotion	25	24	1	23	28	5
F07	Belief in good luck	28	18	10	28	1	27
F08	Voluntary action at work	20	26	6	20	16	4
F09	Emphasis on safety	7	11	4	5	8	3
F10	Work ability	3	3	0	8	5	3
F11	Confidence in rescue	12	16	4	11	21	10
F12	Role model of accepting risk	21	21	0	18	26	8

F13	Regulators' safety attitude	8	14	6	13	17	4
F14	Communication with supervisors	16	6	10	10	11	1
F15	OHS regulation	5	10	5	9	6	3
F16	Peers' behaviour	17	22	5	15	24	9
F17	Managers' safety attitude	9	8	1	4	14	10
F18	Supervision from top-level managers	22	19	3	17	22	5
F19	Personal reputation	23	28	5	25	28	3
F20	Potential gain of profit from risk action	26	23	3	26	15	11
F21	Employers' reputation	24	25	1	24	23	1
F22	Production stress	13	17	4	14	18	4
F23	Little time to assess confronting risk	18	13	5	22	19	3
F24	Completeness of relevant project information	19	9	10	21	20	1
F25	Visibility of project	15	7	8	19	17	2
F26	Confidence in equipment	11	12	1	12	12	0
F27	Family responsibility	14	20	6	16	25	9
F28	Insurance coverage	27	27	0	27	9	18

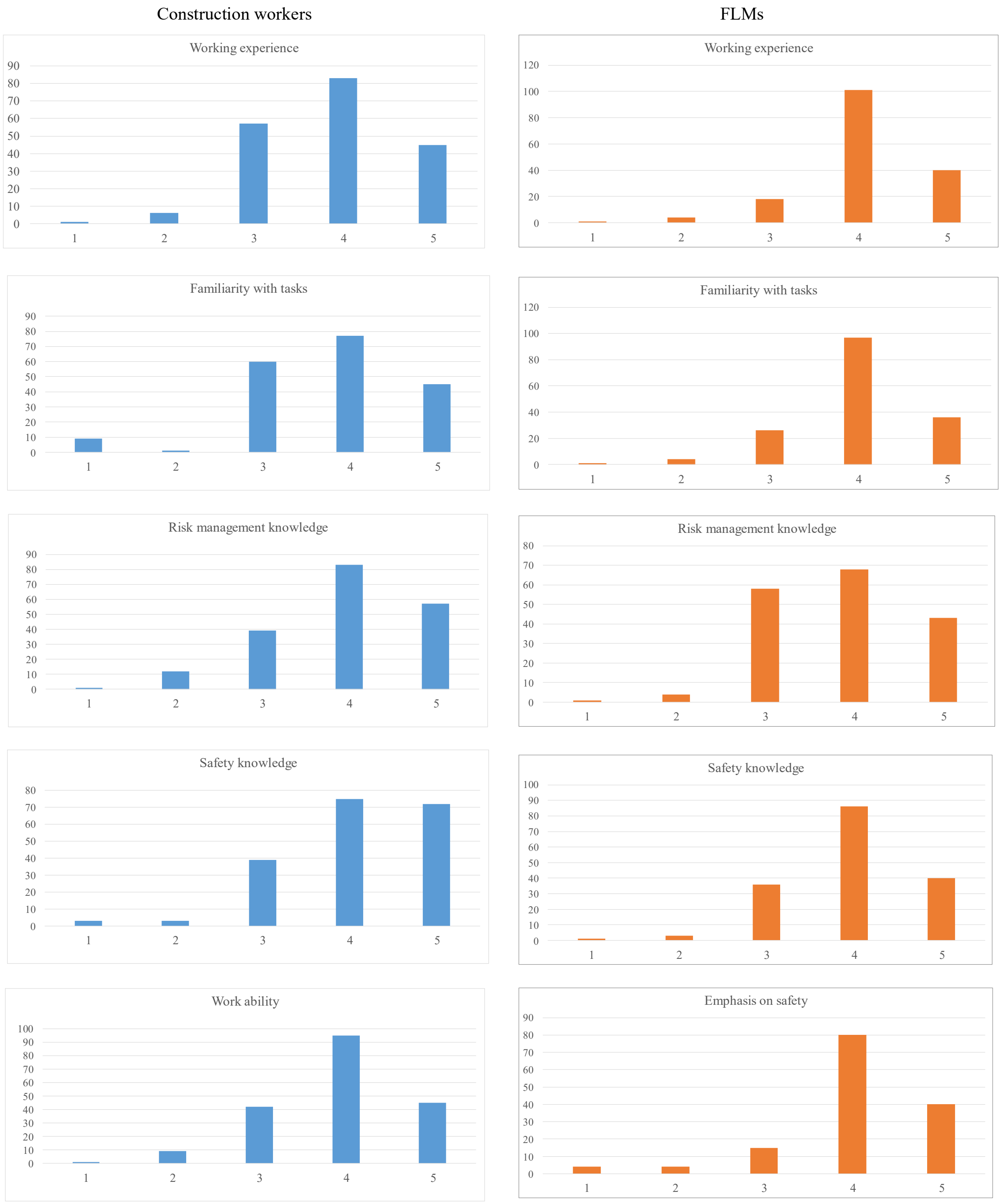


Figure 4.15 Opinion distribution of the most critical influential factors for workers and FLMs

4.4.3.2 Influential Factor with Dispersive Opinion

After identifying the most influential factors of risk tolerance, the next important step is to determine which factors participants have inconsistent views on. The selection rules are (1) the factor ranking based on entropy weight should be relevantly low and (2) the ranking difference between factor rankings based on mean and entropy weight should be low. All identified factors are highlighted in yellow in Table 4.24. The construction worker group, the mean value of emotion, potential gain of profit from risk action, employers' reputation, personal reputation and insurance coverage are found to have relatively low mean and entropy weight. Therefore, workers believe that these factors are not that important to risk tolerance. However, their opinions are inconsistent. Thus, workers are uncertain about these factors' effects on their risk tolerance. The management personnel in FLMs have inconsistent opinions with low influences of emotion, personal reputation and employers' reputation on their risk tolerance. Figure 4.16 shows these factors' opinion distribution. Unlike in Figure 4.15, the relevant opinions on each scale are similar, indicating that the participants' opinions on these factors' influence are inconsistent.

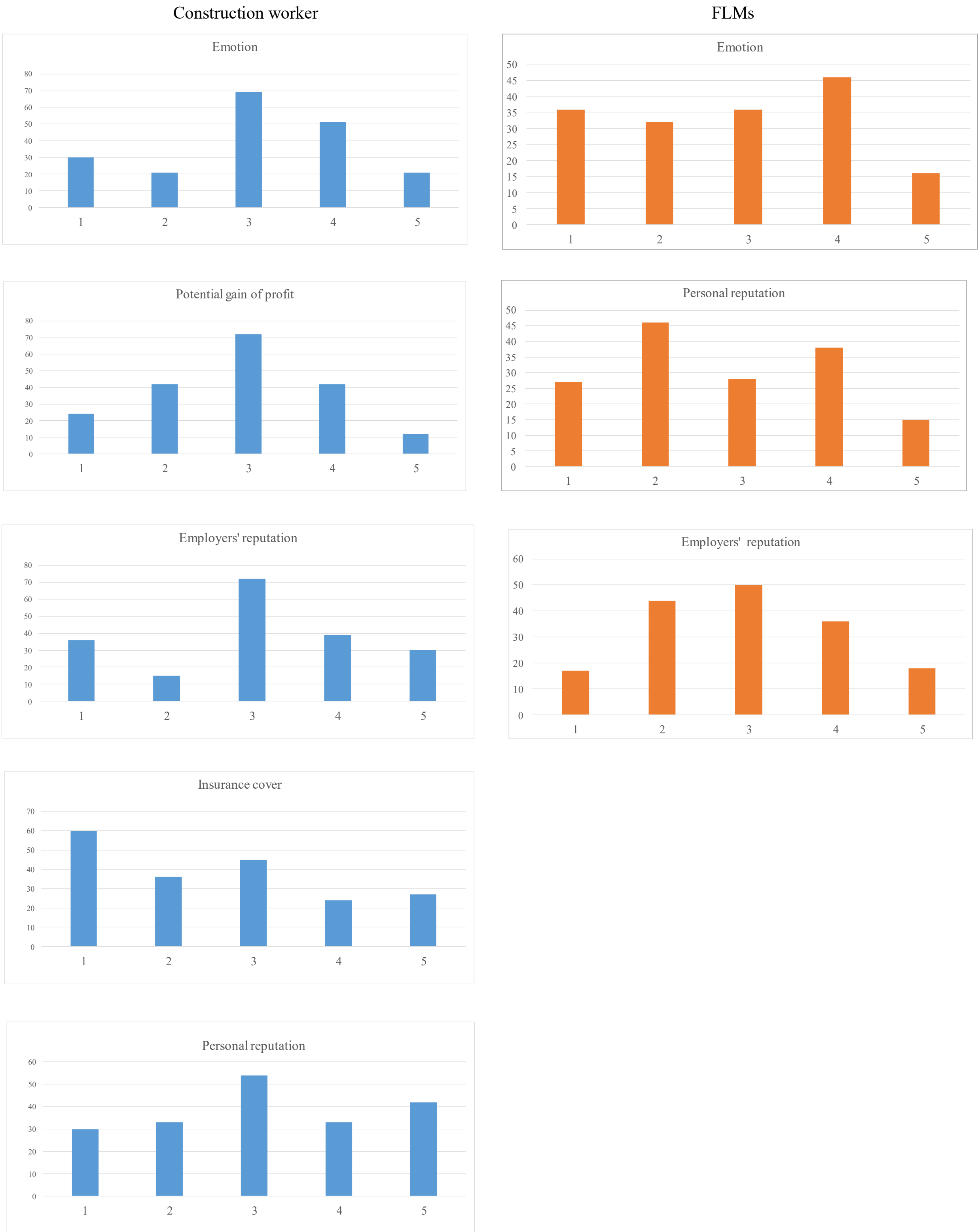


Figure 4.16 Opinion distribution of the influential factors with inconsistent opinions

4.4.3.3 Comparison of influential factors of risk tolerance between workers and FLMs

(1) Independent t-test

This section shows the result of the differences of influential factors between workers and FLMs' safety risk tolerance. Firstly, an independent t-test is conducted to determine whether statistically significant differences exist between the means of each influential factor in two groups. Table 4.25 shows the results. Factors of working experience (F01), familiarity with task (F02), belief in good luck (F07), work ability (F10), regulators' safety attitude (F13), personal reputation (F19), potential gain of profit from risk action (F20), production stress (F22), little time to assess confronting risks (F23), completeness of relevant project information (F24), visibility of project (F25), confidence in equipment (F26), family responsibility (F27) and insurance coverage (F28) show statistically significant differences based on their mean.

Table 4.25 Statistical comparison of influential factors of risk tolerance between workers and FLMs

No.	Factor	t	df	Sig. (two-tailed)	Mean Difference	Standard Error Difference
F01	Work experience	-3.628	314	.000	-.31855	.08780
F02	Familiarity with task	-2.358	314	.019	-.23488	.09962
F03	Control of safety risk	-.901	314	.368	-.10181	.11300
F04	Knowledge of risk management	1.455	261.123	.147	.14617	.10045
F05	Safety knowledge	.990	314	.323	.09375	.09473
F06	Emotion	1.232	314	.219	.17540	.14239
F07	Belief in good luck	5.725	314	.000	.76361	.13337
F08	Voluntary action at work	1.915	286	.056	.27083	.14140
F09	Emphasis on safety	-1.519	314	.130	-.18649	.12279
F10	Work ability	2.563	272.833	.011	2.563	272.833
F11	Confidence in rescue	1.564	272.446	.119	.18952	.12121
F12	Role model of accepting risk	1.221	178.414	.224	.18229	.14934
F13	Regulators' safety attitude	3.681	289.794	.000	.41028	.11145
F14	Communication with supervisors	-.908	287.380	.365	-.09526	.10492
F15	OHS regulation	1.847	314	.066	.23034	.12474
F16	Peers' behaviour	.878	251.380	.381	.11694	.13313

F17	Managers' safety attitude	-1.835	257.180	.068	-.21825	.11891
F18	Supervision from top-level managers	1.015	256.575	.311	.12298	.12119
F19	Personal reputation	2.050	274.605	.041	.30763	.15008
F20	Potential gain of profit from risk action	5.437	299.895	.000	.60081	.11051
F21	Employers' reputation	1.440	296.280	.151	.19153	.13302
F22	Production stress	2.589	271.000	.010	.30292	.11699
F23	Little time to assess confronting risk	3.737	270.127	.000	.42389	.11343
F24	Completeness of relevant project information	2.766	260.919	.006	.31351	.11333
F25	Visibility of project	4.201	314	.000	.51512	.12263
F26	Confidence in equipment	2.152	288.815	.032	.25353	.11780
F27	Family responsibility	2.829	264.420	.005	.43296	.15302
F28	Insurance coverage	4.985	314	.000	.73891	.14822

(2) Canonical discriminant function (CDF) analysis

Secondly, CDF analysis is employed to discover which factors discriminate risk tolerance between workers and FLMs. On the basis of this method, a discriminant function that shows a linear combination of independent variables (influential factors of risk tolerance) discriminates between the categories of the dependent variable (worker or FLM groups) in a perfect manner. The method enables the researcher to examine whether significant differences exist among the groups in terms of predictor variables (influential factors of risk tolerance).

Thus, stepwise DFA is used because it can automatically select the best variables to use in discriminating among different groups. In stepwise DFA, an indicator of Wilks' lambda, which works as the main principle, is used to test how well each level of independent variable (influential factors of risk tolerance) contributes to the discriminant model. The analysis scale ranges from 0 to 1, where 0 means total discrimination and 1 means no discrimination. Independent variables are tested by integrating them into the model and then removing them, thereby generating a Wilks' lambda statistic. The significance of the change in Wilks' lambda is measured with an F-test. If the F-value is greater than the critical value, then the variables are kept in the model (Nath and Pavur, 1985, Field, 2009). After conducting this analysis, the variables that may discriminate different categories are identified, and the classification accuracy is provided. According to the principle of stepwise DFA, two important things must be noted.

(1) A large range of F-value corresponds to more discriminant variables that are identified;
(2) The classification accuracy is different with different numbers of discriminant variables.

Thus, an experiment is designed, as shown in Figure 4.17. In the first test, all factors identified in the independent t-test are used to determine their performance in classifying worker and FLM groups. Then, stepwise method is applied with a small range of F-value. On the basis of this step, several discriminant factors are selected along with their contribution to the classification of workers and FLMs. In the last test, the range of F-value is set to large to select few variables that are believed to have the greatest power to discriminate workers and FLMs. Then, the accuracy of the three classification methods is compared.

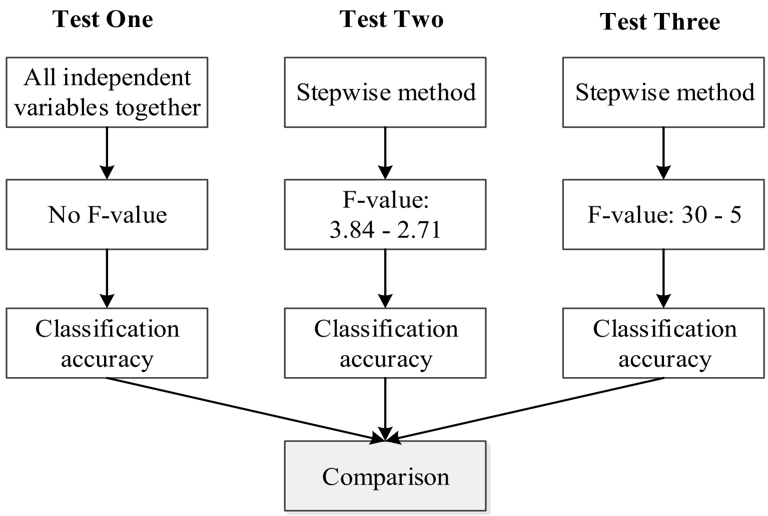


Figure 4.17 Experiment design for the selection of discriminant factors

1) One condition for applying DFA is that the predictive variables that refer to the influential factors of risk tolerance in this study should be independent from each other. The correlation between each of them cannot be high. Table 4.26 shows that the correlation between each influential factor is low, and no correlation exceeds 0.3. Thus, such factors can be used in the following analysis.

Table 4.26 Pooled within-group matrices

Factor	F01	F02	F07	F10	F13	F19	F20	F22	F23	F24	F25	F26	F27	F28
F01	1.000													
F02	.137	1.000												
F07	-.039	-.093	1.000											
F10	.393	.228	.079	1.000										
F13	-.017	.166	.013	.093	1.000									
F19	.033	.108	.244	.081	.178	1.000								
F20	-.007	-.076	.048	-.038	.308	.262	1.000							
F22	.062	.011	.132	.138	.278	.149	.195	1.000						
F23	.051	.045	.246	.205	.119	.225	.162	.255	1.000					
F24	-.002	.270	.021	-.095	.277	.087	.241	.283	.262	1.000				
F25	.045	.136	-.110	-.200	.301	.068	.343	.167	.248	.205	1.000			
F26	.064	.067	-.139	.051	.351	-.035	.217	.198	.234	.335	.299	1.000		
F27	.161	.091	-.009	.031	.138	.282	.154	.184	.160	.225	.197	.217	1.000	
F28	-.141	-.017	.280	-.157	.202	.234	.301	-.012	.112	.209	.209	.180	.137	1.000

2) Test 1. All influential factors identified in the independent t-test are used in Test 1. Table 4.27 shows that the eigenvalue of the created CDF can explain 100% of the variances. Also, this function has statistical significance as the Sig. is less than 0.000. Table 4.28 shows the coefficients of CDF. Thus, the function calculated in Test 1 is as follows:

S1 = -2.241-0.702*F01-0.436*F02+0.369*F07+0.865*F10+0.074*F13-0.102*F19+0.180*F20-0.058*F22-0.061*F23+0.253*F24+0.537*F25-0.239*F26+0.199*F27+0.095*F28

The structure matrix represents the largest absolute correlation between each variable and the discriminant function. Therefore, a large structure matrix coefficient corresponds to increased importance of the variables in differentiating workers and FLMs. On the basis of the results shown in Table 4.28, F07, F20 and F28 are identified as the top three discriminant factors.

Table 4.27 Summary of CDF in Test 1

Eigenvalue test	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
	.418	100.0	100.0	.543
Wilks' Lambda test	**Wilks' Lambda**	**Chi - square**	**df**	**Sig.**
	.705	107.290	14	.000

Table 4.28 Coefficient and structure matrix in CDF of Test 1

Factor	F01	F02	F07	F10	F13	F19	F20	F22	F23	F24	F25	F26	F27	F28	cons
Coefficient in CDF	-.702	-.436	.369	.865	.074	-.102	.180	-.058	-.061	.253	.537	-.239	.199	.095	-2.241
Structure matrix	-.317	-.206	.500	.221	.311	.176	.452	.224	.323	.242	.367	.182	.246	.435	
Order	6	12	1	11	7	14	2	10	5	9	4	13	8	3	

Table 4.29 displays the classification results based on Function S1. A total of 150 cases (78.1% of the total workers) and 124 FLMs (75.8% of the total FLMs) are classified correctly. Thus, considering all variables identified in the independent t-test in Test 1, the classification accuracy is 77.2%.

Table 4.29 Classification results*a—Test 1

Group	Predicted Group Membership	Total

			Worker	FLM	
Original	Count	Worker	150	42	192
		FLM	40	124	164
	%	Worker	78.1	21.9	100.0
		FLM	24.2	75.8	100.0

a. Approximately 77.2% of original group cases are correctly classified.

3) Test 2. Stepwise discriminant analysis is conducted in Test 2. Firstly, the F-value, which is set by default (enter: ≥ 3.84 and remove: ≤ 2.71), is used to select the discriminant variables. Table 4.30 displays the variables identified by each step. The statistic in the table represents the F value, and the larger it is, the smaller the Sig. can become. Thus, variables with the largest statistic should enter the model first. All Sig. are smaller than 0.000. Thus, all entered variables contribute significantly to discrimination. The mean value of the variables is significantly different because of the difference of various groups rather than because of random errors. Seven influential factors are selected.

Table 4.30 Variables entered/removed*a, b, c, d—Test 2

Step	Entered	Wilks' Lambda—F test			
		Statistic	df1	df2	Sig.
1	F07	32.781	1	354	0.000
2	F20	28.371	2	353	0.000
3	F01	22.654	3	352	0.000
4	F10	20.841	4	351	0.000
5	F25	20.674	5	350	0.000
6	F02	18.551	6	349	0.000
7	F23	16.669	7	348	0.000

Variables that minimise the overall Wilks' lambda is entered at each step.
a. The maximum number of steps is 28.
b. The minimum partial F to enter is 3.84.
c. The maximum partial F to remove is 2.71.
d. F level, tolerance or VIN is insufficient for further computation.

Secondly, CDF is calculated based on these variables. Table 4.31 summarises that the eigenvalue of the created CDF can explain 100% of the variances. Also, this function has statistical significance given that the Sig. is less than 0.000. Table 4.32 shows the coefficients of CDF. Thus, the function calculated in Test 2 is as follows:

S2 = -2.388-0.695*F01-0.416*F02+0.400*F07+0.791*F10-0.211*F20+0.248*F24+0.479*F25

On the basis of the structure matrix, F07, F20, and F25 are identified as the top three discriminant factors. In Test 2, F28 is not identified as the significant discriminate variable. Table 3.33 displays the classification results based on Function S2. A total of 150 cases (78.1% of the total workers) and 130 FLMs (79.0% of the total FLMs) are classified correctly. Thus, considering all variables identified in the independent t-test in Test 1, the classification accuracy is 78.5%.

Table 4.31 Summary of CDF of Test 2

Eigenvalue test	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Canonical Correlation**
	.379	100.0	100.0	.524
Wilks' lambda test	**Wilks' lambda**	**Chi - square**	**df**	**Sig.**
	.725	99.744	7	.000

Table 4.32 Coefficient and structure matrix in CDF of Test 2

Factor	**F01**	**F02**	**F07**	**F10**	**F20**	**F24**	**F25**	**cons**
Coefficient in CDF	-.695	-0.416	.400	.791	-.211	.248	.479	-2.388
Structure matrix	-.333	-0.216	.525	.232	.475	.254	.385	
Order	4	7	1	6	2	5	3	

Table 4.33 Classification results*a—Test 2

Group			Predicted Group Membership		Total
			Worker	FLM	
Original	Count	Worker	150	42	192
		FLM	34	130	164
	%	Worker	78.1	21.9	100.0
		FLM	21.0	79.0	100.0

a. Approximately 78.5% of original group cases are correctly classified.

4) Test 3. A further stepwise discriminant analysis is conducted in Test 3. Firstly, the range of F-value is set to large (enter: ≥ 30 and remove: ≤ 5) to select the most different influential factors of risk tolerance in workers and FLMs. Table 4.34 shows that one factor is selected, namely, F07. After variable selection, the relevant CDF is calculated. Table 4.35 summarises that the eigenvalue of the created CDF can explain 100% of the variances. Also, this function has statistical significance given that the Sig. is less than 0.000. Table 4.36 shows the coefficients of the CDF. Thus, the function calculated in Test 3 is as follows:

S3 = -1.752+0.864*F07

Table 3.37 displays the classification results based on Function S3. A total of 120 cases (62.5% of the total workers) and 113 FLMs (69.4% of the total FLMs) are classified correctly. Thus, considering all the variables identified in the independent t-test in Test 3, the classification accuracy is 65.2%.

Table 4.34 Variables entered/removed*a, b, c, d—Test 3

Step	Entered	Wilks' lambda—F test			
		Statistic	df1	df2	Sig.
1	F07	32.781	1	354	0.000

Variables that minimise the overall Wilks' lambda is entered at each step.

e. The maximum number of steps is 28.

f. The minimum partial F to enter is 30.

g. The maximum partial F to remove is 5.
h. F level, tolerance or VIN is insufficient for further computation.

Table 4.35 Summary of CDF of Test 3

Eigenvalue test	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Canonical Correlation**
	.104	100.0	100.0	.307
Wilks' lambda test	**Wilks' lambda**	**Chi-square**	**df**	**Sig.**
	.905	31.130	1	.000

Table 4.36 Coefficient and structure matrix in CDF of Test 3

Factor	F07	cons
Coefficient in CDF	0.864	-1.752
Structure matrix	1	
Order	1	

Table 4.37 Classification results*a—Test 3

Group			Predicted Group Membership: Worker	Predicted Group Membership: FLM	Total
Original	Count	Worker	120	72	192
		FLM	31	113	164
	%	Worker	62.5	37.5	100.0
		FLM	30.6	69.4	100.0

a. Approximately 65.2% of original group cases are correctly classified.

5) Summary and comparison of the three CDFs. Table 4.38 shows that classification accuracy decreases with few influential factors in CDF. Only F07 is used in the third function, and the classification accuracy is still similar to the classification accuracy obtained from the first and second discriminant functions. From this point, the

influential factor of F07 is identified as the most different factor in construction workers and FLMs. On the basis of the first two tests, F20 is identified as another important factor that is significantly different in the worker and FLM groups.

Table 4.38 Comparison of the three tests

Test	Selection criterion	Variable	CDF	Classification accuracy
Test 1	Independent t-test	14 influential factors	S1 = -2.241-0.702*F01-0.436*F02+0.369*F07+0.865*F10+0.074*F13-0.102*F19+0.180*F20-0.058*F22-0.061*F23+0.253*F24+0.537*F25-0.239*F26+0.199*F27+0.095*F28	77.2%
Test 2	F: enter: ≥ 3.84 and remove: ≤ 2.71	Seven influential factors	S2 = -2.388-0.695*F01-0.416*F02+0.400*F07+0.791*F10-0.211*F20+0.248*F24+0.479*F25	78.5%
Test 3	F: enter: ≥ 30 and remove: ≤ 5	One influential factor	S3 = -1.752+0.864*F07	65.2%

4.4.4 Discussion

4.4.4.1 Summary of analysis results

This section mainly aims to identify and compare the critical influential factors of safety risk tolerance in worker and FLM groups. On the basis of a series of statistical analysis techniques, including descriptive statistical, information entropy and canonical discriminant analyses, results of factor ranking, factor relative importance, opinion distribution and factor difference between the two groups are obtained. Thus, four questions are answered: (1) What are the most influential factors of safety risk tolerance for workers and FLMs? (2) What are the factors whose influences that workers and FLMs are not quite certain about? (3) What are the similarities between the influential factors of workers and FLMs' risk tolerance? (4) What are the differences between the influential factors of workers and FLMs' risk tolerance?

(1) The most influential factors of safety risk tolerance. In general, factors related to knowledge and experience are identified as the most important influential factors for construction practitioners' risk tolerance assessment. Working experience, familiarity with task, knowledge of risk management, safety knowledge and work ability are the top five factors which workers believe have strong influences on risk tolerance. Working experience, familiarity with task, safety knowledge, work ability and emphasis on safety are the top five factors which FLMs believe have strong influences on risk tolerance. These factors not only have high factor ranking based on mean but also have high entropy weight. Therefore, participants have consistent opinions about these factors' influences.

(2) Influential factors with inconsistent opinions. In the worker group, factors such as emotion, potential gain of profit from risk action, employers' reputation, personal reputation and insurance coverage have relatively low mean and a low entropy weight, which means the participating workers do not reach a consensus on these factors' effects on risk tolerance. FLM group has discrepant opinions regarding the influences of emotion, personal reputation and employers' reputation influences on risk tolerance. Thus, both workers and FLMs showing inconsistent opinions about the effects of emotion, employers' reputation and personal reputation on risk tolerance.

(3) Similarities of influencing factors between workers and FLMs. Results of the first two questions indicate that knowledge and experience are common and important factors in evaluating risk tolerance. Workers and FLMs give high and consistent assessment on these factors' influences. Another similarity is reflected in the inconsistent opinions regarding emotion, personal reputation and employers'

reputation. Workers and FLMs have different opinions on these factors' influence on their risk tolerance assessment.

(4) Differences of influential factors between workers and FLMs. Firstly, the independent t-test identifies 14 factors that have statistically significant differences between the two groups. Secondly, DFA provides further insights and reveals that the most contributing factor in differencing workers and FLMs is F07. This factor alone can reach 65.2% accuracy in distinguishing workers and FLMs. Another significant difference is reflected in F20. The analysis provides evidence of statistically significant difference, revealing that FLMs show consistent opinions of these two factors' influence, whereas workers show evidently inconsistent opinions.

4.4.4.2 Theoretical contribution and practical implication

Firstly, this study enriches the literature of factors that influence risk tolerance in the context of construction safety by identifying the most influential and controversial factors. To date, several studies have investigated the critical factors that influence people's risk tolerance (Lind, 2002a, Lind, 2002b, Hartford, 2009, Lehmann et al., 2009, Huang et al., 2013, Vanem, 2012, Tchiehe and Gauthier, 2017). This research provides several important insights and devotes considerable attention to risk tolerance of construction practitioners. This knowledge is important because an objective assessment of risk tolerance ensures that construction practitioners behave safely (Wang et al., 2016). This study introduces the idea that the influential factors of risk tolerance should be analysed from two perspectives: (1) the most influential and (2) controversial factors. In the first part, the findings demonstrate that factors related to risk knowledge and work experience are assessed, having the strongest effects on construction workers and FLMs' risk tolerance. Such results indicate that frontline workers and site management personnel believe and agree that relevant risk and safety knowledge and risk working experience can help in objectively evaluating risk tolerance level regarding confronted safety risks. This finding is in line with the current research given that the importance of relevant knowledge and experience in risk information processing has been widely confirmed and strengthened in the field of risk and safety management (Wang et al., 2016, Wang and Yuan, 2011, Lyons and Skitmore, 2004, Loosemore and Andonakis, 2007). Thus, construction practitioners must continue to learn and update safety and risk knowledge.

In the second part, this research innovatively identifies the factors with inconsistent opinions from participants. Prior research on identifying critical influential factors mainly focuses on discovering the most relevant, important or influential factors. The underlying hypothesis is as follows: The higher the factor ranking is (usually measured by mean), the more important that participants believe the factor is, thus resulting in a higher likelihood that the factor is critical for a certain problem (Wang et al., 2016, Aksorn and Hadikusumo, 2008, Ismail et al., 2012, Lombardi et al., 2009). Intuitively, this logic has no problem, and many studies follow its reasoning. Meaningful research findings are also provided. However, some important factors may be overlooked due to their relatively low factor ranking, which may be caused by people with different opinions about them (Potter et al., 2013). If people have significant controversial opinions on factors, then the importance of such factors is not ensured. By contrast, these factors are of great value for practice. For example, some factors are critical, but people are unfamiliar with them because they have little relevant knowledge or these factors are newly emerged ones. Also, people are reluctant to admit the importance of certain factors in some situations. For instance, 'potential gain and profit from risk action' (F20) is recognised as one encouraging factor for workers' risky behaviours (Canadian Occupational Safety, 2015). Moreover, construction workers are often prepared to take risks simply to get the job done for money, production or to keep their employment secure (Choudhry and Fang, 2008, HSE, 2003). For workers working on price, site supervisors often turn a blind eye to risk-taking if the necessary production is achieved (HSE, 2001). If taking risks has positive consequences such as getting the job done quickly, improving production and earning money, then the act is likely to continue. However, not all participants are willing to acknowledge such behaviours. Therefore, the mean of these factors is relatively low. If we only check the mean without considering opinions' distribution, then these factors are ignored.

Identifying these factors with consistent and dispersive opinions is of great practical importance given that an effective safety training can be achieved by obtaining such information. For the identified critical influential factors of risk tolerance, current safety training should provide reinforcement learning strategies. For the factors with inconsistent opinions, the reason some people believe they are important and other people think they are not important should be investigated in the first step. Then, managers can update current training content based on information by providing supplementary learning strategies to minimise the discreteness of people's assessment and strengthen their understanding of such strategies. Thus, construction practitioners' awareness of these factors' influences on their risk tolerance would improve, and, accordingly, more objective and rational risk judgement will be achieved.

Secondly, this research contributes to the research method of factor evaluation by introducing the theory of information entropy, showing how such a theory can be applied in identifying critical factors and making people's opinions tangible. Current methods regarding factor evaluation mainly pay attention to the score of each factor. Minimal concern is given to opinions' distribution on each measurement scale. Research on discovering factors with inconsistent opinions is notably lacking. This information is intriguing because it conveys valuable information regarding the potential weakness of the current safety management. With the analysis of information entropy, participants' opinions can be reflected by their answers' distribution on employed measurement scale. A scattered distribution on each scale corresponds to different evaluation by the participants. From the perspective of information theory, these factors contain valuable information given that uncertainty is included (Gray, 2011). Variance in conventional statistics is also used for quantifying uncertainty. However, unlike information entropy, variance deals with two major limitations: (1) variance must consider the values of X (where entropy only considers the distribution of X and may thus have less bias), and (2) variance application requires an even distribution of data (where entropy is distribution-free). Thus, entropy is a general and flexible way to quantify uncertainty information. In summary, this research offers a new way to evaluate influential factors by combining two ideas: (1) traditional factor ranking based on mean to obtain a direct understanding of factors' importance and (2) information entropy-based method to obtain further understanding of factors' uncertainty and to offer comprehensive and revealing results.

Thirdly, this research contributes to the literature of construction workers and management personnel's difference in risk information processing. To date, considerable research has investigated frontline workers and site management personnel's divergences in safety culture (Fung et al., 2005, Gilkey et al., 2012) and risk perception (Hallowell, 2010). This study provides several important insights and devotes considerable attention to workers and FLMs' attitude towards their risk tolerance. Research on their opinion difference in the influential factors of risk tolerance is notably lacking. This information is crucial because it bridges two important domains of construction management research (i.e. risk decision making and safety management) that are strongly related but seldom intermingled. Our research contributes by discovering the distinguished factors which influence workers and FLMs' risk tolerance. On the basis of these findings, practical suggestions are provided for further safety management, such as why workers and FLMs have different views regarding certain factors and what strategies can be applied to strengthen people's awareness if they show inconsistent opinions towards one factor. Targeted safety training programmes can also be designed based on these identified differences to improve the efficiency of safety management in the construction industry.

4.5 Summary

The principal aim of this research is to investigate the effects of risk tolerance on the safety behaviour of two parties: frontline workers and FLMs. Therefore, four research questions arise: (1) What are workers and FLMs' tolerance level for different safety risks? (2) What is the relationship between risk tolerance, risk perception and safety behaviours (for workers)/involvement of safety management (for FLMs)? (3) Under what safety climate conditions can the influence of risk tolerance be changed, strengthened or weakened? (4) What are the critical influential factors of workers and FLMs' safety risk tolerance? These questions are answered by quantitative analysis. The next chapter presents interviews conducted with several construction practitioners to obtain their insights into the validation and further explanation of the quantitative results.

Chapter 5 Qualitative Analysis and Discussion

This chapter provides the qualitative analysis result of the study. A semi-structured interview method for data collection and the thematic analysis for data analysis are applied to achieve this aim. Specifically, this qualitative analysis confirms and obtains practical explanations concerning the quantitative results. The interview participants are listed in Table 3.6, in total there are were 10 interviewees, including four OHS managers, two project managers, one construction manager, two site managers and one Work Health and Safety (WHS) specialist. These various positions offer the possibilities of gathering opinions from different perspectives. The average work experience of the interviewees in the construction industry is 15.6 years, which ensures that they have sufficient experience and ability to answer safety questions in the context of the construction industry.

5.1 Interview Questions

This follow-up interview is as an important part of the mixed methodology–explanatory design, which uses qualitative data to explain or build upon initial quantitative results (Creswell et al., 2003). Thus, the interview questions must be designed based on the quantitative results. Nine questions that aim to confirm and explain four research findings are designed accordingly.

Part one: Warm-up question

1. In your opinion, what is risk tolerance, especially tolerance of construction safety risk?

Part two: Confirm and explain the results of quantitative analysis

- **Confirm and explain the risk tolerance difference between workers and FLMs**

2. According to our research, construction workers and FLMs have a significantly different risk tolerance. What do you think of this result?

3. Can you explain why workers have such high risk tolerance and why FLMs have such low risk tolerance?
4. What is affected by practical safety management, considering the difference of risk tolerance?

- **Confirm and explain the influence of risk tolerance on safety behaviour (involvement of safety management)**

5. We find that construction workers show different risk behaviour patterns when considering the common injury risks and risks with severe consequences, such as death. What do you think of this?
6. We find that FLMs show different risk behaviours when considering the common injury risks and risks with severe consequences, such as death. What do you think of this?

- **Confirm and explain the importance of safety climate**

7. Safety climate has many elements, such as top management's safety attitude, supervisors' safety attitude, signs, warnings around sites, co-workers' influence and communication between supervisors and workers. Which element do you think is the most significant for workers and FLMs, and why?

- **Confirm and explain the identified critical influential factors of safety risk tolerance**

8. Risk tolerance is important. Thus, we identify several critical factors that can affect workers and FLMs' risk tolerance, such as emotion, belief in good luck, potential gain or profit from risk action, employers' reputation and personal reputation. How do you perceive these factors when thinking of risk tolerance?

- **Suggestions for improving safety management**

9. According to our study, if workers have a higher risk tolerance, then they tend to have lower risk perception and be less sensitive to positive safety climate. Based on your experience, what are the key factors to improve workers and FLMs' risk thinking?

5.2 Thematic Analysis

Thematic analysis is a qualitative research method that can be widely used across a range of epistemologies and research questions (Nowell et al., 2017). Such an analysis is used to identify, analyse, organise, describe, interpret and report themes found within a data set (Braun and Clarke, 2006). A theme is a pattern found in the data that describes and organises the possible observations at a minimum and interprets aspects of the phenomenon at maximum. Identifying themes can help examine the perspectives of different research participants, highlight similarities and differences and generate unanticipated insights (King, 2004, Braun and Clarke, 2006). Also, thematic analysis has the advantage of summarising key features of a large data set. Such an analysis forces researchers to consider a well-structured approach to handle data and help produce clear and organised final reports (King, 2004).

In contrast to grounded theory or hermeneutic phenomenology, which requires a high level of interpretive complexity, thematic analysis is suitable for researchers who wish to employ a relatively low level of interpretation (Vaismoradi et al., 2013). Therefore, thematic analysis cannot be claimed as a full-blown grounded theory because the analysis does not fully subscribe to the theoretical commitments of a ground theory, which always requires analysis to be directed towards theory development (Braun and Clarke, 2006). This qualitative analysis aims to (1) confirm quantitative results and (2) obtain a rich explanation rather than develop a new theory. Thus, thematic analysis is suitable for this research.

Braun and Clarke (2006) introduced a step-by-step approach to achieve a trustworthy thematic analysis. This approach is a linear, six-phased method, but it is an iterative and reflective process that develops over time. It also involves a constant moving back and forward between phases (Nowell et al., 2017). Table 5.1 explains the thematic process and how to achieve it efficiently.

Table 5.1 Phases of thematic analysis (adapted from [Nowell et al., 2017])

Phase of thematic analysis	Way of establishing trustworthiness
Phase 1: Familiarising yourself with your data	• Prolong engagement with data • Document theoretical and reflective thoughts • Document thoughts about potential codes/themes • Store raw data in well-organised archives • Keep records of all data field notes and transcripts
Phase 2: Generating initial codes	• Peer debriefing • Reflexive journaling • Use of a coding framework • Audit trail of code generation • Documentation of all peer debriefings
Phase 3: Searching for themes	• Diagramming to make sense of theme connections • Keep detailed notes about development and hierarchies of concepts and themes
Phase 4: Reviewing themes	• Themes and subthemes vetted by peers • Test for referential adequacy by returning to raw data
Phase 5: Defining and naming themes	• Peer debriefing • Documentation of peer meeting • Documentation of theme naming
Phrase 6: Producing reports	• Describing process of coding and analysis in sufficient details • Thick descriptions of context • Description of the audit trail

Phase 1: Familiarising yourself with your data

In this stage, researchers are encouraged to engage with the analysis as a faithful witness, being honest and vigilant about their perspectives' pre-existing thoughts and beliefs (Starks and Brown Trinidad, 2007). On the basis of the interview transcription, researchers can document their theoretical and reflective thoughts that develop through immersion in the data.

Also, researchers can make notes about ideas for coding that can be returned to in subsequent phases (Lincoln, 1985). In this study, we use an Excel spreadsheet to log all raw data to detail the interview information that can be subsequently analysed in NVivo (version 11).

Phase 2: Generating initial codes

Once researchers have read and familiarised themselves with the data and have gained ideas about what is in the data and what is interesting about them, the initial coding should begin (Braun and Clarke, 2006). On the basis of the coding process, specific characteristics hidden in the data are identified, which allows researchers to move from unstructured data to the development of ideas about what is going on in the data (Richards and Morse, 2012). NVivo 11.0 is used to sort and organise the data in this study, enabling efficient coding schemes. The credibility of coding is further enhanced by having two PhD students analyse each data set. Each person extracts data coded in as many different themes as they fit and as many times as deemed relevant. Memos are recorded to trace the logic behind coding. At the end of initial coding, 78 codes are identified.

Phase 3: Searching for themes

After initially coding and collating the data, themes can be generated inductively from the raw data or generated deductively from theory and prior research (Boyatzis, 1998). DeSantis and Ugarriza (2000) found that 'a theme is an abstract entity that brings meaning and identity to a recurrent experience and its variant manifestation. As such, a theme captures and unifies the nature or basis of the experience into a meaningful whole' (p. 362). Also, a theme is dependent not necessarily on quantifiable measures but rather on whether it captures something important about the overall research question (Braun and Clarke, 2006). Initial codes may begin to form main themes, and others may form subthemes. Once themes are identified, they become important concepts that link substantial portions of the data together

(DeSantis and Ugarriza, 2000). In this research, we cover a wide variety of concepts in our interviews based on quantitative results. Therefore, we initially utilise the conceptual framework to develop broad, high order codes to help organise the data. This deductive method helps form the main themes that match interview questions and are represented as parent nodes in NVivo. Subthemes are formed inductively without trying to fit into a pre-existing coding framework.

Phase 4: Reviewing themes

The fourth phase starts after a set of themes has been devised, and then they require refinement (Braun and Clarke, 2006). Reviews must consider whether the coded data extracted for each theme appear to form coherent patterns (Nowell et al., 2017). The initial coding and themes are revealed and may require various changes to determine whether the themes accurately reflect the meanings evident in the data set. Then, the validity of individual themes can be ensured (King, 2004, Pek et al., 2017). Some themes are discarded accordingly. Some collapse into each other, whereas others are broken down into separate themes or subthemes. For this study, we review the coded data extracted for each subtheme to determine if coherent patterns are apparent. After a team meeting, four main themes and 10 subthemes are determined based on the collected interview data.

Phase 5: Defining and naming themes

In the fifth phase, researchers determine what aspect of the data each theme captures. They also identify what is interesting about the theme and why (Braun and Clarke, 2006, Nowell et al., 2017). Braun and Clarke (2006) suggested that theme names must be punchy and must immediately give readers a sense of what the themes are about. Thus, researchers need to consider how each theme fits into an overall story about the entire data set in relation to the research questions (Braun and Clarke, 2006). At the end of this stage, the names of themes should be distinguishable. If researchers can clearly and succinctly describe the scope and content of each theme, then they may be ready to move on to the next phase. Otherwise, further refinement may be required (Braun and Clarke, 2006). In this study, the author and the two PhD students discussed their personal insights into individual themes to ensure all aspects of the data are thoroughly analysed in relation to the research objectives. Such objectives confirm the risk tolerance difference between workers and FLMs and discuss the influence of risk tolerance on safety behaviour, the role of safety climate and the identified influential factors of risk tolerance. Insights into strategies to develop the ability of risk decision making are also found. Figure 5.1 presents the final thematic map of the data. The first main theme discusses the risk tolerance difference between workers and FLMs. Under this main theme, three sub-themes are included, namely, confirmation of current findings, possible reasons and consequences. The second main theme confirms the risk behaviour patterns in which two sub-themes are identified, such as risk thinking difference in common injury and death risk scenarios and the importance of communication in safety climate. The third theme confirms the identified critical factors of safety risk tolerance assessment. The last theme is about the strategies for the improvement of safety management.

Phase 6: Producing reports

The final stage begins after the themes are fully established (Braun and Clarke, 2006). Then, a concise, coherent, logical story should be given to convince readers of the merit and validity of the analysis. The storytelling needs to avoid simple descriptions that offer a flat descriptive account with little depth. Ideally, researchers can build a valid argument for analysing the themes by referring to the literature. Thus, the constructed story can stand with merit (Nowell et al., 2017). In this study, the report embedded with analytic narratives and accompanied with arguments related to the research objectives is shown in the following sections.

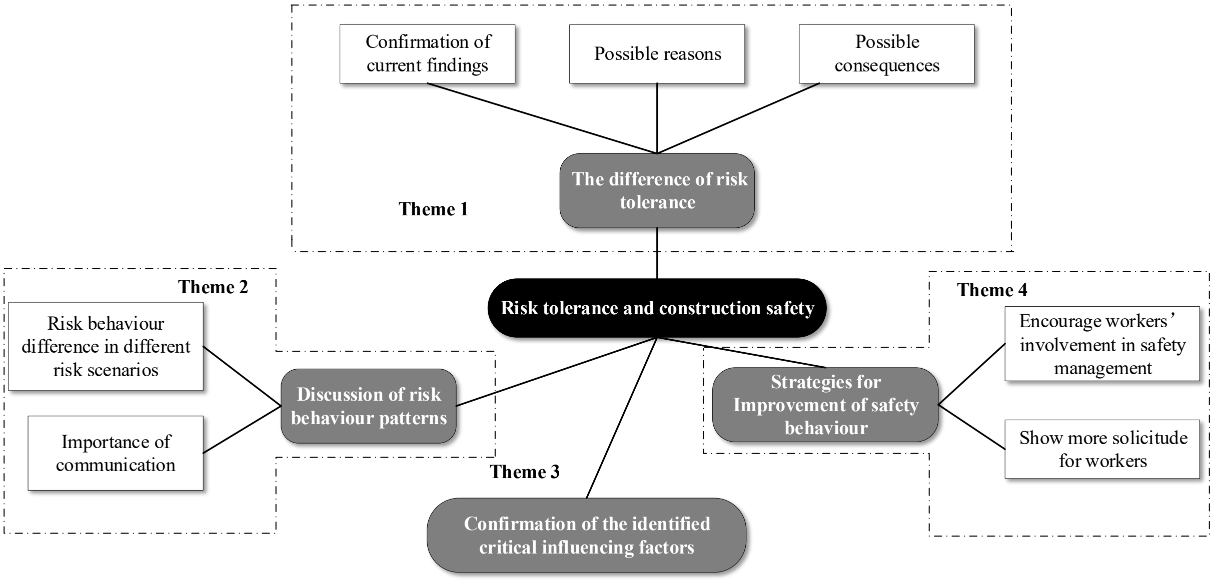


Figure 5.1 Thematic map showing the four themes and their interrelated subthemes

5.3 Risk Tolerance Difference between Workers and FLMs

This section explains why construction workers and FLMs have significant differences regarding safety risk tolerance. Moreover, factors affected by such differences in the safety management practice are discussed.

5.3.1 Confirmation of Risk Tolerance Difference between Workers and FLMs

Before asking why workers and FLMs show significantly different risk tolerance, the question 'On the basis of our research, a significant difference of risk tolerance exists between worker and FLM groups. Specifically, workers' risk tolerance is much higher than that of FLMs. What do you think of this result?' is asked to determine interviewees' initial opinion about such result. The difference of risk tolerance between workers and FLMs was fully confirmed based on the responses, such as 'This is reasonable (OHSM-01, OHSM-08, SM-10)' and 'I am not surprised with this result (OHSM-06, OHSM-09)'. Two interview participants also mentioned that 'Workers and FLMs truly belong to different worlds (CM – 03 and CM – 05)'. This result is consistent with the findings of Harvey et al. (1999), McDonald et al. (2000), Smallwood and Haupt (2005) and Hallowell (2010), who found that management personnel and frontline workers do not share the same risk perception.

5.3.2 Reasons for the Risk Tolerance Difference between Workers and FLMs

5.3.2.1 Reason for workers' high risk tolerance

The study primarily aims to explore why construction workers and FLMs have different risk tolerance. For workers, the major reasons obtained from interview responses can be categorised into overconfidence, utilitarian outcome and construction work habit.

Overconfidence (mentioned and emphasised by all interview participants) is the most appealing facilitator for construction workers to have high risk tolerance during construction work. Three reasons are identified as the reasons for overconfidence. Firstly, overconfidence comes from a no-injury working experience. The obtained responses include 'Workers have experiences where they can always successfully finish risky tasks (PM-02)' or 'Workers finish tasks by taking some risks without any injury (SM-04, SM-10)'. These responses indicate that construction workers have blind confidence, which is driven by ignorance of the real potential dangers. As a result, workers may underestimate potential risks (Jiang et al., 2014, Shin et al., 2015a). Secondly, overconfidence is caused by workers' familiarity with construction work. The obtained responses include 'Workers always do the same or similar job, so for them, the potential risks may not be a big deal (PM-02, OHSM-08)' and 'The people who perform real construction tasks know what they are doing. The experienced people in particular are familiar with the work and know which behaviours are not dangerous (CM-05)'. As Lafuente et al. (2018) indicated, previous working experience has a significantly negative effect on perceived work safety, that is, risk awareness decreases with respect to labor experience. Workers' confidence in these situations increases because they believe that they can perform risky tasks and control the consequences of behaviours. For example, an experienced worker may say, ‘Come on, I’ve done this task hundreds of times and nothing happened, so we can continue doing it this way (SM-04)’. In summary, if construction workers have high confidence in completing construction work, then they may either believe that risky tasks are easy to accomplish because they have not experienced any negative consequences. They may also deem that they can control potential risks because they are familiar with what they are doing. These findings are consistent with the study of Ganah and John (2017) and Aksorn and Hadikusumo (2007).

Utilitarian outcome, which mainly refers to the perceived outcomes of risk-taking behaviours, is another reason construction workers have a high risk tolerance. Finishing more tasks and earning more than usual are the most frequently mentioned motivations for having high risk tolerance. Such motivations are expressed as ‘If workers can complete more tasks within a fixed working time, then they will get more pay (PM-02, WHSM-07 and SM-04, SM-10)’. Thus, workers tolerate risks such as fatigue and ignore risks from repetitive work so they can finish the job quickly and efficiently. This result is consistent with the findings of Sawacha et al. (1999), which reveal that economic benefit is one of the most important facilitators that encourage unsafe behaviours on construction sites. Time-saving or pursuing work convenience is another explanation for tolerating further risks. Workers consider that applying all safety measures require effort, which may sometimes compromise working time. For example, a door opening appears on the site, and a temporary platform is placed above the opening. Thus, workers are not allowed to go through the door opening. However, workers may prefer to go through it rather than take a detour to save time (OHSM-06). Respondents also mentioned that workers prefer to use ladders rather than build working platforms when they are working at heights (SM-04). Thus, workers tolerate safety risks to save working time or improve working convenience. This result is consistent with the research of Man et al. (2017), which indicates that effort saving and convenience are major reasons construction workers take safety risks. In construction practice, project developers impose scheduling pressure on general contractors. Then, project managers pressure the builders or subcontractors. People who tolerate these pressures are construction workers who are working on sites. Therefore, workers tolerate more risks than usual to secure their job by finishing several tasks, saving time and working in a convenient way.

A third significant reason for the high risk tolerance of the construction worker group is their work habit. Although workers are aware of the dangers when they perform tasks in a certain way, they persist in working that way out of repetition and habit rather than by consciously considering potential economic benefits. The response 'Sometimes, workers have relevant safety knowledge. They know that working in a certain way may have some risks, but they still continue it because they are already accustomed to their working style and their work routine, and it is hard to change (CM-05)'. This result is consistent with the findings of Ajzen (2002) and Verplanken (2012), which reveal that the frequently performed behaviours can become habits or routines that can be enacted without substantial deliberation attention.

5.3.2.2 Reason for FLMs' low risk tolerance

This study also explores the reasons FLMs show significantly low risk tolerance regarding construction safety risks. On the basis of the qualitative responses, four categories of reasons are identified: less construction work experience, safety management manner, liability and measurement of work performance.

Unlike construction workers, FLMs without equivalent construction work experience are considered one of the major reasons for relevant lower risk tolerance. The responses obtained include 'Workers who perform the job know what they are doing, and they can understand what is going on. However, a manager doesn't (OHSM-01)', 'For the management personnel, their risk tolerance is low, which is also related to their work experience (PM-02)' and 'The managers do not have many accident experiences (PM-02)'. These responses indicate that having minimal construction work experience makes FLMs less prompt in paying attention to safety risks. Thus, FLMs' understanding of risk probability and severity is not as in-depth as that of workers. As a result, FLMs assess risk tolerance from the point of safety management rather than performing the tasks. 'A good example could be you know, the managers; they manage the construction project, which means they don't need to do the real job themselves. So, they have some ideas, like, oh, that job is dangerous (PM-02)'. Another example is that 'A technician fixes the aircraft. He needs to analyse the engine, and the manager probably doesn't know what the technician is doing and thinks the technician should be more careful and follow the rules. Otherwise, it could be dangerous (OHSM-01)'.

Safety management manner, which refers to FLMs' perception, concern and work effort in safety management work, is another critical factor that results in the low risk tolerance of FLMs. Safety management manner can be explained from two perspectives: before and after injuries happen. The response regarding the first situation is 'Workers think less than managers when performing construction tasks', which indicates that risk thresholds exist for FLMs (CM-05 and OHSM-06). For instance, electricians fix machines by isolating and checking them. Electricians only care about this task. However, managers may think differently, asking questions such as 'Is the procedure correct?', 'Will electricians be injured in the back or neck?' and 'Are there any other possible parameters that can jeopardise their work?' However, electricians focus on electricity only. They do not care about mechanical factors and other things (OHSM-01). These comprehensive considerations in safety management tend to result in low risk tolerance. Also, workers pay attention to injuries only if they get injured because workers did something wrong. By contrast, FLMs consider these situations a major issue no matter how serious the injuries are. When construction workers trip on site, FLMs think, 'Is the process wrong?' or 'Is it because the lighting in that area is not enough or are workers carrying too many items (WHSS-07, OHSM-06, OHSM-09)?' Thus, this safety manner, which considers injuries a serious issue, makes FLMs cautious and discreet when considering how much risks they can tolerate.

Liability plays an important role in determining the extent of how many safety risks FLMs can tolerate. Consideration of budget and safety responsibility are identified as the two main liabilities for FLMs. Responses such as 'From the top management, project management to FLM, the budget is the main concern' (PM-02) and 'Everything operates under a certain budget in the construction project' (CM-03) indicate that budget is an essential factor that must be considered in safety management. This finding is consistent with the research of Abudayyeh et al. (2006), which revealed that FLMs need to keep the budget in mind given that construction costs increase when injuries happen. For instance, construction companies must buy insurance for their employees. However, if employees get severely injured on site, then companies must also pay for workers' compensation (CM-05, WHSS-07). Construction companies must have a safety budget for supplying safety equipment, employee training and education programme. When injuries happen, additional safety equipment and training must be provided because equipment damage must be updated (CM-03). Thus, FLMs tend to have low risk tolerance because they need to manage the budget. Safety responsibility mainly refers to the awareness of safety law or regulation. Safety managers or supervisors who look after safety issues are responsible for construction safety (OHSM-08, SM-10). Each high-level position critically has high responsibility (CM-05). Therefore, FLMs must be aware of the budget and the law, which is the bare minimum compliance for operation. As a result, management feels burdened because they must answer to regulators when injuries happen. 'Regulators come and investigate when an injury happens on site. Even if administration and management weren't found to have any fault, they still are answerable because the injury caused life/health loss (OHSM-01, CM-03)'. The liability required by budget and law results in the tendency of FLMs to have low risk tolerance compared with workers to achieve management's commitment.

The fourth reason for FLMs' low risk tolerance can be explained from the perception of their work performance measurement: safety key performance indicators (KPI). Responses such as 'Safety always has KPI. So, for our company, KPI is the number of fatalities, major or minor injuries. So, fatality is less than or equal to 0, which means people cannot die. Now, major injuries that were equal to 1 about five years ago were less than 3. Driven by the government and the union, safety is prioritised and becomes one (CM-05)' were obtained. OHSM-01 did not provide any solid figure for tolerance criteria, but she reported that the injury and fatality figure reported from the year before are typically used as the criteria for the current management of project safety. Thus, safety risks for FLMs are not only potential issues that must be properly managed but are also directly related to FLMs' career. FLMs have high risk tolerance to secure their job and to achieve a satisfactory work performance.

5.3.3 Consequence of Risk Tolerance Difference between Workers and FLMs

The question 'The difference of risk tolerance between workers and FLMs exists. Thus, what are the factors affected in safety management practice?' is asked to explore the possible consequences of risk tolerance difference between construction workers and FLMs. However, answering this question is difficult for the interview participants because the difference is invisible and difficult to observe and control. Despite this, one possible consequence is identified, namely, 'It causes difficulty for effective safety management (OHSM-01, PM-02, OHSM-09)'. In practice, a systemic safety training, which includes safety induction before starting new projects, weekly box meeting for updating risk information for coming tasks and frequent safety inspection on sites, is always provided to ensure that workers are aware of potential risks and to improve their safety knowledge. These measures are implemented to ensure workers can be cautious of potential risks and behave safely. FLMs may think workers should feel okay when performing construction tasks because they already have relevant safety training. However, the problem is that FLMs cannot observe and understand how workers think of safety risks based on the safety training only. Thus, inattentive safety management from managers and unsafety behaviours from workers may happen because FLMs think workers perform the job as they expected.

5.4 Discussion of Risk Behaviour Patterns

This section aims to confirm the quantitative results regarding the relationship of risk tolerance, risk perception, perceived safety climate and safety behaviours. Specifically, whether workers and FLMs have different risk behaviours when dealing with safety risks with different importance is determined. Moreover, the importance of safety climate is discussed.

5.4.1 Risk Behaviour differences in Different Risk Scenarios

Section 4.2 reveals that workers and FLMs have different concern and risk judgement regarding low severity/common safety risks (which have light severity) and high severity risks (which have major consequences, like permanent disability or fatal). Gathering workers' opinions about this finding (as risk tolerance is difficult for workers to understand) is difficult. Thus, this section obtains an indirect response from safety experts' opinions. The question 'On the basis of our study, we find that construction workers show different risk behaviours when considering common injury and risks with severe consequences, such as fatal. What do you think of this result?' Responses obtained from interviewees show that answering this question is difficult: 'It's not that clear. It's hard to notice (CM-05)' and 'It sounds interesting, but I am not quite sure (OHSM-01).' We then ask a specific question. 'When workers face risks that can threaten their life, how do you think the influence of their risk tolerance works under this situation?'

The received responses confirm the quantitative results in Section 4.2. All interviewees mentioned that risk tolerance may not work if workers perceive risks that can threaten their life. OHSM-01 mentioned that 'I think not only workers but any person won't continue to do risky things if they really pose a risk of losing one's life'. OHSM-08 provided an example by saying, 'When you observe construction workers' behaviours on site, unsafe behaviours are usually shown in common situations, such as carrying too many objects and working on ladders that are not that high without wearing a safety helmet. However, if a 30-metre-high crane must be used, then no one takes a risk'. Then, we ask them to explain why workers have different risk thoughts under these two different risk scenairos. The major reason can be summarised as 'Construction workers are already used to the common risks that happen on site'. SM-10 explained, 'Construction work is risky and dangerous, but I am not saying that it can always threaten people's life. "Dangerous" means that nearly every task on site may have a certain danger. So, workers may have already gotten used to injuries such as a sprained wrist and a back injury. Given that they are already familiar with these risks, workers may not be that afraid or sensitive to such risks'. On the basis of these responses, our quantitative results in Section 4.2 reflect the true risk behaviour pattern of workers; they have different risk thinking when dealing with different risks with different severity.

The question 'We find that the site management shows different risk behaviours when managing common and non-serious risks of injury and risks with severe consequences, such as death. What do you think of this result? is also asked. The interviewees mainly answer this question from the perspective of how they manage safety risks. Responses such as 'We have a risk matrix (CM-05, OHSM-08, OHSM-09)' and 'For each risk, we have a score (OHSM-01, OHSM-08, OHSM-09)' indicate that the risk matrix, which consists of risk frequency and consequence, is the most common way to score potential safety risks. Then, the following question 'Different risks have different scores. Can you give the same concern to all of them?'

is asked. The obtained responses reveal that in safety management practice, FLMs allocate different efforts for different safety risks. OSHM-01 mentioned, 'We obtain low, medium and high risk. What we define as high risk is anything that can cause permanent disabilities and any risk that can cause death. So, we pay attention to high risks.' She also gave an example: 'A crane can be used to lift some objects to level 50 or whatever, and that is a high risk. We usually organise a special workshop before it starts to outline the methodology from start to finish. Then, we have a toolbox in the morning for all workers and tell them what should be done to make sure that work is delivered properly. We highlight things to workers. When workers perform tasks, we also observe them to check if they are doing things right. However, we do not give high attention to risks that have been assessed as low'. Current research has no clear statement as to whether FLMs expend different efforts regarding risks with different importance. However, the results of quantitative analysis and qualitative interview indicate that FLMs have different risk behaviours and management effort for risks with varying significance.

5.4.2 Importance of Communication in Safety Management

Quantitative results from Section 4.3 reveal that communication between supervisors and workers has the strongest moderation effect during workers' risk judgement. Communication is the second important dimension for FLMs. To confirm this finding, the following question is asked: 'Construction safety climate has many elements, such as managers' safety attitude, safety signs on sites, communication between supervisors and workers, and safety policy. Which one do you think is the most significant for workers and FLMs, and why?' Most responses mentioned that communication between workers and supervisors is the most important dimension. Responses such as 'Yes, communication is the most important thing for workers (WHSS-07, SM-10, OHSM-09),' 'Yes, I agree. I think so (CM-03)' and 'You are right. Communication is the most important part of how managers implement safety procedures (PM-02)' are collected. These responses confirmed the importance of communication in workers' risk judgement. Detailed explanations are also provided. For example, '*If I have to pick one measure on site, it should be consultation with workers. It's like constant communication, because you know if you are under the charge of safety management, you have to set some safety goals. For me, I will put the goal of high consultation with workers because if you come to the job and no one tells you what is going on and there is no coordination, things go terribly, like not just the safety goes terribly. So it's like when you are working for a big company; sometimes, you can feel like you are not that included. You can also feel that you're separate from the management and workers. And at XXX (the company where OHSM -01 currently works), we don't like that; we like to be integrated. We have a very* collaborative *approach. So, in consultation, especially for safety, we do have toolboxes usually once a week or once a fortnight with workers, and we go through all the agenda with safety warnings. If we notice something wrong in the building, we bring everyone's attention to why it happened, how it happened, how it can be rectified and what we can learn from it to remind everyone to not do that again* (OHSM -01)'.

PM-02 mentioned that '*First of all, managers' communication is very important. You see if a supervisor notices a worker is doing something risky, but the supervisor thinks it should be okay and not a big risk, and so he says nothing to the worker. Next time, when the worker does the job again, he may think that his supervisor even thinks it's okay, so it's okay, I can do it. But, you know, if the supervisor immediately says, you can't do that, it's risky, stop. Then, the worker will keep this in mind, and it may reduce the possibility that he will do the same risky thing again. Also, if a one-time warning is not effective, the supervisors can talk many times to the workers. Then, the workers will improve their safety awareness regarding this risk and follow the rule because they don't want to lose this job* (PM - 02)'. Communication is a way to show solicitude (CM-05). Workers can feel when FLMs care about them. Safety is the most important issue for everyone. Thus, if individuals, including workers and FLMs, feel that their managers and colleagues care for them, then they care about their safety. These findings are consistent with the research of Cigularov et al. (2010) and Ismail et al. (2012), which states that effective communication in construction management can avoid information error and improve safety compliance.

5.5 Factors Influencing Risk Tolerance

The quantitative results from Section 4.4 suggest that workers and FLMs have different opinions regarding the factors of emotion, reputation and potential gain from risky action. Thus, the question 'In your opinion, what do you think of the role of emotion, personal reputation, employers' support, communication and working experience in affecting risk tolerance?' is asked.

Responses regarding emotion, such as 'It could have some influences (OHSM-01, OHSM-08, OHSM-09)', 'Yes, it will have a really big influence (CM-03)', 'It is hard to say (SM-04)' and 'I am not quite sure, but kind of (CM-05)', indicate that people who are experienced in construction management are not 100% certain about the influence of emotion on safety risk tolerance assessment. Describing such an emotion is difficult for them. This interview result is consistent with the quantitative results where workers and FLMs show decentralised opinions regarding the influence of emotion on risk tolerance assessment. However, emotion can influence risk tolerance to a certain extent. CM-05 gave an example by saying, 'If workers must work in a confined space, which is a closed environment, then workers must have a confined-space working license. However, the license has different levels. FLMs must select experienced workers who have the senior-level license. If experienced people are unavailable, then workers with minimal experience may be selected. Thus, such workers may feel nervous or unstable when working in a confined space. At the same time, FLMs must improve their risk tolerance given that workers with minimal experience are the only ones selected.' This example clearly shows that workers and FLMs can be affected by their emotions during construction work. In the context of construction safety, construction workers and management personnel are inevitably affected by their emotions whilst performing construction tasks (Leung et al., 2010). Decision researchers argued that emotion is an independent factor in the decision making process (Lerner and Keltner, 2000, Forgas, 2001). Emotion normally has an indirect effect on risk behaviour by implicitly sharpening decision makers' cognitive activities, such as attitude and judgement. These interactions between emotion and the factors of situational, environmental, experience, perceived benefits and risks and gains play important roles in forming decisions, especially in risky and uncertain situations. Also, owing to the dual nature of emotion—positive emotions (e.g. happiness and pleasure) and negative emotions (e.g. anger, stress and fear)—the effects of emotion on risk decision making may be different (Forgas, 2001). These complex effects enhance the difficulty in revealing the influences of emotion on risk decision making. Thus, specifying emotion's role and ensuring that construction practitioners are equipped with awareness are necessary for objective risk tolerance assessment (Rawlinson and Farrell, 2009).

Responses obtained regarding the influence of reputation, such as 'It can be (OHSM-01)', 'It is hard to say (PM-02)' and 'It depends, and different individuals have different reputations (WHSS-07)', indicate that no consensus exists regarding the influence of personal reputation on risk tolerance assessment. The major reason is that some people care about reputation, whereas others do not (WHSS-07). Risk tolerance emphasises individuals' ability to tolerate potential losses resulting from their risk behaviour. Thus, a clear understanding of the possible losses is important for construction practitioners. In the context of construction safety, attention regarding potential losses has been paid to visible injuries, such as broken legs, cut fingers and death (Feng and Wu, 2015). However, further invisible losses that result from these injuries and fatalities cannot be ignored. Larkin (2002) said that individuals' reputation matters to them because it indicates whether they are good in what they do. If workers have a reputation for risk-taking in the modern commercial world, then finding a place in the construction industry is difficult. On the basis of this study, workers and management personnel inconsistently agree upon the effects of personal reputation and family responsibility on risk tolerance assessment. One possible reason can be the low awareness of the importance of these invisible losses. Therefore, further efforts to improve the status quo are necessary.

With regard to the influence of potential gain from risky action, responses such as 'For management, we have no such concern (OHSM-01)' and 'Managing safety is one of our liabilities (CM-05)' indicate that management personnel do not take risks deliberately because doing so is against their work liability. However, responses such as 'Workers may take risks if they can earn more than usual (OHSM-01)' and 'Certain workers are paid by how much work they can finish. Others may have a fixed pay, say, $200 for a day. (OHSM-09)' indicate that whether or not workers may acknowledge the influence of potential gain from risky action may depend on their payment. If they are paid by work measure, then they may take risks. This result has been supported by Rawlinson and Farrell (2009), Lehmann et al. (2009) and Wang et al. (2016).

5.6 Proposed Strategy for Construction Safety Management

This section aims to explore strategies of how to effectively avoid unsafe behaviour and improve construction employees' risk decision making. On the basis of the responses obtained from interview participants, suggestions can be categorised into two aspects: (1) improve workers' involvement in safety management and (2) show solicitude for workers rather than focusing only on safety.

Responses regarding the improvement of workers' involvement in safety management are 'Encourage workers to do mutual supervision (SM-04),' 'Share experiences (SM-04),' 'Provide rewards and bonuses for reporting risk issues (CM-05 and CM-03)' and 'Provide a real-time safety management platform in which workers can have access to report potential risks (CM-03)’. In practice, safety managers and supervisors cannot stay on sites all the time and observe all unsafety behaviours. Thus, safety procedures cannot be fully implemented only by the supervision provided by management staff (Wang et al., 2012). FLMs also lack safety supervision sometimes (CM-03). Thus, safety management may be at risk if it relies only on management personnel. As a result, encouraging workers to be involved in safety management is necessary. Doing so not only deepens their risk understanding and increases safety awareness but also helps ensure an invulnerable safety management system. Aksorn and Hadikusumo (2008) indicated that workers’ safety risk decision making can be strengthened by the degree of their participation in safety-related activities, such as taking part in activities of the workplace safety committees, reporting and correcting hazards under their operations and analysing routine hazards within each step of tasks or processes. Also, Guo et al. (2018) mentioned that safe behaviour can be reinforced by rewards and that repetitive rewards produce sustainable improvement in safety behaviours.

Supportive responses regarding the showing of solicitude for workers are ‘Current safety training focuses only on telling people what the potential risks for certain tasks are and how to perform these tasks in a right way. No content cares about workers’ health and well-being (PM-02 and WHSS-07)’ and ‘The most important thing is real solicitude. If FLMs care for workers, workers can feel it. If they feel it, then the safety message can be conveyed and convince workers to make safety decisions (CM-05)’. In practice, most companies talk about safety, but they currently focus too much on safety only rather than health and well-being. Therefore, health and well-being are not addressed as much as safety (WHSS-07). Health is the factor that is directly related to workers themselves, such as how to perform manual handling correctly without resulting in muscle injury. Well-being is the factor that ensures that people get enough rest before they start their shift and cares about workers’ mental health

(WHSS-07). If safety is the only factor that is strengthened, then risky behaviour may be difficult to avoid completely because workers are not confused about the real safety attitude of management personnel. For instance, if workers cannot contact certain people when they suffer from mental issues or need counselling service regarding health problems, then they may feel that FLMs do not care about safety, given that health is the important thing for FLMs (CM-03 and WHSS-07). Another example can be that 'During morning meetings, safety managers and supervisors discuss many things about safety. However, when it comes to production, they say that we must do it today. Otherwise, we may fall behind schedule (CM-03 and WHSS-07)'. This situation can confuse workers about the real priorities in their work given that they may make risky decisions because they want to catch up on the schedule. In these situations, more care can be provided than usual, such as (1) care for workers' health and well-being, which are directly important matters to them, and (2) frequent talks between individuals and supervisors. 'If supervisors notice that workers are doing something wrong, they should approach each worker and talk with them individually. Supervisors can remind workers that they have a family to look after. Thus, if they get hurt, then their family can suffer. This individual talk not only reminds workers to be conscious of their responsibility but also gives them a strong sense of care, which is a powerful way to improve safety awareness (OHSM-01 and OHSM-06)'. Positive messages can be conveyed to workers, and they can have a positive impression that their managers care for them. Therefore, they should be careful when performing construction tasks. Thus, caring for workers is an effective way of preventing them from making risky decisions.

5.7 Summary

This chapter discussed the qualitative analysis and findings of this research. Thematic analysis is used to analyse qualitative data collected using the semi-structured interview method. The major findings are as follows:

Firstly, the risk tolerance difference between workers and FLMs is confirmed by all interview participants. Also, the possible reasons workers have high risk tolerance are (1) overconfidence, (2) utilitarian outcome and (3) work habit. Moreover, the reasons FLMs have relatively low risk tolerance are (1) less construction work experience, (2) safety management manner, (3) liability and (4) measurement of work performance. The influence of such difference on safety management is also discussed. Secondly, the question of risk tolerance's influence on common injury and fatal risk scenarios were asked. The answer reveals that workers have different risk behaviours when facing these two scenarios. Moreover, FLMs pay attention to high risks instead of giving equal effort for all the identified safety risks. Among other elements in safety climate, communication between workers and supervisors is confirmed as the most important dimension which can improve workers' safety awareness and sense of careness. Thirdly, the influences of emotion, personal reputation, employers' support, communication and working experience on safety risk tolerance assessment are discussed in detail by integrating findings from interview responses and literature review. Lastly, two strategies for helping employees to make safety decisions are obtained and explicated. These strategies are to (1) improve workers' involvement in safety management and (2) show solicitude for workers rather than focusing only on safety.

Chapter 6 Risk Tolerance between Workers and FLMs

Construction workers and FLMs have an important responsibility and a role to play in behaving safely and in performing safety management tasks in construction sites. During this process, they need to acquire certain understanding of the current status of their risk tolerance, its influence on their behaviours, their behaviour responses under a certain safety climate and the critical influential factors of safety risk tolerance assessment to fulfil these responsibilities and roles. This chapter summarizes the similarities and differences between workers and FLMs in terms of risk tolerance research undertook in this study and accordingly, provides a management model for safety risk tolerance management in construction projects.

6.1 Risk Tolerance Difference between Workers and FLMs

Through the integration of the results of quantitative (see Chapter 4) and qualitative (see Chapter 5) analyses, a compressive comparison (see Figure 6.1) was developed to demonstrate the similarities and differences of workers and FLMs' risk tolerance. On the basis of the research scope of this study, four research topics are included: (1) the risk tolerance level of different safety risks, (2) the influence of risk tolerance and risk perception on safety behaviour and management, (3) how workers and FLMs respond to perceived safety climate and (4) the critical influential factors of safety risk tolerance.

In the first topic, workers and FLMs' tolerance levels for different safety risks are revealed. Their similarities are reflected as follows: (1) risk tolerance decreases as risk level increases, (2) they are sensitive to risk severity in risks with moderate levels and (3) they show significant different risk tolerance levels in common injury and fatal risk scenarios. The significant differences are (1) workers' risk tolerance is significantly higher than FLMs' and (2) workers are sensitive to risk frequency in risks with low levels. On the basis of these differences, the underlying reasons these two groups show significantly different risk tolerance levels are obtained based on interviews with safety experts. The reasons construction workers have high risk tolerance are summarised as follows: (1) they are sometimes overconfident, (2) they are encouraged by utilitarian outcome and (3) they have certain habits in conducting construction work. The reasons FLMs have relatively low risk tolerance are concluded as follows: (1) they have less real construction work experience, (2) safety management manner, (3) liability and (4) the measurement of their work performance. These results not only provide basic knowledge of risk tolerance towards safety risks but also act as the foundation to further explore the influence of risk tolerance in different risk scenarios as workers and FLMs have significantly different considerations when confronted with common injury and fatal risk scenarios. Accordingly, these two different risk scenarios are used to further investigate the influence of risk tolerance on workers and FLMs' safety behaviour.

In the second topic of this study, the risk behaviour pattern (refers to how risk tolerance and risk perception influence workers' safety behaviour and FLMs' involvement in safety management) is investigated under two risk scenarios: common injury risk scenarios and fatal risk scenarios. Quantitative results show that workers and FLMs have different risk behaviours in these two scenarios. When considering common injury risks, workers' risk perception can fully mediate the relationship between risk tolerance and safety behaviour while FLMs' safety management involvement only be influenced by risk tolerance. When considering fatal risks, FLMs' risk tolerance can influence their safety behaviour by affecting risk perception whereas workers' safety behaviours are only decided by their risk perception under fatal risk scenarios. The qualitative analysis also validates and reveals the underlying reasons from a practical perspective. Workers may have already become accustomed to the common injury risks on site. Their assessment of risk tolerance can still influence risk perception, which is their subjective assessment of risks. However, given that no one likes to take risks with the possibility of losing their lives, workers' risk tolerance will not function anymore in fatal risks. For FLMs, interviewed safety experts show that people in safety management allocate different management efforts based on the importance of safety risks. They usually focus on risks with severity outcomes because they know they cannot tolerate such risks. However, the occurrence of common injury risks may not cause severe losses. Managers already have a clear understanding of these risks and know that no serious injuries can occur. Thus, their involvement in safety management does not need to rely on the risk assessment results in the common risk scenarios. Hallowell (2010) mentioned that site management personnel have a shallow level of risk perception regarding less serious injuries, such as temporary discomfort, temporary pain and minor first aid. These low injuries are not their first concern because site management personnel are not the direct victims on site.

After identifying the significant risk behaviour path, the third topic, which refers to the moderating effect of perceived safety climate, is explored. The similarities for workers and FLMs are that four dimensions of safety climate are tested as having significant moderating effects on the relationship between risk tolerance and risk perception, including (1) safety attitude of top management, (2) safety attitude of supervisors, (3) communication between supervisors and workers and (4) safety support. The major difference is that the moderating direction of perceived safety climate for workers and FLMs is different. Workers' risk perception will tend to be lower if they perceive a more positive safety climate, especially for workers with higher risk tolerance. By contrast, FLMs' risk perception will tend to be higher if they perceive a more positive safety climate. As the results in workers' group is unexpected, two possible explanations are identified. One is that construction workers who score high on willingness to tolerate risks are thought to accept a great level of risks in pursuit of goals. In this context, workers are thought to be fearless (Rodrigues et al., 2015b) and/or to easily support hazardous attitudes, such as being macho, believing in good luck, believing in their invulnerability and being impulsive and anti-authoritarian (Ji et al., 2011). These emotions and attitudes may manifest in behaviours that are contrary to safety, such as finishing tasks quickly, ignoring supervisors' advice, believing only themselves and thinking that accidents can never happen to them. Hence, they may underestimate the likelihood and severity of safety risks. Another possible explanation can be conducted from the perspective of risk compensation theory (Peltzman, 1975) applied to the construction of workers' activities. Construction workers behave in a less cautious way than usual when they feel 'safe' or protected (Feng and Wu, 2015, Stromme, 2004). Thus, workers, especially who has higher risk tolerance tend to negatively respond to positive safety climate.

In the fourth topic, the critical influential factors of safety risk tolerance are identified based on their relevant importance and people's opinion distribution. The similarities for workers and FLMs are as follows: (1) influential factors related to knowledge and experience are identified as the most important ones for safety risk tolerance and (2) these two groups show inconsistent opinions regarding emotion, personal reputation and employers' reputation. The differences between workers and FLMs in this topic are that they have different opinions of the factors of potential gain of profit from risk action and belief in good luck, whereas the workers shows inconsistent opinions and FLMs show consistent opinions.

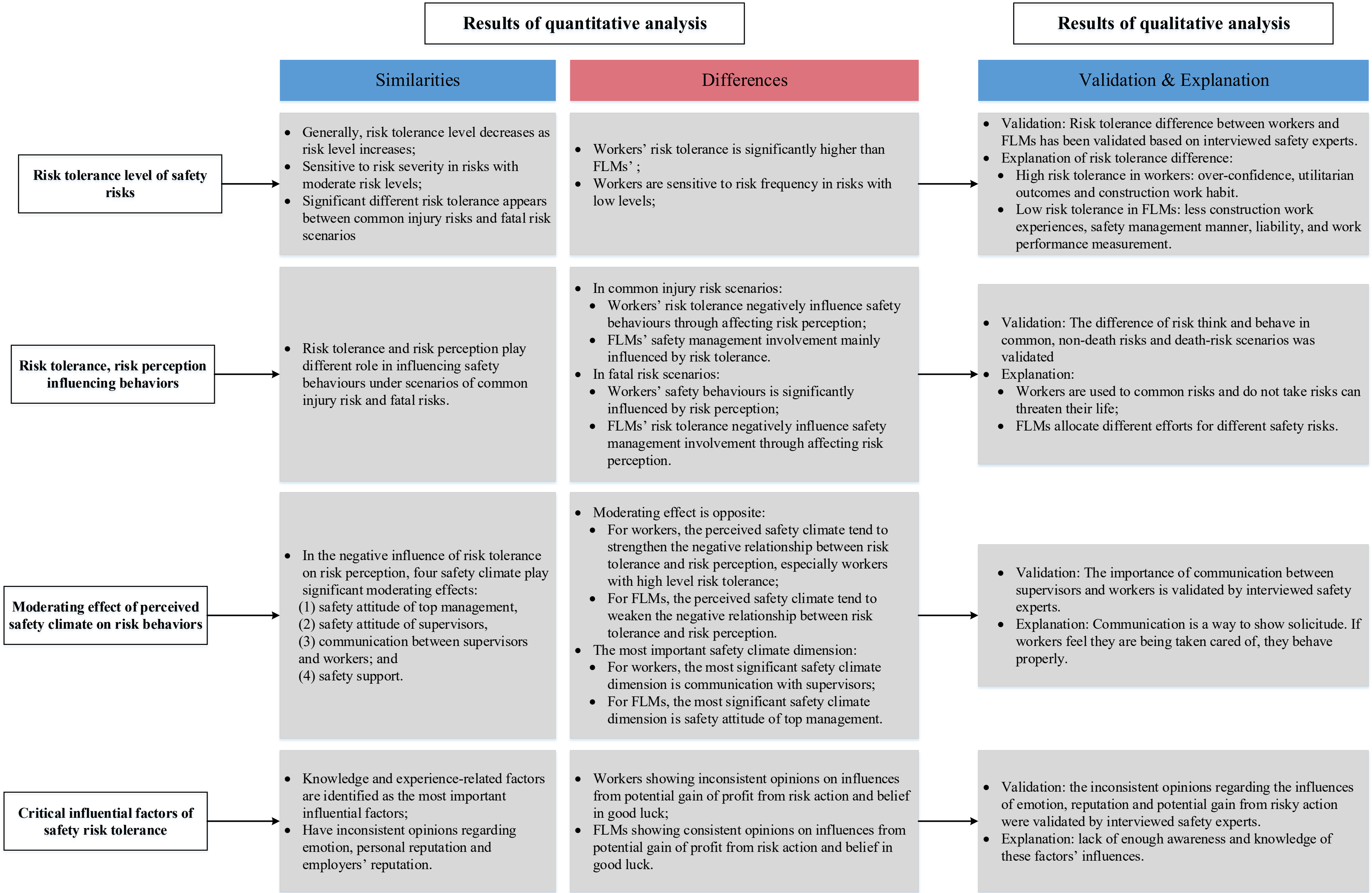


Figure 6.1 Risk tolerance similarities and differences between workers and FLMs

6.2 Safety Risk Tolerance Management

6.2.1 Safety Risk Tolerance Management Framework

Based on the research findings, risk tolerance plays an important role in workers' safety behaviours and FLMs' safety management involvement. In common injury risks, if workers have higher risk tolerance, then, they are likely to conduct unsafety behaviours; same as FLMs; if FLMs show higher risk tolerance, they will give less effort in relevant risk management (these conclusions are got from Section 4.2). Thus, it is necessary to evaluate workers and FLMs' risk tolerance to prevent potential unsafety behaviours which result from the negative effects of high risk tolerance. On the other hand, if a big difference of risk tolerance between workers and FLMs exists, especially workers' risk tolerance are significantly higher than that of FLMs, unsafety behaviours are also likely to occur. It is because FLMs would thought workers have the same risk tolerance as them and workers would be careful when performing relevant tasks. However, the real situation is that workers may conduct unsafety behaviours because they have higher risk tolerance than FLMs' thought. This situation is confirmed by interview survey. As mentioned in Section 5.3.3, if FLMs cannot get the information of risk tolerance difference between themselves and works, then inattentive safety management from FLMs and unsafety behaviours from workers may happen because FLMs think workers would perform the job as they expected. Thus, the comparison of risk tolerance between workers and FLMs is also necessary as it can contribute to managers' risk management.

Based on these potential issues, a safety risk tolerance management framework for construction projects has been developed. As shown in Figure 6.2, there are four major steps, including evaluate risk tolerance, analyse risk tolerance, identify potential safety issues and apply relevant strategies. After the establishment of safety risk list for a construction project, a first step is to evaluate safety risk tolerance of the key participants, such as workers and FLMs. Then, three analyses can be conducted, including (1) analyse workers' current risk tolerance, (2) analyse FLMs' current risk tolerance, and (3) compares risk tolerance difference between workers and FLMs. It is noticed that in the first two analysis, there is no general rules to judge the exact 'high' and 'low' in risk tolerance. Based on interview responses, companies can analyse whether or not workers and FLMs have higher risk tolerance based on companies' own criteria.

After risk tolerance analysis, potential safety issues may appear, including (1) workers having higher risk tolerance than companies' criteria, (2) FLMs having higher risk tolerance than companies' criteria, and (3) workers having significantly higher risk tolerance than FLMs. Thus, it needs to help workers and FLMs have more objective risk tolerance evaluation and also help them to reduce risk tolerance difference. To achieve these aims, five strategies of risk tolerance management, which obtained from Chapter 4 and Chapter 5, should be considered and implemented. From the perspective of further current safety training and education, it is suggested to identify and manage the critical influencing factors of risk tolerance. As shown in Section 4.4, 'knowledge and experience' are identified as the most important factors influencing risk tolerance, reinforcement training should be provided for these factors. For the factors with inconsistent opinions, such as 'emotion and reputation', the reason of why some people believe they are important and other people think they are not important should be investigated; then, based on this obtained information, managers may need to update current training content by providing 'supplementary learning' strategies to minimize the discreteness of people's opinions and strengthen people's understanding of these influential factors. Eventually, construction practitioners' awareness of these factors' influences on their risk tolerance would be improved and accordingly more objective and rational risk tolerance evaluation will be achieved. From the perspective of improving risk perception and awareness, it aims to improve workers and FLMs' awareness of the risks with high frequency and less severity and risks with low frequency and high severity. As Section 4.1 indicates that workers and FLMs showing higher risk tolerance about these risks, this strategy may help to decrease risk tolerance for the risks that workers and FLMs tend to overlook. The third strategy comes from strengthening tailored safety climate. Inspired by the results of Section 4.3, safety climate has significant moderating effects on workers and FLMs' risk behaviours, for workers, the most effective safety climate dimension is communication with supervisors and for FLMs, the most effective safety climate dimension is top managers' safety attitude. Thus, build and implement targeted safety climate to strengthen positive influence from risk perception on safety behaviours and weaken the negative influence of risk tolerance on safety behaviours is another effective way of risk tolerance management. Based on the results of Section 5.6, risk tolerance management could also be implemented by showing real solicitude for workers' well-being and health rather than just focus on safety issues and by encouraging workers' active involvement in safety management, such as do mutual supervision, set rewords mechanism for actively report safety issues and give workers access of real-time safety management.

To better understanding the application of these five strategies, two important things need to be noticed: (1) the success of risk tolerance management couldn't be achieved if applying any single of these five strategies, the strategies are complementary and mutually reinforcing; and (2) after implementing these strategies, it is recommended to evaluate safety risk tolerance periodically to further validate and improve the effectiveness of current risk tolerance management.

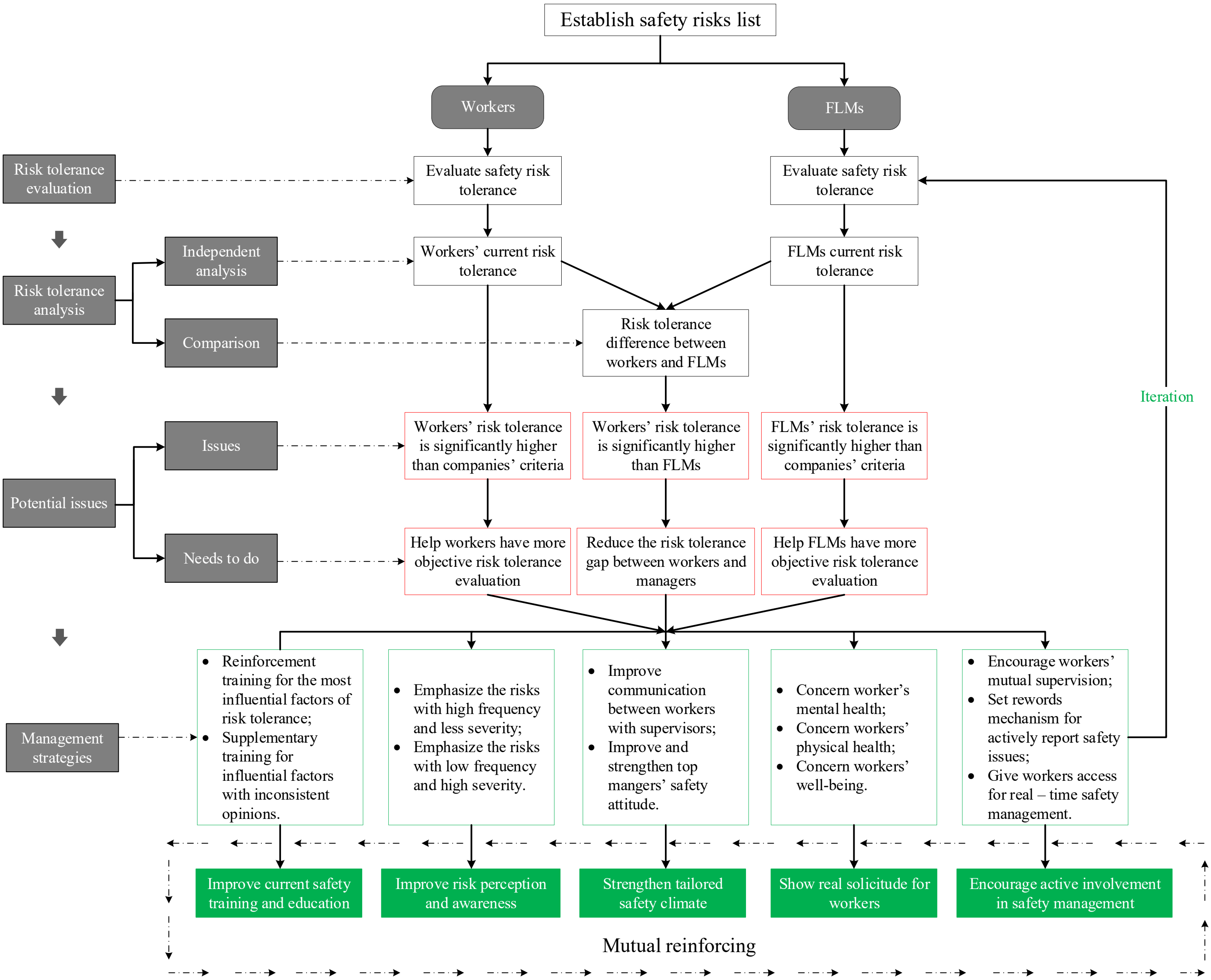


Figure 6.2 A framework for safety risk tolerance management in construction projects

6.2.2 Practical Application of Safety Risk Tolerance Management Framework

Regarding the practical application of the proposed safety risk tolerance management framework, four issues should be considered.

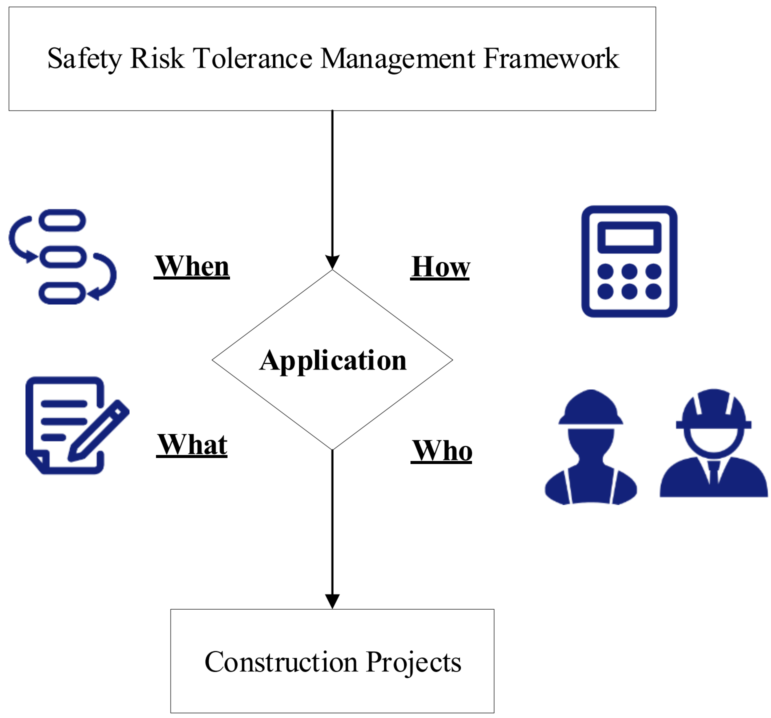


Figure 6.3 Safety risk tolerance management framework application

(1)When to perform safety risk tolerance management during the process of construction?

Construction projects have a long process from the beginning to the end. At each important project point, such as during planning, digging the foundation, building construction and inside renovation, there are different safety risks. So, it suggests to conduct the safety risk tolerance management from the very beginning of the project construction and repeat it in an iteration way. For example, perform the safety risk tolerance management framework at the beginning of construction, then, implement management strategies to prevent safety risks which may result from high-risk tolerance. After this first round of application, perform the safety risk tolerance management framework during construction, i.e., after the foundation works, to re-assess risk tolerance and also check the efficiency of previous safety management strategies. The benefits of doing this including: (a) the management can have an early understanding of workers and FLMs' risk tolerance and then, based on this evaluation, to determine and implement relevant strategies to prevent potential unsafe behaviours; and (b) ensure the management can have a prompt understanding of risk tolerance at different stages during project construction, and as a result, the strategies to ensure safety behaviours can be modified and implemented more effectively.

(2) What safety risks should be considered?

The safety risks can be decided by two ways: (1) use the questionnaire designed in this study, as it includes the most common safety risks on construction sites; or (2) decide safety risks based on risk analysis for the project. Actually, what safety risks should be included is completely depends on the real requirement of the project. For example, if the organization only have construction experiences of commercial building before, but now, the new project is a chemistry factory. So, a new list of safety risk is needed, which can be obtained from safety risk analysis.

(3) How to analysis safety risk tolerance evaluation?

This research provides statistical analysis of safety risk tolerance evaluation, which has already been used in this study (Section 4.1.2). This method can be easily programmed by excel. So, it suggests to prepare the excel spreadsheet first, then, it will be easy-to-use for safety risk tolerance analysis. In addition, as risk tolerance is a kind of subjective, we also suggest to conduct an interview after quantitative evaluations to have a deeper and realistic understanding of why some safety risks are evaluated as high risk and others are evaluated as low risk.

(4) Who is the target for safety risk tolerance evaluation, only one cohort or both cohorts?

As construction workers and FLMs are two important cohorts in construction projects, it suggests performing the evaluation for both of them. Also, if there are other important stakeholders in the project, companies should also evaluate stakeholders' risk tolerance, such as supplier, safety inspection people, etc.

This research is the first to provide a comprehensive and systematic investigation of risk tolerance, a human-related factor, in the context of construction safety management. Firstly, a parallel analysis between workers and FLMs is conducted throughout the research, which offers valuable insights into the risk tolerance difference between workers and FLMs. Secondly, distinguished risk scenarios are employed to explore risk behaviour differences, and the results are validated based on the literature and the qualitative results. Thirdly, a new research design that considers factors' relative importance and people's opinion distribution is introduced to help identify the critical influential factors of risk tolerance. These results not only contribute to the knowledge of risk tolerance in construction safety but also should assist construction organisations in realising and managing the potential issues resulted from higher risk tolerance of workers and big risk tolerance differences between workers and FLMs.

Chapter 7 Conclusion

Risk decision making plays an important role in deciding how to behave in risky situations. During individuals' risk information processing, risk tolerance is a critical element that must be fully understood. To understand how risk tolerance may influence construction workers' safety behaviour and FLMs' involvement in safety management, this research investigates the risk tolerance level for different safety risks. Risk tolerance and social cognitive variables (risk perception and perceived safety climate) are also considered sources of variation in behaviours and critical influential factors of safety risk tolerance assessment.

A mixed methods research design is adopted in this research. In the quantitative part, a questionnaire survey is applied to measure risk tolerance, risk perception, five dimensions of safety climate, workers' safety behaviour and FLMs' involvement in safety management. A total of 192 and 164 valid responses are obtained from workers and FLMs, respectively. Descriptive statistical, mediating effect, moderating effect, information entropy and canonical discriminant analyses are applied to answer the four research questions. Then, thematic analysis of the qualitative data collected through semi-structured interviews with ten experienced construction practitioners is employed to validate and obtain further explanations concerning the quantitative findings. Strategies and approaches for construction safety management from the perspective of risk tolerance management are also discussed.

7.1 Key Findings

(1) Risk tolerance of safety risks

Under this topic, construction workers and FLMs' risk tolerance levels of safety risks are revealed.

- In general, scenarios with higher risk levels were assessed as more intolerable, whereas scenarios with lower risk levels were regarded as more tolerable for both workers and FLMs.
- Workers and FLMs show significantly lower tolerance for fatal risks compared with common injury risks.
- In general, workers' risk tolerance level is significantly higher than FLMs'.
- With regard to mental stress scenarios, construction workers' risk tolerance is higher than that of FLMs.
- In scenarios with lower risk levels (e.g., in this research the risk level is under 0.1) where the risk severity is small but the frequency of the event is very high, workers' risk tolerance levels tend to be more sensitive to the incident frequency, whereas FLMs' risk tolerance does not show this trend.
- In scenarios with moderate (e.g., in this research the risk level is around 0.5) and high (e.g., in this research the risk level is bigger than 0.7) risk levels. Workers and FLMs' risk tolerance tend to be more sensitive with the variation of risk severities. When the severity of consequences increases, the influence of risk frequency seems to disappear.

(2) Mechanism of how risk tolerance influences workers' safety behaviour and FLMs' involvement of safety management

Under this topic, how risk tolerance influence construction workers' safety behaviours and how risk tolerance influence construction FLMs' safety management involvement were answered. In general, both workers and FLMs showing different risk behaviour patterns under the common injury risk scenarios and fata risk scenarios. Table 7.1 summarises the hypotheses and main results. Ten hypotheses are developed and tested in the quantitative part of this research. Hypotheses of 1, 2, 3, 4-1 and 4-2 focus on construction workers, whereas Hypotheses of 5, 6, 7 8-1 and 8-2 concerned about FLMs. Two (Hypotheses 1 and 5) out of the ten hypotheses are fully supported, and the other eight are partially supported or rejected.

It is found that workers' risk tolerance is negatively associated with risk perception only in common injury risk scenarios. Workers' risk perception can fully mediate the relationship between risk tolerance and safety behaviour in common injury risk scenarios. Thus, Hypotheses 2 and 3 are partially supported because they are not supported in fatal risk scenarios. Hypothesis 4-1 is rejected given that the relationship between risk tolerance and risk perception is negatively moderated by perceived safety climate, including attitude of top management (H4-1a), safety attitude of immediate supervisors (H4-1b), communication with supervisors (H4-1c) and safety support (H4-1e). In these moderating effects, when workers perceive higher level of safety attitude of top management, safety attitude of immediate supervisors, communication with supervisors and safety support, they tend to have lower perception of risks, which increased the probability that they will behave unsafely. Hypothesis 4-2 is rejected given that no moderating effect of perceived safety climate is found in the relationship between risk perception and safety behaviour.

For FLMs, the negative relationship between risk tolerance and risk perception is validated only in fatal risk scenarios. Thus, Hypothesis 6 is partially validated. Hypothesis 7 is also partially supported because it is confirmed only in fatal risk scenarios. When dealing with fatal risks, FLMs' risk tolerance can influence their safety management involvement by affecting risk perception. Hypotheses 8-1 is regected because no moderating effect of perceived safety climate is found in the relationship between risk tolerance and involvement of safety management. Hypotheses 8-2 is partially supported because the relationship between risk tolerance and risk perception is positively moderated by perceived top management attitude (8-2a), immediate supervisors (8-2b), communication with workers (8-2c) and safety support (8-2e). When FLMs perceive a high level of safety attitude from top and immediate management, communication with workers and safety support, they tend to have a high perception of risks, which decreases the probability that they will behave unsafely.

Table 7.1 Results of hypothesis testing

Hypothesis No.	Hypothesised relationship	Testing result
Hypothesis 1	Risk tolerance is negatively related to construction workers' safety behaviour.	Supported
Hypothesis 2	Risk tolerance is negatively related to construction workers' risk perception.	Partially supported
Hypothesis 3	Risk perception mediates the relationship between construction workers' risk tolerance and safety behaviour.	Partially supported
Hypothesis 4-1	When construction workers deal with common injury risks of safety, their perceived safety climate moderates the negative correlation between risk tolerance and risk perception: This correlation is weak when positive safety climate is perceived. Specific sub-hypotheses of this hypothesis include safety attitude of top management (4-1a), safety attitude of immediate supervisors (4-1b), communication with supervisors (4-1c), co-workers' influence (4-1d) and safety support (4-1e).	Rejected
Hypothesis 4-2	When construction workers deal with fatal risk scenarios, their perceived safety climate moderates the positive correlation between risk perception and safety behaviours. This correlation is strong when a positive safety climate is perceived. Specific sub-hypotheses of this hypothesis include safety attitude of top management (4-2a), safety attitude of immediate supervisors (4-2b), communication with supervisors (4-2c), co-workers' influence (4-2d) and safety support (4-2e).	Rejected
Hypothesis 5	Risk tolerance is negatively related to FLMs' involvement in safety management.	Supported
Hypothesis 6	Risk tolerance is negatively related to FLMs' risk perception.	Partially supported
Hypothesis 7	Risk perception mediates the relationship between FLMs' risk tolerance and involvement in safety management.	Partially supported
Hypothesis 8-1	When FLMs deal with common injury risks, their perceived safety climate moderates the negative correlation between risk	Rejected

	tolerance and involvement of safety management. This correlation is weak when a positive safety climate is perceived. Specific sub-hypotheses of this hypothesis include safety attitude of top management (8-1a), safety attitude of immediate supervisors (8-1b), communication with supervisors (8-1c), co-workers' influence (8-1d) and safety support (8-1e).	
Hypothesis 8-2	When FLMs deal with fatal risks, their perceived safety climate moderates the negative correlation between risk tolerance and risk perception. This correlation is weak when a positive safety climate is perceived. Specific sub-hypotheses of this hypothesis include safety attitude of top management (8-2a), safety attitude of immediate supervisors (8-2b), communication with supervisors (8-2c), co-workers' influence (8-2d) and safety support (8-2e).	Partially supported

(3) Critical influential factors of safety risk tolerance

To identify the critical influential factors of risk tolerance, this study offers a new way to evaluate influential factors by combining two ideas: (1) traditional factor ranking based on mean to understand factors' relative importance, and (2) information entropy-based method to further understand factors' uncertainty, which is reflected by the participants' opinion distribution on each measurement scale. Results of similarities of influential factors of risk tolerance between workers and FLMs indicate that knowledge and experience are common and important factors in evaluating risk tolerance. Workers and FLMs give high and consistent assessment on these factors' influences. Another similarity is reflected in the inconsistent opinions regarding emotion, personal reputation and employers' reputation. Both workers and FLMs show inconsistent opinions on these factors' influence on their risk tolerance.

Regards to the differences between workers and FLMs, it indicates that 14 factors showing statistically significant differences between the two groups. Then, DFA (Canonical discriminant function) provides further insights and reveals that the most contributing factor in differencing workers and FLMs is factor F07 (belief in good luck). This factor alone can reach 65.2% accuracy in distinguishing workers and FLMs. Another significant difference is reflected in factor F20 (potential gain or profit from risk action).

(4) Result of qualitative analysis

Interview transcripts are analysed using the thematic analysis method, in which four themes emerged, namely, the difference of risk tolerance between workers and FLMs, discussion of risk behaviour patterns, discussion of the influential factors of risk tolerance assessment and strategies for construction safety management.

The difference of risk tolerance between workers and FLMs is confirmed by the interviewees. The proposed reasons for such risk tolerance difference, including workers having relatively high risk tolerance, are as follows: (1) overconfidence, (2) utilitarian outcome and (3) work habit. The reasons FLMs have relatively low risk tolerance are as follows: (1) less construction work experience, (2) safety management manner, (3) liability and (4) measurement of work performance. The proposed consequences that result from this difference, such as increasing the difficulty for site safety management, are also provided.

The second theme focuses on confirming the differences of risk behaviours in common injury risk and fatal risk scenarios. Results reveal that workers have different risk behaviours when facing these two scenarios because they are already used to the common injury risks. Moreover, they do not take risks that may threaten their life. FLMs pay more attention to high risks instead of giving equal effort for all the identified safety risks. Thus, workers and FLMs showing different risk behaviours when dealing with risks with different importance is reasonable. Communication between workers and supervisors is also confirmed as the most important element in safety climate because communication can improve workers' safety awareness and sense of care.

The third theme discusses the identified critical influential factors of risk tolerance. In the fourth theme, two strategies for helping employees make safety decisions are obtained and explicated: (1) improve workers' involvement in safety management and (2) show solicitude for workers' well-being and health rather than focusing only on safety.

7.2 Achievement of Research Objectives

Five research objectives are formulated at the beginning of this research. This section reviews the achievement of these objectives, also briefly mentioned the potential research limitations for each research objective. The detailed research limitations are discussed in Section 7.4.

Research objective one: Investigating and comparing risk tolerance levels among workers and FLMs

This research revealed the risk tolerance changing trend with different safety risks. Workers' risk tolerance is also found to be significantly higher than that of FLMs. Discussions supported by the existing literature and interview responses to elaborate the possible reasons and consequences of this difference are provided for researchers and practitioners' in-depth understanding. Therefore, this objective has been achieved. However, due to all of the data collected from a self-reported research method, perception bias may exist in the responses. As a result, there may exist subjective bias in the analysis results. Also, the current survey only consider three common safety risks, which can only provide analysis of risk tolerance.

Research objective two: Exploring the mediating effect of risk perception on the relationship between risk tolerance and safety behaviour

This research found that the relationship between risk perception, risk tolerance and safety behaviours is different in worker and FLM groups. When both groups deal with safety risks with different importance, such as risks with low severity and fatal risks, workers and

FLMs show different risk behaviour patterns towards them. Discussions that are supported by the existing literature, and qualitative analysis are provided to confirm and explain these findings. Thus, this objective has also been achieved. However, due to all of the data collected from a self-reported research method, perception bias may exist in the responses. As a result, the analysis results may suffers the potential of not strong accurate. Also, only risk tolerance and risk perception were considered when discussed how unsafe behaviours can be formed and prevented, which cannot provide a comprehensive picture in the topic of behaviour research. Thus, other risk related factors should also be considered in the future study.

Research objective three: Exploring the moderating effect of perceived safety climate in risk behaviours

On the basis of the results of objective two, some significant relationships between risk perception, risk tolerance and safety behaviours were identified. Then, this research tests the moderating effects of the five dimensions of safety climate. Communication with supervisors has the largest moderating effect for workers, whereas it is the second important one for FLMs. Also, if workers have higher risk tolerance, then they tend to underestimate safety risks when they perceive a positive safety climate, whereas FLMs show an opposite respond. These results are confirmed and explained based on the literature and interview results. The triangulated and inter-supported quantitative and qualitative results demonstrate the achievement of this objective. However, due to the participants are recruited from different organizations, their perception of safety climate may be different. Also, only five dimensions of safety climate were considered, which cannot fully present safety climate.

Research objective four: Determining and comparing the critical influential factors of workers and FLMs' safety risk tolerance

This research identifies the critical influential factors of risk tolerance from two perspectives of concerning factors' relative importance and people's opinion distribution. Assisted by the descriptive statistical information entropy and canonical discriminant analyses, the most influential factors, factors with inconsistent opinions and the most distinguishing influential factors between construction workers and FLMs are identified. Discussions that are supported by the existing literature and interview responses provide further understanding of the identified factors. Thus, this objective has also been achieved. However, due to all of the data collected from a self-reported research method, perception bias may exist in the responses. As a result, the analysis results may be not exactly the same as the current one. For example, the identified influential factors may being imitated to the current identified ones.

Research objective five: Proposing strategies for construction organisations to improve safety management by managing safety risk tolerance

Providing suggestions to change risk tolerance is difficult given the subjective and invisible nature of risk tolerance. What companies can do is to help their employees have more objective of risk tolerance assessment and to reduce the negative effect of high risk tolerance on safety behaviours. Based on the quantitative and qualitative analysis results, five strategies were proposed, including (1) improve current safety training and education by adding the critical risk tolerance influential factors, (2) improve risk perception and awareness for the risks with high tolerance, (3) build and emphasize tailored safety climate for workers and managers, (4) show real solicitude for workers and (5) encourage workers' active involvement in safety management. Only when employees feel that safety issues really matter to them and that supervisors and managers care about them could safe behaviours be achieved. These results indicate that the abovementioned objective has been achieved. However, the achievement of this research objective suffers the limitations of all proposed strategies cannot be verified immediately in real projects. Thus, how to further verify these proposed strategies can be considered in the future research. Also, the proposed strategies were developed by interviewing 10 safety experts, if there are other strategies or if other safety experts agree with these strategies need further verification.

7.3 Research Contribution and Implication

This research offers contributions to the advancement of theoretical understanding in safety behaviour field. The study also provides practical implications for the safety management. Detailed discussions of theoretical contribution and practical implication for each research topic can be seen in Section 4.1.3, 4.2.5, 4.3.6, and 4.4.4. A summary is provided as below.

7.3.1 Theoretical Contributions

First, this research contributes to safety literature by showing the difference of workers and FLMs' safety risk tolerance. Workers and FLMs are two critical contributors for construction projects, questions as whether or not they have different safety risk tolerance, how much these differences could be and in what particular risk scenarios that the differences tend to be significant have not been clearly answered. This research explored workers and FLMs' risk tolerance in three types of safety risks: (1) common injury risk, (2) mental stress risk and (3) fatal risk. It is found that workers' risk tolerance level, in general, is significantly higher than FLMs', and significant differences between workers and FLMs were found in mental stress and fatal risk scenarios. Thus, this research contributes to safety knowledge by validating the difference of safety risk tolerance between workers and FLMs.

Second, this research expands the safety behaviour literature by adding new knowledge of the influence of risk tolerance together with social cognitive variables (risk perception and perceived safety climate) in construction safety field. Though the influence of risk tolerance on safety behaviours has been mentioned in other fields, such as immigration behaviours and pilot's safety behaviours, there is no explicit explanations of whether or not risk tolerance could influence construction practitioners' safety behaviours, what the mechanism of this influence could be and if the influence mechanisms would be different under common injury risk scenarios and fatal risk scenarios. As risk perception and safety climate are important social cognitive variables in risk behaviours, this research answered above questions by building, testing and validating the relationships between risk tolerance, risk perception, perceived safety climate and safety behaviours (safety management involvement in FLMs). It is found that when workers and manamgnet personenl encouter risk scenarios with common injury and fatal risks, their risk behavior patterns are different. Also, counter to expected, workers, who have higher risk tolerance, tend to have lower risk perception even perceived better safety climate. Thus, this research made contributions to the safety behaviour literature.

Third, this study provides a fresh insight in identifying the critical factors influencing risk tolerance. Information entropy theory was employed to investigate whether participants had consistent evaluations by checking their opinion distributions on each measurement scale. Prior research on identifying critical influential factors mainly focuses on discovering the most relevant, important or influential factors. The underlying hypothesis is as follows: the higher the factor ranking is (usually measured by mean), the more important that participants believe the factor is, thus resulting in a higher likelihood that the factor is critical for a certain problem (Wang et al., 2016, Aksorn and Hadikusumo, 2008, Ismail et al., 2012, Lombardi et al., 2009). However, some important factors may be overlooked due to their relatively low factor ranking, which may be caused by people with different opinions about them (Potter et al., 2013). Based on discussion in Section 4.4.4.2, a factor with significant controversial opinions may indicate that people are lack of relevant knowledge of these factors or people are reluctant to admit the importance of certain factors. As a result, the mean of these factors would be relative low and if only check the mean without considering people opinion's distribution, these factors would be overlooked. Thus, this research contributes to risk tolerance influencing factors identification by firstly quantifying workers and FLMs' opinion distributions, which further validates important factors identified by mean value method and provides more valuable insights for factors evaluation. Also, the method of integrated consideration of mean value and information entropy not only can be used for risk tolerance influencing factor identification but also could be used in other research topics related to factor identification and evaluation. Given this, the integrated method proposed in this research also contributes to research of factor identification and evaluation.

In a s summary, this research contributes to safety management knowledge by (1) uncovering how risk toleracne together with social cognitive variables (risk perception and perceived safety climate) influence workers' safety behaviours and FLMs' safety management involvement, and (2) revealing the differences of risk behaviour patterns between workers and FLMs.

7.3.2 Practical Implications

From the perspective of practice, the risk tolerance differences between workers and FLMs indicates that the health and safety vision of FLMs, which is often manifested through safety procedures and standards, is not fully shared by the workers working for the same projects. Though the participated construction companies set safety as a high priority, it is found that fully and effectively convey shared safety values to workers is much difficult. The prevailing safety training techniques involve one-way delivery of slideshow presentations with written handouts that often describe common hazards and generic solutions. Such delivery does not facilitate active learning, development of contextual examples, or emotional engagement necessary for adult learners to gain new knowledge (Bhandari and Hallowell, 2017). From this point, an important task is to facilitate workers' risk perception and actively safety management engagement. Based on the quantitative and qualitative analysis results, relevant strategies were proposed: (1) improve communication between workers and supervisors, (2) encourage workers' active involvement in safety management and (3) show solicitude for workers rather than just focusing on safety.

Furthermore, the results of safety climate's moderating effects are inspiring for construction safety management. As noticed, different dimensions of safety climate play different levels of moderating effect, and the importance of these dimensions are even distinct for workers and FLMs. For workers, they tend to be more sensitive to the dimension of communication with supervisors, while FLMs seems to be more sensitive to the dimension of top managers' safety attitude. Thus, construction organizations may need to design and implement taillored safety management strategies for workers and FLMs.

In addition, identification of the risk tolerance influencing factors is of great practical importance as a more effective safety training could be achieved by obtaining these information. For the influencing factors with consistent opinions, current safety training should provide 'reinforcement learning' strategies. For the factors with inconsistent opinions, in the first step, the reason of why some people believe they are important and other people think they are not important should be investigated; then, based on this obtained information, managers may update current training content by providing 'supplementary learning' strategies to minimize the discreteness of people's opinions and strengthen people's understanding of them. Eventually, construction practitioners' awareness of these factors' influences on their risk tolerance would be improved and accordingly more objective and rational risk judgement will be achieved.

7.4 Research Limitation and Recommendation for Future Research

Four potential limitations of this research require attention. Firstly, only three types of common injury risks for analysis were selected. These risks are regarded as the most common safety risks in Australian construction sites according to the report of *Safe Work Australia*. Due to the common nature of these risks, it is argued that they can be used for workers in different trades. However, there are some risks that are specific to different trades, such as non-roadway safety risk for drivers and electric shock risk for electrician. This research can provide only limited in-depth analysis of risk tolerance level on the work trade level. Thus, further research on this topic is necessary because this information can offer valuable insights into safety management.

Secondly, under this study's scope, only the descriptive analysis of the risk tolerance level of different safety risks was conducted, including the changing trend of general risk tolerance with risk level, with the influences of risk frequency and with the severity on risk tolerance assessment. Though some of findings under this topic were mentioned in previous research (e.g. Rodrigues et al.; 2015a), further validation, such as through behaviour observation, statistically test and experiment, is necessary to provide solid evidences for the influences of risk level, frequency and severity on risk tolerance. Moreover, this research was based on cross-sectional data, which prevented making definitive conclusion of risk tolerance level at different safety risks, especially after the conduction of relevant safety training. Thus, future research may explore and trace the changing trend of risk tolerance levels by conducting longitudinal research.

Thirdly, all responses are based on self-report measures. Thus, percetion bias by the subject may affect the accuracy and outcome. Perception bias is a general term that many psychologists and other behavioral experts use to describe a systematic error in how people perceive others or their environment. Individuals, whether we are talking about our neighbors or coworkers, filter or perceive information based on their own past experiences. When an individual constructs their own subjective social reality based on their past perceptions and not on objective input, we classify their behavior as being perception biased. One obvious impact of this limitations is that it may affect the objectiveness of survey response; in another word, some responses may not reflect the true thinking of partisans. This study adopts the following strategies to minimise the potential threats of this limitation to the validity of findings: (1) proactively identifying possible threats of bias and carrying out precautions to mitigate them and (2) setting controllable questions in the questionnaire to ensure the quality of responses. Another limitation lies in the generalisability of the findings. The research is conducted based on the data collected from companies with high safety priority and that target building construction projects in Australia. The measurement scales of risk perception and risk tolerance are also designed based on the safety statistics reported in Australia. These scales were validated with good reliability and validity, but they cannot be used in other areas, especially those that have different safety situations from Australia. Thus, the findings of this study should be interpreted in the context of building constructions with high safety priority in Australia. Extending such findings to other populations, such as small-scale companies that place less emphasis on safety or companies that specialise in other types of projects, may be difficult. The geographical location where the research data are collected arguably has a high safety culture maturity (based on its accident and fatality rates). This research must be conducted by collecting data from the construction industry in other countries, preferably those that have different cultures and low safety culture maturity. This way, the effects of organisational, industrial and national cultures on workers and FLMs' risk tolerance assessment can be investigated in future research.

Fourth, this current research mainly investigated the influences of risk tolerance, risk perception and perceived safety climate on workers and FLMs' unsafe behaviours. But, it is noticed that there are some other important factors can affect individuals' behaviours. Such as the treat-off between risk and reward, situational awareness, normalization of deviance and risk normalization. Thus, it is suggested to consider these factors in future safety research.

- Under the context of safety management, reward mainly refers to the incentive programs, which is a common way to reward employees based on a safety record's lagging indicators. For example, workers will get a reward for working hundred hours without an OSHA recordable injury. But, if they take safety risks and get injured, they couldn't get the reward. So, from this point of view, the reward would encourage workers and managers behave more safety. Thus, it is suggested to examine (1) how the treat-off between risk and reward would influence workers and FLMs' unsafe behaviours and (2) how the tread-off between risk and reward would influence workers and FLMs' risk tolerance and perception in the future research.
- Regarding situational awareness, it means an appropriate awareness of an situation (Smith and Hancock, 1995). It is the perception of environmental elements and events with respect to time or space, the comprehension of their meaning, and the projection of their future status (Endsley, 2016). In construction safety, situational awareness can refers to the awareness of potential risks or hazards that workers faces. Thus, it is important that each worker is looking out for his or her own safety as well as looking out for their workmates. However, even the most experienced workers can lack situational awareness, especially when doing tasks that have become routine. So, how to improve workers and FLMs' safety related situational awareness and based on appropriate risk awareness to make objective risk tolerance assessment is important in the future research.
- Regarding normalization of deviance, it was coined by sociology professor Diane Vaughn in 1997: Deviance refers to behaviour that violates the norms of some group. No behaviour is inherently deviant; rather it becomes so in relation to particular norms (Vaughan, 1997). In social research, normalization of deviance means that people within the organization become so much accustomed to a deviant behaviour that they don't consider it as deviant, despite the fact that they far exceed their own rules for the elementary safety (Pinto, 2014).

In other words, normalization of deviance suggests that the unexpected becomes the expected, which even becomes the accepted. For example, the normalization of deviance is that while a series of behaviours may appear deviant to people outside the organization, for people within the organization, the deviance often goes unrecognized, that is, it is simply assumed to be normal occurrence. Thus, normalization of deviance can be important in construction safety management. The reason is that if workers have no awareness of some deviant safety risks, they may easily take these risks due to they have no awareness of how the potential losses could be. Thus, how to improve workers and FLMs' awareness of the normalization of deviance related safety risks is important in the future research.

- Regarding risk normalization, it can be an example of normalization of deviance. Normalization of deviance, as discussed above, can refer to anything (which in reality is a deviant) that are regarded as a normal thing in an organization. Risk normalization, mainly refers to people are so much accustomed to a deviant risk that they don't consider it as real risk. Thus, it is important in safety management because it indicates a situation, which is that the more workers perform a risky behaviour without suffering a bad outcome, the harder it becomes for workers to remain aware of the risks associated with that risky behaviour. In other words, when workers start a task, at the beginning, he may be aware and cautious of potential risks related to this task, however, as time goes on, no injuries happen, he may become comfortable and with a false sense of security of the dangers associated with his risky behaviours. Thus, how to improve workers and FLMs' awareness of risk normalization and how risk normalization could affect safety are important topics in the future safety research.

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Appendix 1 – Survey Questionnaire

Swinburne University of Technology
Department of Civil and Construction Engineering

Dear participants,

You are invited to participate in a project of '**The effects of risk tolerance and risk perception in construction risk behaviours: frontline workers versus managers**' that is being undertaken as part of the PhD research of Penny Li, supervised by Professor Patrick Zou and Associate Professor Palaneeswaran Ekambaram in the Faculty of Science, Engineering and Technology (FSET) of Swinburne University of Technology.

The purpose of this study is to investigate how to improve construction safety by considering the influences of risk tolerance and risk perception on managers and workers' risk behaviors. This research can help decision-makers in construction project to make more informed decisions. The survey results will be of interest to both academia and practitioners in construction management.

The survey questionnaire contains **three parts** and will take approximately 20 minutes to answer. In the first part, there are some background information will be asked, please feel free to answer based on your true situation.

The responses provided will be **kept confidential** and will be used for academic research purposes only. Individual responses **will not be released or shared.** The archived data can be accessed only by the principal investigator and student investigator. Information provided will be stored electronically on a password protected computer and server in Swinburne University of Technology and will be accessible to the researchers only. Results from the collective analysis of responses will be published in a publicly available PhD thesis and may be published in journal articles and conference papers.

If you would like further information about the project and need explanation of the items of questionnaire, please do not hesitate to contact:

Student Investigator : Penny Li

Swinburne Contact Address : Faculty of Science, Engineering and Technology,
Swinburne University of Technology, PO Box 218
Hawthorn, Victoria 3122 Australia

(Swinburne) Tel No (s) : +61 0 414998895

(Swinburne) Email (s) : pengpengli@swin.edu

(For construction workers)

Part A. General Information

1. Personal details. Please a tick √ on the □ which can best indicate your background.

Gender	□ Female	□ Male		
Age	□ 18-24	□ 25-29	□ 30-34	□ 35-39
	□ 40-44	□ 45-49	□ 50-54	□ more than 55
Highest Education	□ High school	□ Diploma	□ Vocational education and training	□ Bachelor's degree
	□ Master's degree	□ Doctoral' degree	□ other_______________	
Trades	□ Boilermaker	□ Carpenter	□ Capet layer	□ Dredger
	□ Electrician	□ Linemen	□ Elevator mechanic	□ Fencer
	□ Glazier	□ Heavy equipment operator	□ Insulation	□ Ironworker
	□ Landscaper	□ Plumber	□ Roofer	□ Plasterer
	□ Truck driver	□ Pipefitter	□ Mason	□ Other_____
Work experience	□ less than 3 years	□ 3-7 years	□ 8-12years	□ 13-17 years
	□ 18-22years	□ 23-25years	□ more than 25 years	
Annual income	□ less than A$ 50,000	□ A$ 50,000-80,000	□ A$80,001-100,000	□ more than A$100,000
Have you ever sustained injuries resulting from construction work?			□Yes	□No
Have you ever witnessed others' injuries that resulted from construction work?			□ Yes	□ No

Part B. Factors influencing safety risk tolerance. When you think about risk tolerance, what kind of influences of below factors will have on your risk tolerance assessment? Please a tick √ on the number that best represents your assessment.

Factors	**The smallest influence**	**Slight influence**	**Moderate influence**	**Bing influence**	**The largest influence**	**Factors**	**The smallest influence**	**Slight influence**	**Moderate influence**	**Big influence**	**The largest influence**
Work experiences	1	2	3	4	5	Little time for assess confronting risks	1	2	3	4	5
Work ability	1	2	3	4	5	Production stress	1	2	3	4	5
Safety knowledge	1	2	3	4	5	Completeness of relevant project information	1	2	3	4	5
Risk management knowledge	1	2	3	4	5	Supervision from top level mangers	1	2	3	4	5
Familiarity with the task	1	2	3	4	5	Communication with supervisors	1	2	3	4	5
Belief in good luck	1	2	3	4	5	Potential gain or profit from action	1	2	3	4	5
Emphasis on safety	1	2	3	4	5	Role models accepting risk	1	2	3	4	5

Insurance cover	1	2	3	4	5	Voluntary action	1	2	3	4	5
Behaviours' of peers	1	2	3	4	5	Employers' reputation	1	2	3	4	5
Safety attitude of managers	1	2	3	4	5	Control of the risk	1	2	3	4	5
Emotion	1	2	3	4	5	Confidence in protection and rescue	1	2	3	4	5
Personal reputation	1	2	3	4	5	Confidence in equipment	1	2	3	4	5
Family responsibility	1	2	3	4	5	Visibility of project	1	2	3	4	5
Personal financial situation	1	2	3	4	5	Company's financial situation	1	2	3	4	5
OHS regulations	1	2	3	4	5	Regulators' safety attitude	1	2	3	4	5

Part C Your opinion

1. Risk perception. For the scenarios below, please indicate how risky do you think? Please a tick √ on the number that best represents your assessment.
For example, if you are working in a company with 1000 workers, and each year there are 9 workers suffering a lower back injury, which make them cannot work for 1 day. In this case, if you believe this situation is risky, please tick√on 2.

Items	Not risky at all	Not risky	Slightly not risky	Slightly risky	Risky	Very risky
In 100 workers, each year there are 14 worker suffering lower back injury due to fall from a 2-meter high ladder, which need 0.5 day time off.	1	2	3	4	5	6
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.	1	2	3	4	5	6
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.	1	2	3	4	5	6
In 100 workers, each year there are 14 worker suffering wrist injury due to disconnect power tools when the tool is not in use, which need 0.5 day time off.	1	2	3	4	5	6
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.	1	2	3	4	5	6
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.	1	2	3	4	5	6
In 100 workers, each year there are 8 worker suffering a leg injury due to slip on sites, which need 1 day time off.	1	2	3	4	5	6
In 100 workers, each year there are 1 worker suffering a leg injury due to slip on sites, which need 1 week time off.	1	2	3	4	5	6
In 100 workers, each year there are 10 worker suffering a leg injury due to slip on sites, which need 1 week time off.	1	2	3	4	5	6

In 100 workers, each year there are 5 workers suffering a mental stress, as a result of injury, which need 18 weeks off.	1	2	3	4	5	6
In one million workers, 8 of them dead per year.	1	2	3	4	5	6
In one million workers, 30 of them dead per year.	1	2	3	4	5	6

2. Risk tolerance: Please indicate the **extent of your tolerance** of the situations below. And image you are in below situation.
For example, if you are working in a company with 1000 workers, in every year there are 9 workers suffering a lower back injury, which make them cannot work for 1 day. In this case, if you believe this situation can be tolerated, please tick √on 5.

Items	Definitely intolerable	Intolerabl e	Slightly intolerable	Slightly tolerable	Tolerable	Definitely tolerable
In 100 workers, each year there are 14 worker suffering lower back injury due to fall from a 2-meter high ladder, which need 0.5 day time off.	1	2	3	4	5	6
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.	1	2	3	4	5	6
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.	1	2	3	4	5	6
In 100 workers, each year there are 14 worker suffering wrist injury due to disconnect power tools when the tool is not in use, which need 0.5 day time off.	1	2	3	4	5	6
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.	1	2	3	4	5	6
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.	1	2	3	4	5	6
In 100 workers, each year there are 8 worker suffering a leg injury due to slip on sites, which need 1 day time off.	1	2	3	4	5	6
In 100 workers, each year there are 1 worker suffering a leg injury due to slip on sites, which need 1 week time off.	1	2	3	4	5	6
In 100 workers, each year there are 10 worker suffering a leg injury due to slip on sites, which need 1 week time off.	1	2	3	4	5	6
In 100 workers, each year there are 5 workers suffering a mental stress, as a result of injury, which need 18 weeks off.	1	2	3	4	5	6
In one million workers, 8 of them dead per year.	1	2	3	4	5	6
In one million workers, 30 of them dead per year.	1	2	3	4	5	6

3. Safety behaviours: This section will ask general questions about your behaviour. Create a clear picture in your mind of how you are in different situations. There is no right or wrong answer. Please a tick √ on the number that best represents your assessment.

Items	Never	Rarely	Sometime s	Often	Frequently	Always
I follow all of the safety procedures for the jobs that I perform.	1	2	3	4	5	6

My co-workers follow all of the safety procedures for the jobs that they perform.	1	2	3	4	5	6
I take chances to get the job done.	1	2	3	4	5	6
My co-workers take shortcuts that involve little or no risk.	1	2	3	4	5	6

4. General questions: This section will ask general questions about your experiences. In responding to each question, please try to follow the instructions below:
- Create a clear picture in your mind of how you are in different situations. There is no right or wrong answer. Please answer honestly to what extent do you agree below statement.
Please a tick √ on the number that best represents your assessment.

Perceived Safety Climate	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The top management always referring to safety when talking about company, especially to the public	1	2	3	4	5	6
The top management takes safety into account when planning work procedures	1	2	3	4	5	6
The top management frequently checks to see if we are all obeying the safety rules	1	2	3	4	5	6
The top management endeavor to improve safety performance of all projects in company						
My supervisor uses explanations (not just compliance) to get us to act safely	1	2	3	4	5	6
My supervisor emphasizes safety procedures when we are working under pressure	1	2	3	4	5	6
My supervisor refuses to ignore safety rules when work falls behind schedule	1	2	3	4	5	6
My supervisors is strict about working safely when we are tired or stressed	1	2	3	4	5	6
My supervisor reminds workers who need reminders to work safely.	1	2	3	4	5	6
My supervisor makes sure we follow all the safety rules (not just the most important ones).	1	2	3	4	5	6
My supervisor is strict about safety at the end of the shift, when we want to go home	1	2	3	4	5	6
I feel comfortable discussing safety issues with my supervisor.	1	2	3	4	5	6
I try to avoid talking about safety issues with my supervisor.	1	2	3	4	5	6
I feel that my supervisor encourages open communication about safety.	1	2	3	4	5	6
I sometimes follow my co-workers' risky behaviour.	1	2	3	4	5	6
My co-workers' behaviour could sometimes influence my decisions.	1	2	3	4	5	6
As a group, we (my workmates and I) often remind each other of how to work safely	1	2	3	4	5	6
If I were injured at work, I would not be worried about medical costs, because the insurance I get through my employer would cover them.	1	2	3	4	5	6

If I were injured at work and needed three weeks off, the weekly payment I would receive during time off would cover my basic living expenses.	1	2	3	4	5	6
If I were injured at work, my employers would do what they could to support me.	1	2	3	4	5	6
If I were injured at work, my employer would provide enough information about my rights and responsibilities.	1	2	3	4	5	6
My employer would treat me fairly during the claim process.	1	2	3	4	5	6
My employer would treat me fairly after the claim process.	1	2	3	4	5	6
We have sufficient first-aid materials at our site.	1	2	3	4	5	6
I am happy with my current income from construction work.	1	2	3	4	5	6
I feel my job is secure	1	2	3	4	5	6

(For construction first-line management)

Part A. General Information

1. Personal details. Please a tick √ on the □ which can best indicate your background.

Gender	□ Female	□ Male		
Age	□ 18-24	□ 25-29	□ 30-34	□ 35-39
	□ 40-44	□ 45-49	□ 50-54	□ ≥ 55
Highest level of education	□ High school	□ Diploma	□ Vocational education and training	□ Bachelor's degree
	□ Master's degree	□ Doctoral degree		
Current position	□ Construction manager	□ Project manager	□ Site manager	□ Engineer
	□ Safety manager	□ Safety supervisor	□ Crew leaders	□ Foremen
	□ other________________			
Working experience	□ less than 3 years	□ 4-7 years	□ 8-12years	□ 13-17 years
	□ 18-22years	□ 23-25years	□ more than 25 years	
Annual income	□ less than A$ 80,000	□ A$ 80,000-120,000	□ A$120,001-160,000	□ more than A$160,000
Have you ever been injured as a result of construction work?			□ Yes	□ No
Have you ever witnessed injuries resulting from construction work?			□ Yes	□ No

Part B. Factors influencing safety risk tolerance. When you think about risk tolerance, what kind of influences of below factors will have on your risk tolerance assessment? Please a tick √ on the number that best represents your assessment.

Factors	**The smallest influence**	**Slight influence**	**Moderate influence**	**Bing influence**	**The largest influence**	**Factors**	**The smallest influence**	**Slight influence**	**Moderate influence**	**Big influence**	**The largest influence**
Work experiences	1	2	3	4	5	Little time for assess confronting risks	1	2	3	4	5
Work ability	1	2	3	4	5	Production stress	1	2	3	4	5

Safety knowledge	1	2	3	4	5	Completeness of relevant project information	1	2	3	4	5
Risk management knowledge	1	2	3	4	5	Supervision from top level mangers	1	2	3	4	5
Familiarity with the task	1	2	3	4	5	Communication with supervisors	1	2	3	4	5
Belief in good luck	1	2	3	4	5	Potential gain or profit from action	1	2	3	4	5
Emphasis on safety	1	2	3	4	5	Role models accepting risk	1	2	3	4	5
Insurance cover	1	2	3	4	5	Voluntary action	1	2	3	4	5
Behaviours' of peers	1	2	3	4	5	Employers' reputation	1	2	3	4	5
Safety attitude of managers	1	2	3	4	5	Control of the risk	1	2	3	4	5
Emotion	1	2	3	4	5	Confidence in protection and rescue	1	2	3	4	5
Personal reputation	1	2	3	4	5	Confidence in equipment	1	2	3	4	5
Family responsibility	1	2	3	4	5	Visibility of project	1	2	3	4	5
Personal financial situation	1	2	3	4	5	Company's financial situation	1	2	3	4	5
OHS regulations	1	2	3	4	5	Regulators' safety attitude	1	2	3	4	5

Part C Your opinion

1. Risk perception. For the scenarios below, please indicate how risky do you think? Please a tick √ on the number that best represents your assessment.
For example, if you are working in a company with 1000 workers, and each year there are 9 workers suffering a lower back injury, which make them cannot work for 1 day. In this case, if you believe this situation is risky, please tick √ on 2.

Items	Not risky at all	Not risky	Slightly not risky	Slightly risky	Risky	Very risky
In 100 workers, each year there are 14 worker suffering lower back injury due to fall from a 2-meter high ladder, which need 0.5 day time off.	1	2	3	4	5	6
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.	1	2	3	4	5	6
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.	1	2	3	4	5	6

In 100 workers, each year there are 14 worker suffering wrist injury due to disconnect power tools when the tool is not in use, which need 0.5 day time off.	1	2	3	4	5	6
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.	1	2	3	4	5	6
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.	1	2	3	4	5	6
In 100 workers, each year there are 8 worker suffering a leg injury due to slip on sites, which need 1 day time off.	1	2	3	4	5	6
In 100 workers, each year there are 1 worker suffering a leg injury due to slip on sites, which need 1 week time off.	1	2	3	4	5	6
In 100 workers, each year there are 10 worker suffering a leg injury due to slip on sites, which need 1 week time off.	1	2	3	4	5	6
In 100 workers, each year there are 5 workers suffering a mental stress, as a result of injury, which need 18 weeks off.	1	2	3	4	5	6
In one million workers, 8 of them dead per year.	1	2	3	4	5	6
In one million workers, 30 of them dead per year.	1	2	3	4	5	6

2. Risk tolerance: Please indicate the **extent of your tolerance** of the situations below. And image you are in below situation.
For example, if you are working in a company with 1000 workers, in every year there are 9 workers suffering a lower back injury, which make them cannot work for 1 day. In this case, if you believe this situation can be tolerated, please tick √on 5.

Items	Definitely intolerable	Intolerabl e	Slightly intolerable	Slightly tolerable	Tolerable	Definitely tolerable
In 100 workers, each year there are 14 worker suffering lower back injury due to fall from a 2-meter high ladder, which need 0.5 day time off.	1	2	3	4	5	6
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.	1	2	3	4	5	6
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.	1	2	3	4	5	6
In 100 workers, each year there are 14 worker suffering wrist injury due to disconnect power tools when the tool is not in use, which need 0.5 day time off.	1	2	3	4	5	6
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.	1	2	3	4	5	6
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.	1	2	3	4	5	6
In 100 workers, each year there are 8 worker suffering a leg injury due to slip on sites, which need 1 day time off.	1	2	3	4	5	6
In 100 workers, each year there are 1 worker suffering a leg injury due to slip on sites, which need 1 week time off.	1	2	3	4	5	6
In 100 workers, each year there are 10 worker suffering a leg injury due to slip on sites, which need 1 week time off.	1	2	3	4	5	6

In 100 workers, each year there are 5 workers suffering a mental stress, as a result of injury, which need 18 weeks off.	1	2	3	4	5	6
In one million workers, 8 of them dead per year.	1	2	3	4	5	6
In one million workers, 30 of them dead per year.	1	2	3	4	5	6

3. Safety management involvement: This section will ask general questions about your safety management effort. Create a clear picture in your mind of how you are in different situations. There is no right or wrong answer. Please a tick √ on the number that best represents your assessment.

Items	Never	Rarely	Sometimes	Often	Frequently	Always
Being involved in accident analysis	1	2	3	4	5	6
Participating in prevention plans with contractors	1	2	3	4	5	6
Discussing of how to improve safety with workers	1	2	3	4	5	6
Reluctantly interpreting safety issues and problems occurring on the site	1	2	3	4	5	6
Not spending time helping workers learn to see problems before they arise	1	2	3	4	5	6
Checking workers wearing protective equipment even if it is uncomfortable	1	2	3	4	5	6

4. General questions: This section will ask general questions about your experiences. In responding to each question, please try to follow the instructions below:

- Create a clear picture in your mind of how you are in different situations. There is no right or wrong answer. Please answer honestly to what extent do you agree below statement.

Please a tick √ on the number that best represents your assessment.

Perceived Safety Climate	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The top management always referring to safety when talking about company, especially to the public	1	2	3	4	5	6
The top management takes safety into account when planning work procedures	1	2	3	4	5	6
The top management frequently checks to see if we are all obeying the safety rules	1	2	3	4	5	6
The top management endeavor to improve safety performance of all projects in company						
My supervisor uses explanations (not just compliance) to get us to act safely	1	2	3	4	5	6
My supervisor emphasizes safety procedures when we are working under pressure	1	2	3	4	5	6
My supervisor refuses to ignore safety rules when work falls behind schedule	1	2	3	4	5	6
My supervisors is strict about working safely when we are tired or stressed	1	2	3	4	5	6
My supervisor makes sure we follow all the safety rules (not just the most important ones).	1	2	3	4	5	6

My supervisor is strict about safety at the end of the shift, when we want to go home	1	2	3	4	5	6
I feel comfortable discussing safety issues with workers.	1	2	3	4	5	6
I try to avoid talking about safety issues with workers.	1	2	3	4	5	6
I encourages workers to communicate about safety issues.	1	2	3	4	5	6
I sometimes follow my co-workers' risky behaviour.	1	2	3	4	5	6
My co-workers' behaviour could sometimes influence my decisions.	1	2	3	4	5	6
As a group, we (my workmates and I) often remind each other of how to work safely	1	2	3	4	5	6
If I were injured at work, I would not be worried about medical costs, because the insurance I get through my employer would cover them.	1	2	3	4	5	6
If I were injured at work and needed three weeks off, the weekly payment I would receive during time off would cover my basic living expenses.	1	2	3	4	5	6
If I were injured at work, my employers would do what they could to support me.	1	2	3	4	5	6
If I were injured at work, my employer would provide enough information about my rights and responsibilities.	1	2	3	4	5	6
My employer would treat me fairly during the claim process.	1	2	3	4	5	6
My employer would treat me fairly after the claim process.	1	2	3	4	5	6
We have sufficient first-aid materials at our site.	1	2	3	4	5	6
I am happy with my current income from construction work.	1	2	3	4	5	6
I feel my job is secure	1	2	3	4	5	6

Appendix 2 – Interview Questions and Transcripts

1 Peng: In your opinion, what is risk tolerance? Especially tolerance of construction safety risks?

1a. Occupational Health and Safety Manager, 15 years of experience

Risk tolerance like what we accept, that sort of thing. We have across of companies we have retrofitting, which is a percentage of a figure which is how many loss time injuries, some of the injury has to take into work, per how many main hours we perform as business. So that's one source of piece of data we compare across different years. But in regards to the rest of them, so like first-day injuries that's sort of thing, we don't really have a figure that we really accept, but we do try and maintain the same or less from the year before. We have safety meeting and we compare the data of last five years and we notice this year in somewhere it is double than last year because we have done 2 million as extra. So we do compare it as the year before. But is serves as HSE plan, which in each project task, we still emphasize 0 as everything. So, there is no one really accept.

1b. Project Manager, 14 years of experience

In my opinion, I think if one person shows higher risk tolerance, which means he or she believe can acceptance more risks, losses, it is possible, I mean it is reasonable that this person may have higher possibility to take some risks, say behave unsafely.

1c. Construction Manager, 34 years of experience

Well, it is hard to explain, it is a very, very subjective concept. In project management practice, we seldom really talk about it. But, you know, it is a very important thing. For individuals, they have their own tolerance level. However, you know, this is different from the company. Company usually has their own tolerance level. For different injury type, like minor injury, permanent disability, even death. Company has some inner criteria for acceptance.

1d. Site Manager, 6 years of experience

It’s quite subjective and intuitive. In my understanding, risk tolerance, like a capability, a kind of awareness. Theoretically, if workers believe he can do lots of dangerous work, he may be the dangerous person on site. In fact, it is. Yes, absolutely.

1e. Construction Manager, 12 years of experience

Risk tolerance, it depends, depends what standard and what situations. Safety is general, you have to specify. Let’s say working in height, working in the hot, working in a confined place, they will have different tolerance. So, if you can give me a context of what you mean or you want me give you some examples.

(OK, maybe you can start by telling some examples?) So from operating prospective safety always have KPI. So for our company the KPI is fatalities, major injury or the minor injury. So fatality is less or equal to 0, which means you cannot have people die. Now, the major injures that is equal to 1, about 5 years ago, it was less than 3. So, by driven of the government and also the union the safety become more prioritize. That’s why becomes one. So how to categorize and define regarding to major injury you can look at the working safety act so that this can be categorized based on people's permanent injury, cannot recovery and the dollar values, reimbursement like that.

1g. Well-being, Health and Safety specialist, 15 years of experience

I think it really depends on what city, which company and which industry you work. Sometimes it can also depends on the company culture, say, if it really focus on the money, you know sometimes the priority of safety and money are blurred. It’s like different company have different criteria for the injury number. For example, for some big company, if every time the injury occurs, there are costs related to that, right? So, the costs will be the management of the person’s surgery, doctors, all of the things related to. Also, you need to pay someone else if the injured worker cannot come to work. So, you see, companies have to tolerate certain costs if injury happen. And a lot of companies will do their best to control this cost to avoid the injury occurrence.

(Ok, I think you just explained risk tolerance from the company, management perspective, but, for workers, what is risk tolerance for them?) Well, for workers, it is very hard to tell. For them, you know, if they are working in the platform in the ocean, so, obviously, the risk would be very high, you can image the thing such as gas explosion, so, the workers must understand their work, the potential losses and follow safety rules to perform their job. Say they have to make sure do make the protocol in a right way. And they also need to think what might if I do something wrong?

1h. Occupational Health and Safety Manager, 19 years of experience

Well, interesting topic. I have never really think about it. But it is, based on my personal known, should be a quit important thing. Er, it is difficult to say, it's like a subjective thing.

2 Peng: Based on our research, construction workers and first-line management have significant difference of risk tolerance, what do you think of this result?

2a. Occupational Health and Safety Manager, 15 years of experience

It is reasonable, but a little weird. Because the workers, they don't accept any first-aid injury that sort of something,

2b. Project Manager, 14 years of experience

I think this result is reasonable.

2c. Construction Manager, 34 years of experience

Right, they are truly different world.

2e. Construction Manager, 12 years of experience

I think it is right, reasonable at least from my personal opinion.

2f. Occupational Health and Safety Manager, 13 years of experience

I am not surprised with this result.

2g. Well-being, Health and Safety specialist, 15 years of experience

I think so.

2h. Occupational Health and Safety Manager, 19 years of experience

It's quite reasonable. It is true.

2i. Occupational Health and Safety Manager, 12 years of experience

It's not surprised, I think.

2j. Site Manager, 16 years of experience

You know, I am not surprised with it.

3 Peng: Could you explain why workers have such higher risk tolerance and why first-line management have such lower risk tolerance?

3a. Occupational Health and Safety Manager, 15 years of experience

Because the workers, they don't accept any first-aid injury that sort of something, but, so, I think they looked at it, so workers will look at if they do get injured if it due to they done something wrong. But we looked at is if they get injured, is it the process wrong? So, I think they have better understanding of things of accidental. So, if you have five incidents on site, workers they can see out of the five incidents, they see four incidents. That's what they think: I tripped over or I fallen over. Whereas as management, if there are five incidents on site, we would think it is much significant, because the process is wrong, so he shouldn't be tripped over because there was no enough lighting in that area or he was carrying items, so we think like as more significant issue. So we think as it is like a big process wrong and they need to be better managed. But for workers, they see they are just accidents. Such as maybe they carry to much materials, they are rushing, they carrying things too heavy, and so on. So, we see it as a big issue. For workers, in the end of the whole thing, they don't really, they may get injured and have no time for work. What they need to do is just report to their bosses. But for us, for example, say someone has a fallen on site and in two-years' time, they contacted with the lawyer, legal services and Worksafe, and then they come on site and still do the investigation for the fall. Yes, for management, it is a potential big issues, that's why we cannot acceptant that even some small, very small things happen on site, if a worker injured his knee, and the injury is still, he cannot work, they always come back, come back to the company, there is a big insurance department have to pay of that unless he was doing the wrong thing.

3b. Project Manager, 14 years of experience

I think this result is reasonable. Firstly, the mangers, they don't want the workers to take any risks. But in really, you know the project developers will give some pressure to the contractors, such as project progress, then, the site manager or project manager will give pressure to the builders. In essence, the people who in the end tolerate these pressure, are workers working on site. So, you know, the supervisor cannot be on the site all the time. If in some cases, such as workers need to use some electric equipment, such electric lift to work in the height, and at the same time, the workers really want to finish this job soon as they may think, if my completion delays, my boss will complain me again about slow down the project progress, etc. so, the worker will continue this job. So, you can think one of the reason of why workers' risk tolerance is high is because they have some pressure from project management, project progress.

Another reason of why workers have high risk tolerance is because their own experiences. For example, if a worker successfully finished some dangerous tasks in his previous work. He might be more confident and lower down their tolerance of it.

So, for the management personal, their risk tolerance is low is also related to their work experience. A good example could be you know, the mangers, they manage the construction project, which means they don't need to do the real job by themselves. So, they just have some ideas of, like, oh, that job is dangerous. But for the workers, they always do the same, or similar job, so for them, they may think it is not a big deal for me, so their risk tolerance may be high, and the managers' risk tolerance may be lower.

3c. Construction Manager, 34 years of experience

They mainly concerned around 'budget'. It not always mainly but they are conscious about budget. Because everything is operated within a budget and the PPE which is the personal protective equipment, alright. And you have the labour or the employee. They are aware of safety even if there is a given PPE, some of them, you probably already have seen it in the responses, right. So, let me just explain the generalities phrases, look, so the management just group them as one, OK? so everything operates under budget, they are aware of the law, the permits, otherwise they will not be given the permit to operate. While they are aware of the law, the mindset is bare minimum compliance. There are very exceptional few, there are very exceptional few, yeah.

And then you look at the workers, they will be trained under law because that's part of compliant management. You know I SO 3000, it's part of that. So, every employee is trained, almost always by joining and they will be retrained periodically by the compliance. But, it just, you give them helmet, you give them everything, and you will find tons of excuses. So, two things I'm looking at this be there been team been in the management team at began you on the other side moved to the other side. I saw everything, in our managed appliances as well. So, back to your main objective is obviously see the two groups, so if you try to separate the sides, this side is easier to explain, they follow the rules, the regulate, the bare minimum compliance. Therefore they can operate in because they are meeting the requirements. And here's the other, the other, specifically the young one. Because this side got several layers as well, senior ones have families, children, have a different mindset. If, I don't if you have graphs, you will you will really see the younger ones have higher risk tolerance, if near misses, normally the younger ones. I have seen enough. The senior ones have families, like kids and wife. They should go home and always be careful. (Does it mean they always have family responsibility keep in mind?) Yes, that it is, so they cares. So, they look at PPE as necessary, and some of them are overconfident, it's just crazy. So, To breach the mindset, that's number one.

Secondly, in my consultancy I seen this as well and this is not my direct not my direct employment. So, second is probably how management implement the rules. Because I've seen organizations are really determined, they really put emphasis on safety. I can give you where I am now, you know where I am now. We give very high emphasis on safety, so all our procedures have safety requirement, okay, that's tops, that's number one. The nexus of course is for producing food-based product, so safety is the next. Third is productivity, human safety is always the top priority.

3d. Site Manager, 6 years of experience

Yes, because sometimes the people believe it's OK, it's all right. It doesn't matter. For example, if everyone knows there is a risk of something may fall on a wall, everyone will try to do not stand under the wall, but for him, he may think it may not fall, it's all right. Also, if there is wooden support, which is something very dangerous and not stable. He may think it's OK; I have good balance I will be fine. You know, specifically for those young and un-experienced workers, they just graduated or didn't go to college. They tend to be over-confident. They have no awareness of what is dangerous and not dangerous, what they can do and cannot do.

Their parents, I guess the high-tolerance, I mean the culture here could be another reason. I talked to the young workers and said: it's dangerous, you cannot stand on it. And he said: my father told me you need to explore the new thing. Which means their parents do not tend to tell what is dangerous and what is not dangerous, they always encourage. You know, this encouragement always can be a trigger for risky behaviours. That is to say people like to challenge something they believe dangerous, exciting.

Also, low awareness of the severity of consequence. That is they know it is dangerous but, not a very dangerous one. You know, for workers it is hard to say this risk is big, that risk is small. For them, only accident happen, no matter for what risks. Once an accident happens, they will think this risk is very serious.

[but, if workers have good safety knowledge, we can be sure that they will not take a risk?] This situation does happen. Sometimes workers take risks, are not because they are lack of knowledge, they have lower safety awareness. Sometimes because of their personality, as we talked before.

Another reason why workers' risk tolerance is high I think is decided by the construction work nature. For example, there is a risk if people go through a door-opening, but for work convenience, many workers still try to walk through it rather detour. Sometimes for work efficiency, it saves time if I walk through there, right?

3e. Construction Manager, 12 years of experience

Can I understand the question like the subjective risk tolerance or threshold of the labour you think is much higher than the manager? (yes). All right, cool.

Risk perceptions of the labour and managers may looking differently. (what do you mean looking differently) 20 different of the labours. Ok, let's put it in this way. People has to perform the job, right? So, he is thinking directly just from his perspective, and the manager will be thinking from management perspective, right.

So, the first reason why make a labour or the operators in more confident regarding the operating things. Workers thinking less than managers. So, for example, electrician fix machine. He do the isolation and check the machine. A manager may thinking from many ways. Say how safety in new-down ergonomically, is it will be injury a back or neck? Is there any other possible parameter will jeopardizes his works, and mechanical and other things. But electrician only focus on electricity, they don't care mechanical, they don’t care about other things. This the example why people perform the job they have a less risk threshold than the managers.

Secondly, the people perform the job, he knows what he is doing, he will be more confident, especially for experienced people, right? He can understand what he is going to do. And a manager doesn't. Example can be a technician fixes the aircraft. He is going to do the engines analysis, and for manager, probably he doesn’t know what the technician is doing. And he think the technician should be more careful, follow the rule. But the technician is just do it, because he is knowing what is he is going to do.

3g. Well-being, Health and Safety specialist, 15 years of experience

For managers, you know, it is decided by their job. Their job is to reduce injury and keep things safe, stop injuries from occurring. so, their tolerance cannot be very high! I think if they want to make money, especially for the extra money, they have to do certain things in certain different ways. Another reason is that you know if sometimes workers doing something wrong, such as injured their back a little bit. But the point is that they cannot feel the injury immediately, it might be realized two month later, so, if workers cannot see the potential losses, their tolerance cannot be much lower. Also, workers will say: ok, I have done this before and it is OK, So, I will do the job as exactly what I do in the same way. This situation usually happen even workers have relevant safety knowledge, they have finished some safety training, etc. one example is that manual handling, if they carry something in a certain, not right way, in a year, eventually they found the guy’s back is damaged.

Also, for managers, because the management guy not only manage safety, they also need to look after production. But you know, sometimes these two aims would be quite conflicted.

3h. Occupational Health and Safety Manager, 19 years of experience

You know, injuries, in construction site, never stop. I have been working in this field for almost 20 years. I have seen too much accidents, people get hurt. Construction workers, especially for the young ones, who just fresh to the site. They think they can do everything. But you know, this situation, sometimes will going worse if workers getting more experience. The fact is that, you know, after all, injury not always happen. So, if workers have enough experience, like 10 year-experience without any injury happen. Then, you know, they know how to perform the tasks, they know where is the potential risks. I am trying to say that they are familiar with what they are doing. So, their risk tolerance would be high because these confidence in their job.

But for management people. You know, they are different from workers. They do not have to do the real job. Their point of their job is management, manage site risk, site safety, project progress, stakeholders, etc. that is to say, you know, responsibility or liability. Ensuring no injury happen is one of their job liability. So, their tolerance cannot be high.

3i. Occupational Health and Safety Manager, 12 years of experience

This problem can be explained by the work nature of workers and management people. You know, in real construction site. En, let's explain in this way. OK, if you are a worker working in a construction site, what is your job? [doing construction, such as painting]. Right! But if you are a manager, what is your job? [mange everything on site, for example, the safety?] That's right! So, you see, management, their job is about management, reduce the possibility of irks happening. To do so, managers care all little things, even small thing for work, I mean if the thing, for example, no enough light at night when doing construction, maybe workers will never really cares about this. But management, because of their job, they care all this kinds of little thing on site. So, you can see, their risk tolerance should be much lower.

3j. Site Manager, 16 years of experience

Well, let me think. Ok, maybe I can start by explain management people as it is quite straightforward. Management people are doing management work. You know, they have to make sure everything on site is OK, everyone on site should be safe. So, this kinds of their work nature, or liability, decide they cannot have high tolerance of safety risks. But, the thing for workers are a little bit different. Workers, are the real one doing this job, they know everything about their job, such how to do it, how to work with others, how to protect them from potential risks. So, you know, they are confident, you know, this confidence come from their experience. Another reason should be that, you know, for workers, especially those in sub-contractors. Their pay is highly related to the amount of work they have done. I do not want to say this, but you know, it is real. So, maybe workers, need to take some risks if they want to earn more.

4 Peng: Since this difference of risk tolerance exists, what will be affected in practical safety management?

4a. Occupational Health and Safety Manager, 15 years of experience

If they are willing to accept more injures they more likely to be injured, so the safety, like supervision, will be difficult to be managed. Say, if they more likely to be injured, they would not be compliant with the rules.

4b. Project Manager, 14 years of experience

I think it will have, you know, in every project, almost every project, when a new sub-contract enters the project, there is a safety induction, including emergence call, safety requirement, and sort of things. After this induction, the management staff may think, ok, I told everything import of safety to them, they should be OK to do the job. However, if the new workers have high risk tolerance which the management personal haven't realize, it going to have problems, issues.

4e. Construction Manager, 12 years of experience

OK, you mean the disagreement of risk tolerance among harbors and mangers. In construction base, or in operation base, there always have frequent review procedure for how to manage particular items scenario as always. so as the safety managers is responsible to have weekly meetings for all the group members. (you mean with all workers?) No, no. Give you example right? In factories, what happens before, is that say there have 500 people if you have 300 personalities manufacture labours you can categorize what risks you have, you need to have a manual handling risk, and you have risk related to confined space so maybe five or six different subject items. Each one you have we recalled that a leader in charge that people most experience about that area. I have full license or fully trained. So for each top at least you need to have a weekly review to find out how are we going, last week do we have any kinds of risk, such as confident space, any hazards, any incident and any injury and fatality. You have to review and then you can review the process. Ok, the process at the moment is may be Jaak come here to fill the permit and get Jason to sign them off and then he needs to body up with James to do job and come back Sunny. Is that the process too tedious or is it necessary? do we have to shorten it or we don't have to. There is always a way like a forum to discuss, it's not like a conference but a meeting review and the members have authority to vote to make decision. Right? What have been made must be followed. If you're not happy, if you see that really sort of things, you can report to authorities or union. Normally the managers will do the right things.

So, in the majority case, yes, it will be yes. Yes, the meeting is the avenue to sort that issues, and the meeting is a requirement by the OHS.

4g. Well-being, Health and Safety specialist, 15 years of experience

The thing is that most of companies try to do the right thing, the tried hard to make everything ok and safe. You know, they have done a number of what they can of safety, but you still see the difference. So, all of the thing the effect could be the decision-making. Let me say for workers, you provide them a lot things required by safety, but you still cannot manage them all very well, especially for workers because of their high risk tolerance is hard to observe and control, you can no stop them making fault decisions. Because they usually do not really calculate the safety risks. Also, if the production is run behind, and in the morning meeting the supervisor say we already behind, we behind this that and that, so, they didn't say you going to take risks to get these things done. But, they say we need to get them done in a certain of time. So, the workers might think I need to work faster and quicker. But workers faster always means there are some risks. Don't you see it usually happen? So, it's like we going to be safe, we need to be say. But, the production is balabala… we must done it today, if we don't done it today, we will run really behind of … this can make workers really confused about the really priorities.

5Peng:based on our study, we find construction workers show different risk thinking when considering the common and non-serious injury risks and risks with severe consequence, such as death, what do you think of this?

5a. Occupational Health and Safety Manager, 15 years of experience

It sounds interesting, but I am not qutie sure.

5e. Construction Manager, 12 years of experience

Well, eh, it is not that clear, it is hard to notice.

5(sub-question) Peng: when workers are facing a risk that will threathen their life, how do you think the influence of ther risk tolerance under this situation?

5a. Occupational Health and Safety Manager, 15 years of experience

Well, you see, I think not only worker, any people, you know, they will not continute of the risky things if it really have a risk of lossing life.

5h. Occupational Health and Safety Manager, 19 years of experience

If in this case, risk tolerance may not work, I mean worker may may not consider it. For example, you know, when you are observing cosntruction workers' beahivours on site, usually unsafety behaivours happen on some very common situaions, such as carry too mnay objects, woking on a ladder with no safety helmet if the ladder is not that high, etc. However, if they are working on a 30-meters high crane, no one will take a risk. Why is that? Because you know, the potential loss is their life. Even worekrs are still confident of what they are doing, no one will take a risk of their life.

5j. Site Manager, 16 years of experience

Of couse, risk tolerance wil not work in this case. Let me ask you, if you think you: will you consider your capability of risk tolerance when you may have a potentil loss of your life? Of coure no. but if for some other risks, the situaion amy be different. You know, construction work is high risky one, a dangerous one. But I am not saying it always can threathen people' s life. This danerous measn that nearly every tasks on site may have some dangerous. So, you know, workers may alrealy get used to this environment, for example, a sprained wrist, back injury, etc. You know, as they already very farmilar wih these risks, they may not that afriad or sensive to them.

6 Peng: Based on our results, we find FLMs show different risk thinking when considering the common and non-serious injury risks and risks with severe consequence, such as death, what do you think of this?

6a. Occupational Health and Safety Manager, 15 years of experience

Yes, we call it like the risk register, and we have very big health and safety environmental plan, one of the appendixes is a document, it outlines all the activities in your job, when we start the project, we sit down and say what do we have to do with the project, we say we have to build all of these levels, we have to put in martials in the outside, we have to fill out all the internal stuff, so, once we understand all of that, we will break it up into different sections and think start the very top and for this project, we have to demolish all of the thing and isolate most of the existing services, so all high risks are got highlighted in the workshop. It looks exactly like that, so, we just say if it is a higher risk? Yes or no? so you got low risk, median risk and high risk. What we define as high risk is that anything that can cause permanent disabilities, and any risks can cause death. And then median is just things that can cause things sort of reparable, so many risks are high risk, so even like falling over, it can have a permanent disabilities for the rest of your life. So, definitely pay more attention to the high risks. Say we have to got a crane in to lift some stuff to level 50 or whatever, that's a very high risk item, and for those we will do like a special workshop before head, so go for outline the methodology from the start to finish. Such as the thing could go wrong and then outline it out. So, we have built management standards, they say what, cus it's like the Australia building code. So, before start some high risk activities, we have to sit with everyone and decide what you will accept. On the actually day it happens, everyone who go down just mainly you, site manager, foremen. So you might do the toolbox in the morning for all the workers and say this is what we are doing we have to make sure that it be delivered properly. Just highlight the things to workers.

Also, when workers do the tasks, we also do observations on it, would they done right? Would they done wrong?

6d. Site Manager, 6 years of experience

For supervisors on site, most of them may cares of more about workers arrangement, construction material allocation, say, who will come today to do the fixing, who will come today to do the electrician work, etc. what is their progress, etc. Then, make a record, kinds of paperwork. So they care more issues in project management.

6e. Construction Manager, 12 years of experience

So, you have to consider both of these parameters, its severity and possibility. A good example is that if slip on the floor, and there is a forklift, so slip on the floor may have a relevant higher possibility that people may don't pay much attention. And consequence for normal people, may be not that high. Normally, we have three columns of risk, original risks, you need to put the migration strategies. So something with high like hood and small severity or something very high severity and small like hood, the preventative actions are different, the migration actions are different, okay. Like a floor, you put an sign on it to remind people to pay attention, then, it can reduce the like hood. For forklift, what we going to do? We still going to reduce the like hood. That's the thing, you can only reduce the like hood, and you cannot reduced the consequence. Also the most of the last technology will also have a laser beam, if they scan you, they will stop you with working. So, there are many way that you can reduce the like hood. In practice, we look on the risk score, if the risk with high severity and high frequency we will pay more attention. (but, for the workers, what kinds of risks do they pay more attention?) Well, I think for the labour, they have their own job description, they know their job their daily perform. If they don't know they cannot do the job. That's why labours just focus on themselves. Manager focus on everyone.

6h. Occupational Health and Safety Manager, 19 years of experience

You know, when we trying to manage risks on site, the first thing is to do assessment, like this [pointing to the risk matrix for on the wall]. Based on the matrix, we have clear understanding of the possible risks which may occur on this project. But, the thing is we can not pay equal attention to everything. Based on my experience, safety managers always care more about the important ones. I am not saying we do no manage others, just for optimise resource allocation.

6i. Occupational Health and Safety Manager, 12 years of experience

OK, have you heard about risk matrix? It includes risk possibility and risk consequence. Each of them have five level from the least to the most. [yes, I know that]. All right, you know, this is the common method, you know, we used in managing risks in construction projects. I am sure you have seen it in site office if you visited some of them during your previous interviews [yes, I do]. OK, as you noticed, risk matrix is used to evaluate potential risks. So, why we need to care about it? It is because it gives information of which risks are relative not that important and really important. Ok, you know, for management, no matter which management, the core of a good manager is to know how to rational allocation of resources. So, if you combine what I have mentioned together, you will understand your research findings.

7 Peng: There are many elements in safety climate, such as top management's safety attitude, supervisors' safety attitude, signs, warnings around sites, co-workers' influence and communication between supervisors and workers. Based on our research, the element of communication between supervisors and workers seems play the most significant role in regulating workers unsafe behaviours, what do you think of this?

7a. Occupational Health and Safety Manager, 15 years of experience

Communication is the most important thing for workers. If I have to pick up one measures on site it should be consultation with workers. So, it’s like constant communication because you know if you are under charge of safety management, you have to set some safety goals. For me, I will put the goal of high consultation with workers because if you come to the job and no one tells you what is going on and there is no coordination, things go terribly. Like not just the safety goes terribly, so it’s like when you are working for a big company, sometimes you can feel like you are not that included. But you can feel separation from the management and workers. And at XXX, we don’ t like that, we like to be sort of integration. we have a very collaborative approach. So consultation, especially for safety, we do have toolboxes, usually once a week or once a fortnight with workers and we go through all of the agenda have safety warning. If we notice something wrong in the building, we bring everyone’s attention, why it happened, how it happened, how it can be rectified, what we can learn from it, that make everyone learn, don’t do that again.

7b. Project Manager, 14 years of experience

First of all, you know, the communication, managers communication is very important, you see if a supervisor notice a worker is doing something risky, but the supervisor think it should be Ok, not a big risk and he did nothing to the worker. Next time, when the worker do the job again, he may think my supervisor even think it’s ok, so, it should be oK, I can just do it. But, you know, if the supervisor immediately say oh, you cannot do that, its risky, stop, then, the worker will keep this in mind and it may reduce the possibility to do the same risky thing again. Also, if one time warning is not effective, the supervisors can talk many times to the workers, then, the worker will really improve their safety awareness regarding this risk. And say, workers will follow the rule as they don’t want to lose this job.

7c. Construction Manager, 34 years of experience

Communication is part of the procedure of how you implement them yeah. I've seen I've seen one company in my early days as and that company manufactures on nutrient acid. You know how unsafe that is. We have been given the international safety rating system, it is a very high safety management system, even a person is bite by a mosquito is reportable – this is a more visible example that I have given you the exceptional there are just exceptional company. I am all the employees were given a safety report form and that's always part of their part of the uniform pocket. When you see something that maybe, maybe may be impossibility to cause a hazard, it's still need to be reported. And you'll be rewarded. See, that's the reward system. It really good because you can only picture how dangerous it is. Actually two things, they have been provided the platform, and the reward system, so in a way they are saving everyone's lives. But some companies are catching up, also some government regulators are also catching up. So at the end of the day is how management control the behaviour of all employees to follow the safety rules.

7d. Site Manager, 6 years of experience

It may help because someone has no safety awareness.

7e. Construction Manager, 12 years of experience

I think the most critical things is about the careens. They care for people, if they care for people, people can feel it, right. So the safety is the most important thing for everyone. So if the individual can feel it not only himself but also people also care about his how safety wellbeing, that's the most important thing. So old programs, even legislations is work on these purpose. So you can see we have safety meetings we have many broches, we have many things put on the wall, try to strengthen people's perception about how become to safety. And also people talk, people always talk, this is also careens as well. (what do you mean people talk? Who talk to whom?) it's about co-workers talk to each other, the manager talk to the supervisor, the sub-contractor talk to the manager, there are many talks, they have to talk. So communication and understanding how the way they perform the job, by understanding the way of doing the job, you can find the risk.

7g. Well-being, Health and Safety specialist, 15 years of experience

I think communication is the most important. Let me say like you know safety culture is really difficult to build, and the easiest way, let's say from the top, they say this is the safety culture, this is the way where we want to be. So, if a worker come to the supervisor with sort of issue, if the supervisor cannot share the same as the top the safety culture can be easily break down quickly. And the workers will feel separated from the management. So, every time when you want to presenting that OK, this is the way where we really want to do, then, the worker will think OK, this is something you say not my supervisor say, so the culture will be broken down and hard to be build up.

7i. Occupational Health and Safety Manager, 12 years of experience

Yes, it is reasonable. I mean I am quite agree with. Communication, no matter for workers or management people, or I should say, during construction work, communication is always an important thing. You know, everyone on site, they are not doing an isolated job, for example, if one task is finishing, the worker needs to tell their supervisor, and supervisor needs to check it and arrange the following tasks. For safety thing, it is the same.

7j. Site Manager, 16 years of experience

I think so. You know, in my job, I need to communicate with workers very often to ensure their safety. For example, before a new tasks beginning, I need to do a workshop to show them the things they need to care about. Also, I encourage them to report potential risks, like if they feel there is a danger, something is not right, etc. According my experience, all of these communication is really helpful.

8 Peng: Since the importance of risk tolerance, we identified several critical factors which can affect workers and FLMs' risk tolerance assessment, such as emotion, employers' support and personal reputation, potential gain from risk action, etc. How do you look at then when thinking of risk tolerance assessment?

8a. Occupational Health and Safety Manager, 15 years of experience

They could be. People do value their reputation, and they could be a supervisors' role, because on the construction site, you got lots' of workers, we, as Built, we have our own labours, so these people may have high awareness of reputation because they work for this company, they care more about their reputation, cus it do reflects the company.

You know, everyone is different, I don't think emphasize the family responsibility and personal reputation in the formal safety training is a good idea. But if I see a worker is not doing something right, with dangerous, I will go to him and always say, I am going to tell about you have family, when something happens to you. It always like that they feel so bad come them from there, so they wouldn't do that more. I will say that individually, but I wouldn't say it at the toolbox. And we do say to the supervisors on site, all the foremen that you have to say this things to your apprentices, especially for the very young ones. If you doing something bad, you know everyone is watching what you are goanna to do. So, that's sort of reputation. But we say to that to all the workers in the toolboxes. For potential gain from risky actin, you know, for management, we have no such concern. But, for worker, they may take risks if they can get more pay.

8b. Project Manager, 14 years of experience

Kinds of, it is hard to say. But I think it should also consider emotion, drinking behaviours. I think currently we need to emphasize these soft thinking, but there is a thing which is that not all the people will accept what you are saying, but this kinds of training is the more the better.

8c. Construction Manager, 34 years of experience

Yes, you are right, it's a really big influence. The senior ones have families, like kids and wife. They should go home and always be careful. (Does it mean they always have family responsibility keep in mind?) Yes, that it is, so they cares. So, they look at PPE as necessary, and some of them are overconfident, it's just crazy. So, to breach the mindset, that's number one.

8d. Site Manager, 6 years of experience

It is hard to say, it depends, if workers have family and he cares about family responsibility and personal reputation, then, it may help. But the person does not care about these. It may not that helpful.

8e. Construction Manager, 12 years of experience

Kinds of, kinds of, yes. It can be. I think it because, we talk about the risk of particular tasks. It's always based on people's skill set. An example is confined space, it is a closing environment, right. Working in a confined space you must have a confined license. But licenses have different levels, we always looking for more experienced people to do the job, right. If in a situation you don't have experienced people available, you may have to use Tom, who may not have many experiences compared to David, but you have to use him. Ant in this case, you may assess his emotional influence, such as 'oh, he is too young, he don't have much experience, is his skillset sufficient to do the job or not'. Then, you got the emotional influence, right? When you talk about personal reputation, you more care about your wild audience, right? Regarding family' impact on working safety, what I can think is the, is very common sense, if that a really dangerous job. I think they are quite subjective, some people may consider their own family responsibly and personal reputation, some people may not.

8h. Occupational Health and Safety Manager, 19 years of experience

Well, they are interesting. Let me say like this. In real risk management, we usually do not care much about emotion. We have a routine to follow. But I am not saying these factors are not important. I think, personally, you know, they may have influences. But it is hard to manage or even to see it in real work environment.

8i. Occupational Health and Safety Manager, 12 years of experience

It is really hard to say. But, they may have influences. Regarding the factor of poential gain from risky aciton, you know some workers are paid by how many work they can finish and some worker may have a fixed pay, say $200 for a day, etc.

9Peng: Based on our study, if workers with higher risk tolerance, they tend to have lower risk perception and be less sensitive to positive safety climate. According to your experience, what is the key for improving workers and FLMs' risk thinking?

9a. Occupational Health and Safety Manager, 15 years of experience

You know, everyone is different, I don't think emphasize the family responsibility and personal reputation in the formal safety training is a good idea. But if I see a worker is not doing something right, with dangerous, I will go to him and always say, I am going to tell about you have family, when something happens to you. It always like that they feel so bad come them from there, so they wouldn't do that more. I will say that individually, but I wouldn't say it at the toolbox. And we do say to the supervisors on site, all the foremen, that you have to say this things to your apprentices, especially for the very young ones. If you doing something bad, you know everyone is watching what you are goanna to do. So, that's sort of reputation. But we say to that to all the workers in the toolboxes.

9b. Project Manager, 14 years of experience

But I think it should also consider emotion, drinking behaviours. I think currently we need to emphasize these soft thinking, but there is a thing which is that not all the people will accept what you are saying, but this kinds of training is the more the better.

9c. Construction Manager, 34 years of experience

But how do we implement and how do we make sure that our that our programs are safety programs or rules as our procedures are followed or audited. It's about audit compliance, measure compliance or procedures so there's an audit and if so some we have we have a computerized system program as well. Select if you see something that may endanger someone, your report that one right away into the system; and we call it as the first priority system. Is that safety? (OK, so, do workers can use it?) Workers who have access to or know how to use they can use it at any time, if they don't know how, they can always ask someone. It's really a maturing system. So the only way to make really sustain the program because programs are not just be put there for show. They are created to protect our lives but if management be slacks as well, they, sometimes, not the place I am working, as I know you can feel that our priority. I have given you the exceptional there are just exceptional company. I am all the employees were given a safety report form and that's always part of their part of the uniform pocket. When you see something that maybe, maybe may be impossibility to cause a hazard, it's still need to be reported. And you'll be rewarded. See, that's the reward system. It really good because you can only picture how dangerous it is. Actually two things, they have been provided the platform, and the reward system, so in a way they are saving everyone's lives. But some companies are catching up, also some government regulators are also catching up. So at the end of the day is how management control the behaviour of all employees to follow the safety rules. For obvious reasons people around him will know his behaviour but if this people around him are not given a platform, platform to influence him to change. So, if you look at it, it's the management.

9d. Site Manager, 6 years of experience

Sharing accident experiences. It like that have someone who experienced accidents by himself. So, he has a very high safety awareness about this risk and knows its consequence is very serious. So, we can invite him to share or educate other workers about the potential consequences; it is a high risk, something like that. Another way is that encourage workers do mutual supervision, it’s like if a worker still like to behave riskily even after safety education, training. Other workers can report to supervisors; then, supervisors can give some warnings to him, he may pay more attention. You know, even if the person has no that awareness, but someone tells him, some warn him, he may start to have this kind of awareness.

9e. Construction Manager, 12 years of experience

The training should always be subjective and objective together. So for the common things like ergonomics, manually handle, we have a booklet of what people have to do. What we do is to have experienced people, and they can body up, body up means the new guy will follow him, observe what he is doing in a couple of days. That is what training is. And the critical one is that always restrict or constrain people by the license. If you don’t have you cannot do the job. So, that’s a way because they need licences, they always need to do special training the training is always comprehensive and you have timely review. You need to pass some course periodically. So, that’s a good control. Regarding to build the culture, you can have bonus and warning police to encourage people to participant in safety things.

9g. Well-being, Health and Safety specialist, 15 years of experience

From my opinion, currently, lots of training only focus on safety rather than health and well-being. I feel a lot information was about don't do this, don't do that. Which means you can see many companies talk about safety, safety, safety. But what I think is that what is the really content of safety? You know WHS is the technical word, but currently the company only focus on too much about safety, rather than health and well-being., the health and well-being don't get be addressed as much as safety. Well-beings is like masking sure people get enough rests before they start their shift. Also things like do you have any mental stress, etc. the thing is many workers may have these problems, the point is that usually the company they are working with have no certain people to be contacted with. So, if the safety management stall really focus on safety, health, and well-being, it can generating the good message. Because the message only for safety would be quite political, but if all of the message have been provided, they will think, wow, they really care about us! They care about our safety. So, it would be good to make a good safety decision. Then, they may listen to the message more rather than think these message do not really care for them. So, when they see some risks, they may think of the message passed training or supervisors, and think if I do this it may conflict with what my supervisors saying. And my supervisor have told us if there is a risk, who should I report to.

9h. Occupational Health and Safety Manager, 19 years of experience

There are many things are really important, just as you mentioned, such as effective communication. But there is one thing I haven't think about before, that is what you just talked, the invisible influence, such as emotion, personal reputation. You know, everything is in progress in this modern society, so, maybe next step for us is to think how to manage the subjective things.

Appendix 3 – Human Ethics Approval

Statement: all conditions pertaining to the clearance were properly met, and the final reports have been submitted.

From: resethics@swin.edu.au <resethics@swin.edu.au>

Sent: Friday, 13 July 2018 4:05 PM
To: Patrick Zou <pwzou@swin.edu.au>
Cc: RES Ethics <resethics@swin.edu.au>
Subject: Acknowledgement of Report for SUHREC Project - 2016/095

Dear Patrick,

Re: Final Report for the project 2016/095

'The effects of risk tolerance and risk perception in construction safe risk behaviours: frontline workers versus managers' (Report Date: 13-07-2018)

The Final report for the above project has been processed and satisfies the reporting requirements set under the terms of ethics clearance.

Thank you for your attention to this matter.

Regards
Research Ethics Team

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Research Publications

During the PhD research journey, the following papers have accepted.

1 WANG, J., ZOU, P. X. W. & **LI, P. P**. 2015. Critical factors and paths influencing construction workers' safety risk tolerances. *Accident Analysis and Prevention*.

2 Zou, Patrick X.W., **LI, P.P**. Wang, Jiayuan and Ekambaram, Palaneeswaran. Construction risk tolerance: workers versus site-managers. *CRIOCM 2017 22nd International Conference on* Advancement of Construction Management and Real Estate.

3 **LI, P. P**, WANG, J., ZOU, P. X. W. Factors Influencing Workers' Safety Risk Tolerance in Construction Projects: A Case of China. CIB W099: International Health and Safety Conference: Benefitting Workers and Society through Inherently Safe(r) Construction.

4 Patrick X.W. Zou. Ning Xu. Rebecca J. Yang. Simon X.M. Ma. **LI, P. P**. A Real-time monitoring system for improving Construction workers' Health and safety. CIB W099: International Health and Safety Conference: Benefitting Workers and Society through Inherently Safe(r) Construction

The two papers below were just submitted.

5 Patrick X.W. Z, **LI, P.P.** . 2018. Worker's Risk Tolerance and Safety Behaviour in the Construction Industry. *Journal of Construction Engr. & Management.* (submitted).

6 **LI, P.P**. & P.X.W. 2018. Critical factors affecting safety risk tolerance: entropy information -based analysis. *Journal of Safety Researcht.* (submitted)