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Developing Resilient Safety Culture for Construction Projects in Vietnam

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STATEMENT OF AUTHENTICATION

'The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.'

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Minh Tri Trinh

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EXECUTIVE SUMMARY

Although traditional safety culture approach has significantly contributed to accident reduction, it may be inadequate in responding to all of the changing and unforeseen safety risks associated with the complex nature of construction projects. Resilient safety culture has been therefore proposed as a promising concept to address the limitation of traditional safety culture approach in order to achieve a sustained improvement of safety performance in the construction environment.

The aim of this study is to investigate the development of resilient safety culture in the construction environment. To fulfil the research aim and objectives, a quantitative approach and a survey research design were adopted. Data were collected using questionnaires targeting the construction project managers involved in the delivery of 78 recently completed building projects in Vietnam. The structural equation modelling (SEM) technique with partial least-squares estimation (PLS) was used to analyse the data. The key findings pertaining to the research objectives are:

(1) This study examined the dimensions of resilient safety culture of construction projects. The results confirm 24 measurable scale items

comprising three dimensions (i.e. psychological resilience, contextual resilience and behavioural resilience) to define and assess resilient safety culture.

(2) This study explored the drivers of resilient safety culture. It was found that hazard prevention practice has a positive impact on contextual and behavioural resilience, error management practice has a positive impact on psychological resilience, and mindful organising practice has a positive impact on contextual resilience.

(3) This study examined the interactive effects of resilient safety culture and project complexity on safety performance of construction projects. It was found that resilient safety culture dimensions have positive impacts on safety performance. Psychological resilience has a weaker impact on accident prevention under higher contextual and behavioural resilience levels. Technical and environmental project complexities have negative impacts on safety performance. The negative impact of project complexity on safety performance becomes less significant when there is a higher level of psychological, contextual and behavioural resilience; while this impact might be not significant if psychological, contextual and behavioural resilience were high.

The findings of this study contribute to the knowledge of construction safety management by providing the theoretical development and empirical evidence to clarify the concept of resilient safety culture in terms of definition, purpose, value, and assessment and improvement mechanisms in the context of construction projects. Practically, this study (1) provides a frame of safety

practices to assess the organisations' capabilities to manage safety risks and achieve a sustained improvement of safety performance regardless of the changing complexity levels of construction projects, and (2) recommends the appropriate strategies to build up such capabilities.

Keywords: Construction, Project Complexity, Resilience, Safety, Safety Culture, Safety Performance.

RESEARCH PUBLICATIONS

Based on this PhD research, the following papers have been published or accepted for publication:

1. **Trinh, MT**, Feng, Y & Jin, X 2018, 'Conceptual Model for Developing Resilient Safety Culture in the Construction Environment', *Journal of Construction Engineering and Management*, vol. 144, no. 7, p. 06018003.

2. **Trinh, MT** & Feng, Y 2018, 'Measuring Resilient Safety Culture of Construction Projects', in *International Conference on Applied Human Factors and Ergonomics*, Springer, pp. 580-6.

3. **Trinh, MT** & Feng, Y 2018, 'Interactive impacts of project complexity and resilient safety culture on safety performance of construction projects', in *Conference Proceedings: The 42th Australasian Universities Building Education Association (AUBEA) 2018 Conference, 26-28 Sep 2018, Singapore*, vol. Accepted: 09 Apr 2018

4. **Trinh, MT** & Feng, Y 2018, 'Improving Construction Safety Performance Through Error Management: A Literature Review', in *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate*, pp. 891-8.

5. **Trinh, MT** & Feng, Y 2016, 'Error management culture in construction safety: a literature review', in *Conference Proceedings: The 40th Australasian Universities Building Education Association (AUBEA) 2016 Conference, 6-8 July 2016, Cairns, Queensland*, pp. 89-98.

6. **Trinh, MT**, Feng, Y & Sherif, M 2018, 'Framework for Measuring Resilient Safety Culture in the Vietnam’s Construction Environment', *Journal of Construction Engineering and Management*, no. Accepted: 8 Aug 2018.

Papers that are under review at the writing of this thesis:

7. **Trinh, MT** & Feng, Y 'Impact of Project Complexity on Safety Performance of Construction Projects: the moderating role of Resilient Safety Culture', *Safety Science*, Submitted: 29 Oct 2018.

8. Feng, Y & **Trinh, MT**, 'Developing Resilient Safety Culture for Construction Projects', *Journal of Construction Engineering and Management*, Submitted: 16 Sep 2018.

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CHAPTER 1 INTRODUCTION

1.1 Research background

Despite the substantial improvements in construction safety management have been made over the last decades, construction is one of the most hazardous occupations worldwide (Brunette 2004). Construction industry comprised about 7% of the workforce in the world but contributes to 30-40% fatalities (Sunindijo & Zou 2012). In Vietnam, according to the Work Safety and Health statistics published by Ministry of Labour, War Invalids and Social Welfare, the number of annual injured workers and the number of annual accidents at workplaces across all industries have a tendency to increase in recent years (Department of Work Safety 2018) (See Figure 1.1).

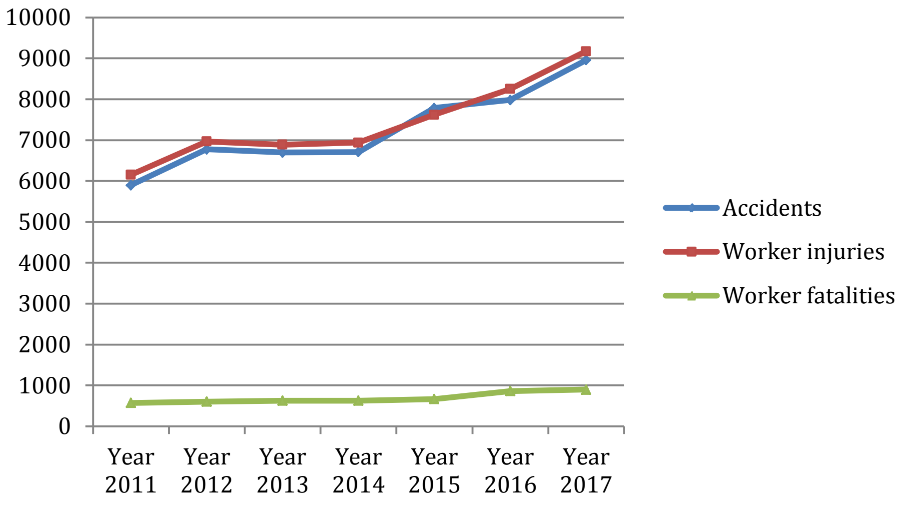


Figure 1.1: Industrial accidents, worker injuries and worker fatalities, Vietnam 2011-2017 (Source: Department of Work Safety, 2018)

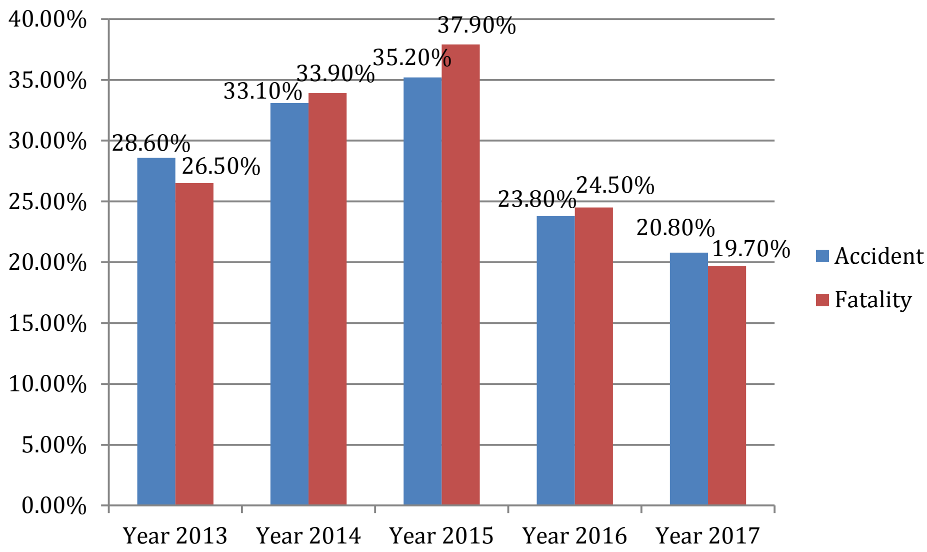


Figure 1.2: Percentage of accidents by the construction industry in Vietnam 2013-2017 (Source: Department of Work Safety, 2018)

In addition, construction has been recognised as the most dangerous industry in the last five years, which contributes to 20-36% accidents and 20-38% fatalities in Vietnam (Department of Work Safety 2018) (See Figure 1.2). Therefore, various strategies for improving construction site safety performance need to be examined.

1.2 Statement of the problem

Since the introduction of the health and safety at work act (Parliament 1974), the past four decades have been seen the evolution of approaches for managing occupational health and safety (OHS). Accordingly, accident causation theories and OHS management have progressed through a series of ages, and each age is distinguished by its emphasis on different aspects of the system (Harvey et al. 2016). These 'ages of safety' include technical, human factors, sociotechnical and organisational culture (Wiegmann et al. 2004). In technical age, accidents were largely attributed to mechanical faults (e.g. design, construction and reliability of equipment) (Wiegmann & Shappell 2001). The age of human error considered the faults of human operators as the main sources of accidents rather than mechanical malfunctions (Perrow 2011). The sociotechnical age recognised the interaction between human and technical factors when investigating the causes of accidents (Rasmussen 1986). The age of organisational culture emphasised the fact that individuals perform their jobs in collaboration with their colleagues who are embedded within a particular culture rather than in insolation (Wiegmann et al. 2004). This age of safety management, therefore, recognised the important role played by organisational and cultural factors in shaping safety performance (Pillay et al. 2010). It has also been noted that, in the process of safety management development, each 'age of safety' does not leave behind, but rather builds on, what has gone before (Glendon et al. 2016). Accordingly, organisational culture has been seen as the latest age of safety management, which evolved and developed upon previous ways of thinking about managing OHS (i.e. technical, human factors and sociotechnical ages) (Glendon et al. 2016). As OHS management in the construction environment has followed the same overall trend, developing and maintaining a positive safety culture is crucial for improving safety performance of construction organisations (Choudhry et al. 2007; Fang & Wu 2013; Guldenmund 2010; Zohar 2010).

Construction organisations traditionally adopted a holistic safety strategy emphasising on prevention and protection, in order to reduce the employees' exposure to on-site hazards (Mitropoulos et al. 2005; Zou 2010). Workplace safety literature indicates that these safety strategies have focused on: (1)

creating a safety knowledge database, (2) the assumption that all accidents are preventable and unacceptable, (3) improving safety management systems to identify, assess and control hazards, (4) extending safety management matters to the entire supply chain and involving all stakeholders, (5) a strong commitment to safety among management, (6) establishing explicit accountability and authority for safety, and rewarding safe behaviour, and (7) shaping beliefs, attitudes and commitment of employees to achieve safe behaviour (Zou 2010).

In recent years, safety risks seem to be more difficult to manage because they have emerged as the result of the increasingly complex nature of sociotechnical systems (Costella et al. 2009; Pęciłło 2016; Steen & Aven 2011). The increasingly inherent complexity of these workplace environments has led to the changing and unforeseen shape of safety risks and poses challenges for traditional safety management approaches (Bergström et al. 2015; Dekker 2016; Shirali et al. 2015). Specifically, traditional safety management approaches are established on knowledge of previous experience, failure reporting and risk assessments by estimating historical data-based probabilities (Steen & Aven 2011). The effectiveness of traditional safety management approaches is dependent on the extent to which safety risks are known or can be made known (Hollnagel 2008b). Consequently, traditional approaches are institutionalised through plans, processes, procedures and policies for safety management, they are not readily and easily adaptable to the natural and inevitable changes in work being conducted, and the emerging and unforeseen safety risks being encountered (Wachter & Yorio 2014). They tend to become obsolete or deteriorate over time as a consequence of changes and uncertainties, and thus leave organisations vulnerable to potentially disastrous failure modes and unforeseen kinds of safety risks (Bergström et al. 2015).

In the context of the construction industry, it is widely acknowledged that the construction process is increasingly complex as the result of the interaction between various parts with dynamic and uncertain properties (Luo et al. 2016; Mihm et al. 2003; Xia & Chan 2012). According to Bosch-Rekveldt et al. (2011), project complexity can be categorised into three groups, namely technical, organisational and environmental. Technical aspect contributes the complexity of construction project as it refers to the changes and uncertainties of goal, scope, task and technology; organisational aspect relates to changes and uncertain properties associated with a construction project team such as lack of contractors' experience, change of project organisation, sources availability, etc.; and environmental aspect refers to the uncertainties of external stakeholders, location and market conditions (Bosch-Rekveldt et al. 2011). As a result, although many of safety risks are well-identified and managed through project risk management procedures, construction projects are known of having inherent risks with high levels of change and uncertainty (Wehbe et al. 2016). Recent reviews (Mitropoulos et al. 2005; Saurin & Carim Júnior 2011; van der Molen et al. 2018; Wachter & Yorio 2014; Zou 2010) concluded that traditional safety management approaches are inefficient to address all types of safety risks being encountered on construction sites.

In light of the above, traditional safety culture approach may be inadequate for organisations to effectively respond to the changing and unforeseen safety risks associated with the increasingly complex nature of construction projects. In order to achieve a sustained improvement of safety performance in the construction environment, there is a need for developing an organisational safety culture based on a new perspective of safety management, which allows organisations to address not only known risks but also potential new risks. This study was proposed to address this need.

1.3 Knowledge gap

Since the 1980s, numerous studies have been conducted to examine the concept and theoretical models of safety culture (Choudhry et al. 2007; Cooper 2000; Fang & Wu 2013; Geller 1994). Safety culture aims to create a self-sustaining environment based on a comprehensive understanding of the causes of workplace safety performance or lack thereof (DeJoy 2005). Accordingly, a safety culture built upon traditional approaches helps an organisation to improve safety performance by preventing the regular safety risks, which occur often enough to develop a standard response. However, these models failed to address the organisation's capabilities to deal with changing and unforeseen safety risks which emerge as the result of the increasingly inherent complexity level of construction projects (See Section 2.3 for a detailed review of safety culture).

Resilience engineering approach has been proposed as a potential solution to address the limitation of traditional approaches in responding to the changing and unforeseen safety risks associated with the increasingly complex nature of sociotechnical systems (Hollnagel 2011; Pęciłło 2016; Woods & Hollnagel 2006) (See Section 2.4 for a detailed review of resilience engineering). Akselsson et al. (2009, p. 4) defined resilient safety culture as "*an organisational culture that fosters safe practices for improved safety in an ultra-safe organisation striving for cost-effective safety management by stressing the resilience engineering, organisational learning and continuous improvements*". In a recent publication, Shirali et al. (2016) attempted to measure resilient safety culture in a petrochemical plant and identified thirteen indicators (See Section 2.5 for a detailed review of resilient safety culture concept).

Although the previous research (Akselsson et al. 2009; Azadeh et al. 2014; Dinh et al. 2012; Shirali et al. 2015; Shirali et al. 2016) has made significant contributions in introducing the resilience engineering theory into workplace health and safety and developing the concept of resilient safety culture, previous studies failed to: (1) identify the dimensions of resilient safety culture, (2) identify what strategic safety management efforts can improve and maintain resilient safety culture for construction projects, and (3) examine relationships between resilient safety culture, organisational complexity and safety performance.

Therefore, in the context of construction projects, the gaps in knowledge are: (1) the dimensions of resilient safety culture were not identified and defined,

(2) it was not clear how resilient safety culture is developed in construction organisations, and (3) it remained unclear how resilient safety culture impacts on safety performance under the changing complexity levels of construction projects. These knowledge gaps will be addressed in this study.

1.4 Research aim and objectives

The purpose of this study is to investigate the development of resilient safety culture in the construction environment. The specific objectives of this study are given below.

1. To identify the dimensions of resilient safety culture of construction projects.
2. To identify the drivers of resilient safety culture.
3. To examine the interactive effects of resilient safety culture and project complexity on safety performance of construction projects.

1.5 Definition of terms

1.5.1 Resilient safety culture

In this study, resilient safety culture is defined as *an organisation's psychological/cognitive, situational/contextual and behavioural capabilities to 'anticipate, monitor, respond and learn' in order to manage safety risks and create an ultra-safe organisation*, and thus is characterised by three dimensions, namely (1) psychological resilience, (2) contextual resilience, and (3) behavioural resilience (See Section 3.2 for detailed explanations of resilient safety culture).

1.5.2 Project hazards and hazard prevention practice

Health Safety Commission (1995) defines hazard as "*the potential to cause harm*". Hazard can also be defined as "*an inherent characteristic of a thing or situation that has the potential of causing an unplanned or undesired event or series of events that have harmful consequences, such as injury, death, environmental harm, or illness*" (Gowen & Collofello 1994, p. 20) . In the construction environment, project hazard is a natural part of the initial construction site conditions owing to the scope and location of the project (Imriyas et al. 2007). In building construction projects, hazard activities can involve: (1) works in confined spaces, (2) welding and cutting works, (3) works on contaminated sites, (4) construction machinery and tools usage, (5) crane use, (6) erection of structural frameworks, (7) roof works, (8) false works (temporary structures), (9) scaffolding and ladder works, (10) excavation works, and (11) demolition works (Davies & Tomasin 1996; Jannadi, MO & Assaf 1998). There are two aspects of control and management of construction hazards: (1) the preventive control measures to reduce the possibility of hazards' occurrence, and (2) the precautionary control measures to reduce the severity of hazard if it occurs (Carter & Smith 2006). In this study, hazard prevention practice represents those safety strategies comprising both aforementioned aspects, which aim to detect and manage project hazards in the construction environment (See Sections 3.3.1 and 4.3.1.2 for detailed explanations of project hazards and hazard prevention practice).

1.5.3 Errors and error management practice

Unsafe behaviour is defined as an undesirable or inappropriate human decision or behaviour that reduces or has the potential for lowering, effectiveness, safety or system performance (Sanders & McCormick 1998). An error is a kind of unsafe behaviour which was not intended (Health and Safety Executive 2009; Rasmussen 1983; Reason et al. 1990). In this study, the terms 'errors', 'unintentional errors' and 'unintentional unsafe behaviours' are used interchangeably. Error management practice represents those safety strategies, which aim to detect and manage unintentional unsafe behaviours of construction workers (See Sections 3.3.2 and 4.3.1.3 for detailed explanations of errors and error management practice).

1.5.4 The unexpected and mindful organising practice

The unexpected is non-routine events such as: (1) the working conditions may be different than planned, (2) materials and tools are missing, inappropriate, not for use or broken, and (3) human resources are not available, cannot be reached or are called away, etc. (van der Beek & Schraagen 2015). In this study, the terms 'the unexpected' and 'unexpected situations/conditions/events' are used interchangeably. Mindful organising practice represents those safety strategies, which aim to detect and manage the unexpected in the construction environment (See Sections 3.3.3 and 4.3.1.4 for detailed explanations of the unexpected and mindful organising practice).

1.5.5 Project complexity

Project complexity is considered as the inherent characteristics of a construction project and results from the interaction of various parts with dynamic and uncertain properties (Luo et al. 2016; Mihm et al. 2003; Xia & Chan 2012). According to Bosch-Rekveldt et al. (2011), project complexity can be categorised into three groups: technical, organisational and environmental factors. In this study, project complexity refers to the dynamic and uncertain properties associated with technical, organisational and environmental factors (See Section 2.2 for detailed explanations of project complexity).

1.6 Research hypotheses

To achieve the research aim and objectives, twenty-two hypotheses were set out (Please refer to Sections 3.2, 3.3 and 3.4 for the detailed information about the development of research hypotheses).

To identify the dimensions of resilient safety culture of construction projects, the following hypothesis is set out (See Section 3.2):

H_1: Resilient safety culture is characterised by psychological resilience, contextual resilience and behavioural resilience.

To identify the drivers of resilient safety culture, the following hypotheses are set out (See Section 3.3):

H_2: Hazard prevention practice has a positive impact on psychological resilience.

H_3: Hazard prevention practice has a positive impact on contextual resilience.

H_4: Hazard prevention practice has a positive impact on behavioural resilience.

H_5: Error management practice has a positive impact on psychological resilience.

H_6: Error management practice has a positive impact on contextual resilience.

H_7: Error management practice has a positive impact on behavioural resilience.

H_8: Mindful organising practice has a positive impact on psychological resilience.

H_9: Mindful organising practice has a positive impact on contextual resilience.

H_{10}: Mindful organising practice has a positive impact on behavioural resilience.

To examine the impacts of project complexity dimensions on safety performance of construction projects, the following hypotheses are set out (See Section 3.4):

H_{11}: Technical complexity has a negative impact on safety performance of construction projects.

H_{12}: Organisational complexity has a negative impact on safety performance of construction projects.

H_{13}: Environmental complexity has a negative impact on safety performance of construction projects.

To examine the impacts of resilient safety culture dimensions on safety performance of construction projects, the following hypotheses are set out (See Section 3.4):

H_{14}: Psychological resilience has a positive impact on safety performance.

H_{15}: Contextual resilience has a positive impact on safety performance.

H_{16}: Behavioural resilience has a positive impact on safety performance.

H_{17}: Safety performance is impacted by the interaction between psychological resilience and contextual resilience.

H_{18}: Safety performance is impacted by the interaction between behavioural resilience and contextual resilience.

H_{19}: Safety performance is impacted by the interaction between behavioural resilience and psychological resilience.

To examine the moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance of construction projects, the following hypotheses are set out (See Section 3.4):

H_{20}: The impact of project complexity on safety performance becomes weaker when there is a higher level of psychological resilience.

H_{21}: The impact of project complexity on safety performance becomes weaker when there is a higher level of contextual resilience.

H_{22}: The impact of project complexity on safety performance becomes weaker when there is a higher level of behavioural resilience.

1.7 Unit of analysis and scope of research

In this study, the research objectives suggest a construction project as the level of analysis. In Vietnam, there are mainly two categories of construction projects including building construction (e.g. civil and industrial building) and civil engineering construction (e.g. road and bridge) (Ministry of Construction 2016). Building construction and civil engineering construction involve different types of technology, production processes and organisational structure of construction projects. It is beyond the scope of this research to cover all categories of construction projects due to time and resource constraints. The focus in this research is on the building projects in Vietnam.

During the construction stage, a building project involves various stakeholders such as clients, consultants and contractors. In this study, resilient safety culture of the building projects is perceived and evaluated from the perspective of a contractor because it is required by law in Vietnam that contractor holds the primary duty of care for health and safety in the construction workplaces. Therefore, a contractor's project is the unit of analysis in this study.

1.8 Research method

A quantitative approach and a survey research design were adopted in this study. Survey data were collected targeting the construction project managers of 78 recently completed building projects in Vietnam. The data were then analysed using the Partial Least Square (PLS) - Structural Equation Modelling (SEM) approach to test the hypotheses. The research results were reported and discussed based on an extensive review of pertinent literature. The overall research process is depicted in Figure 1.3.

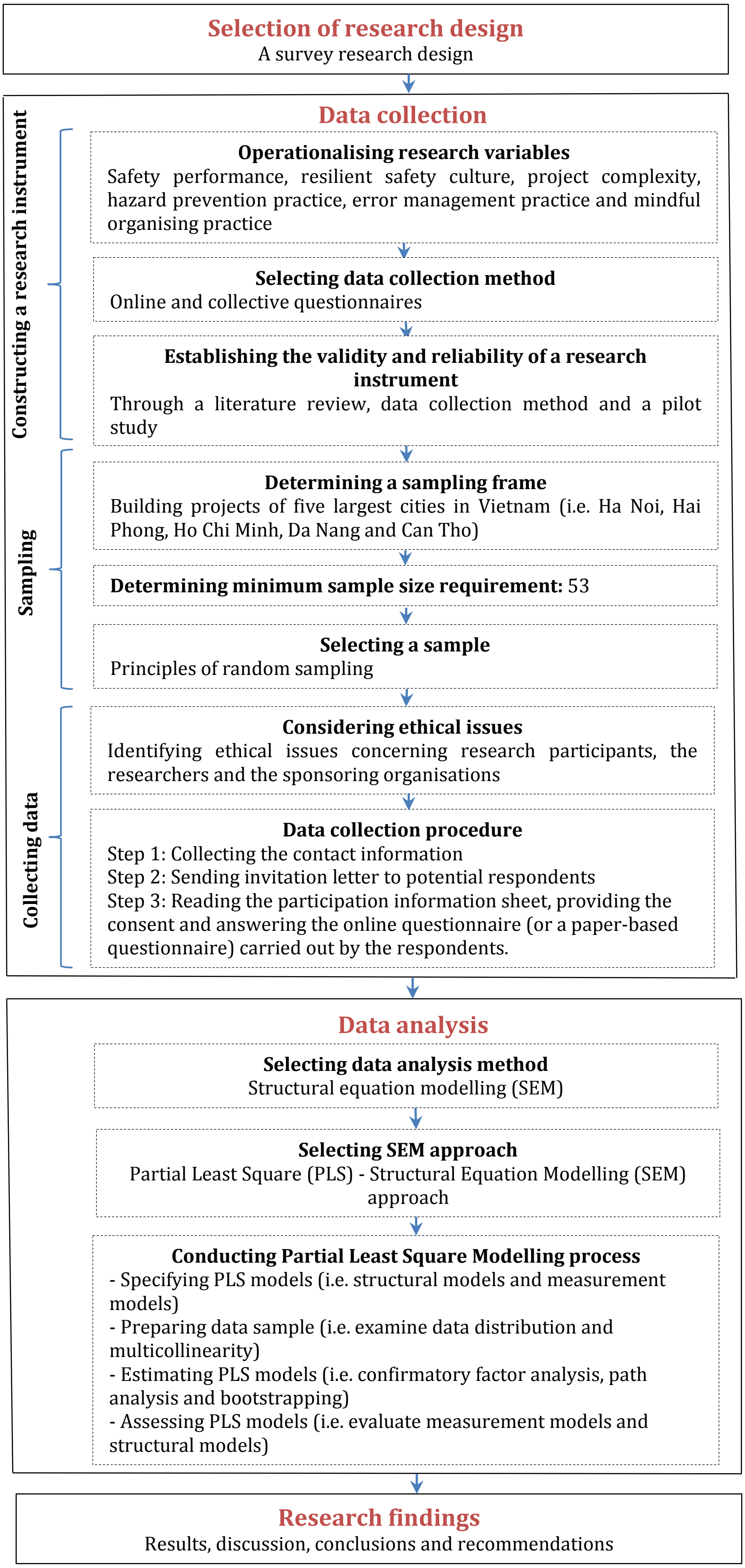


Figure 1.3: Research process

1.9 Significance of the research

This study is significant both theoretically and practically. Theoretically, this study may contribute to the knowledge of construction safety management by providing the theoretical development and empirical evidence to clarify the concept of resilient safety culture regarding definition, purpose, value, and assessment and improvement mechanisms in the context of the construction industry (See Section 7.3). Practically, this study (1) provides a frame of safety practices to assess the organisations' capabilities to manage safety risks and achieve a sustained improvement of safety performance regardless of the changing complexity levels of construction projects, and (2) recommends the best strategies to build up such capabilities (See Section 7.4).

1.10 Thesis structure

The thesis is organised into seven chapters. Chapter 1 introduces the research background, research problem, knowledge gaps, research aim and objectives, definition of terms, research hypotheses, unit of analysis and scope of research, research method, and significance of the research. Chapter 2 reviews the literature on the complex nature of the construction industry, safety culture, resilience engineering and resilient safety culture in order to clarify the research problem and knowledge gaps. Based on the research aim and objectives, Chapter 3 presents the theoretical basis and hypotheses pertaining to conceptualising resilient safety culture of construction projects; developing resilient safety culture for construction projects; and the relationships between resilient safety culture, project complexity and safety performance; followed by the development of conceptual framework for this study. Chapter 4 describes the research methodology, which includes the selection of research design, data collection and data analysis methods. Chapter 5 reports the empirical research results, which comprise the confidence of reliability and validity of constructs and evaluation of structural models. Chapter 6 discusses the model of resilient safety culture developed in this study. The last chapter presents the summary of key findings, the theoretical and practical contributions, the research limitations, and the recommendations for future research.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature regarding the complex nature of the construction industry, safety culture, resilience engineering and resilient safety culture. Section 2.2 presents an overview of the complex nature of the construction industry. Section 2.3 reviews safety culture concept and clarifies the limitations of traditional safety culture approach. Section 2.4 focuses on providing the understandings of resilience and resilience engineering perspective of safety management. In section 2.5, previous studies on resilient safety culture are introduced. Following this review, the research problem and knowledge gaps are presented in section 2.6.

2.2 Complex nature of the construction environment

2.2.1 Project complexity concept

Complexity is a term often used when discussing construction projects. It is broadly acknowledged that, in today's changing environment, the construction process is increasingly complex (Nguyen et al. 2015). Baccarini (1996, p. 202) defined project complexity as "'*consisting of many varied interrelated parts' and can be operationalised in terms of differentiation and interdependency*". In the definition, differentiation refers to the number of varied elements of a project (i.e. subsystems, tasks, parts and specialists) and interdependency refers to the degree of interlinkages among these elements. In line with Baccarini (1996), Gidado (1996) further explained that project complexity has its origins from a number of sources. They include the level of scientific knowledge required, the environment in which construction takes place, the resources that are employed and the number and interaction of different elements in the construction process. Accordingly, project complexity has two features: (1) uncertainty of "*components that are inherent in the operation of individual tasks and originate from the resources*", and (2) interdependence among tasks and represents those sources of complexity that "*originate from bringing different parts together to form a workflow*". The uncertainty can be caused by (1) lack of specification for operations on sites, (2) management is unfamiliar with resources and environment, (3) unpredictability of environment, and (4) lack of uniformity of materials, work and teams pertaining to place and time as every construction project is unique. Interdependence among the operations in the construction process can be due to: (1) the number and interdependence of technologies, (2) the rigidity of sequence between activities, and (3) the overlap of components or stages of the construction process (Gidado 1996, p. 216). Williams's (1999) study summarised that the overall project complexity could result from the interaction of different parts with uncertainty (i.e. uncertainty in goals and methods) and structural complexity (i.e. a number and interdependence of elements).

It is widely accepted that the project complexity has negative impacts on various aspects of the project outcomes, which include environmental performance, participation and user satisfaction, time, quality and commercial value (Nassar & Hegab 2006; Nkado 1995; Tatikonda & Rosenthal 2000). From a perspective of safety management, it is also argued that increasing complexity of an organisation leads to an increase in changing and unforeseen safety risks, thereby making the organisation more vulnerable to accidents (Dekker 2016; Perrow 2011; Rasmussen 1997).

2.2.2 Project complexity dimensions

A review of previous studies reveals the inconsistency in the classifications of factors, which characterise project complexity (Bosch-Rekveldt et al. 2011; He et al. 2015; Lu et al. 2015; Luo et al. 2016; Nguyen et al. 2015; Vidal et al. 2011; Xia & Chan 2012). Baccarini (1996) first divided project complexity into two groups of factors, namely organisational complexity and technological complexity. Lu et al. (2015) characterised the overall project complexity in two aspects, which include task and organisation. Nguyen et al. (2015) classified project complexity into scope, technological, infrastructural, organisational, environmental and socio-political complexities. Luo et al. (2016) grouped the elements of project complexity as information, task, technology, organisation, environment and goal.

Based on a comprehensive literature review to measure project complexity, Bosch-Rekveldt et al. (2011) divided project complexity factors into three groups: technical, organisational and environmental. Technical aspect involves many factors: (1) goals (e.g. diversity of goals, uncertainty of goals, inconsistency of project goals, stakeholder requirements change, project urgency for time limit and urgency for project cost) (Luo et al. 2016), (2) scope (e.g. scope largeness, quality requirements and uncertainties in scope) (Bosch-Rekveldt et al. 2011; Nguyen et al. 2015), (3) tasks (e.g. diversity of tasks, dynamics of task activities, dependence of relationship among tasks, availability of resources and skills, uncertainty of tools and project management methods, sources of funding way and complexity of contractual relationship) (Bosch-Rekveldt et al. 2011; Lu et al. 2015; Luo et al. 2016), and (4) technology (e.g. newness of technology, variety of technologies employed, experience with technology, technological risks, dependence of technological processes, risk of employing highly tricky technologies and novelty of construction products) (Baccarini 1996; Luo et al. 2016; Nguyen et al. 2015).

Organisational aspect of project complexity can include many factors contributing to project complexity. They are: (1) size (e.g. size of organisational structure hierarchies, size of organisational units and departments and cross-organisational interdependence), (2) resources (e.g. resource and skills availability, experience of participants and change of project organisation) (Bosch-Rekveldt et al. 2011; Luo et al. 2016), (3) project team (e.g. variety of nationalities involved, variety of languages involved and cultural differences of project organisation) (Bosch-Rekveldt et al. 2011; Luo et al. 2016), and (4) trust (e.g. sense of cooperation and trust among project organisation) (Bosch-Rekveldt et al. 2011).

Environmental aspect of project complexity may include: (1) external stakeholders (e.g. the influence of external stakeholders, changes in policy and regulation, variety of stakeholders' perspectives) (Bosch-Rekveldt et al. 2011; Luo et al. 2016; Nguyen et al. 2015), (2) location (e.g. remoteness of location, complicated geological conditions, and weather conditions) (Luo et al. 2016; Xia & Chan 2012), and (3) market conditions (e.g. the level of competition and changes in economic environment) (Bosch-Rekveldt et al. 2011; Luo et al. 2016).

2.3 Safety culture

2.3.1 Organisational culture

2.3.1.1 Organisational culture concept

The American Heritage Dictionary defines culture as "*the totality of socially transmitted behaviour patterns, arts, beliefs, institutions, and all other products of human work and thought considered as the expression of a particular period, class, community, or population*". Originally, 'culture' is a term related to nationalities rather than organisations. Since the early 1980s, 'culture' was recognised as an essential concept to give insights into the complex feature of an organisation. Similar to countries, organisations own their history and shared leadership and learning, which shape the attitudes and behaviours of their members (Schein 2010). As a paradigm for thinking about and understanding organisations, Ott (1989) pointed out that the organisational culture approach does not simply appear spontaneously within organisation theory, but rather it was influenced by and built on, the different disciplines which had preceded it. Organisational culture concept has its philosophical foundations in domains such as psychology, sociology, anthropology and management (Feng et al. 2014). The difference in viewpoint leads to the diversity, ambiguity and confusion in defining organisational culture (Cooper 2000).

In terms of ontological and epistemological positions, culture can be distinguished into two broad ideas: interpretative and functionalist approaches (Smircich 1983). The interpretive approach focuses on the meanings and beliefs that organisation's members assign to organisational features and how these assigned meanings and beliefs impact behaviour (Alvesson 2012; Weick 1995). This approach views culture as the interaction between an organisation and its members, where behaviours of employees can change through mutual interaction (Choudhry et al. 2007). According to this approach, organisational culture can be defined as: "*shared values (what is important) and beliefs (how things work) that interact with a company's people, organisational structures and control systems to produce behavioural norms (the way we do things around here)*" (Uttal 1983) or "*shared behaviours, beliefs, attitudes and values regarding organisational goals, functions and procedures*" (Cooper 2000). Thus, based on the interpretive approach, culture acts as "*a metaphor for the organisation; the organisation is a culture.*" (Reiman & Rollenhagen 2014, p. 6).

The functionalist approach to organisational culture is built on the seminal work on the nature of social systems (Parsons 2013; Radcliffe-Brown 1958). According to this approach, organisational culture is the top-down driven by management (Hofstede et al. 1991). A typical definition of organisational culture informed by Schein (2010) is "*a pattern of basic assumptions invented, discovered, or developed by a given group as it learns to cope with its problems of external adaptation and internal integration; that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think and feel in relation to those problems*" (p. 17). Schein (2010) showed the complexity of meanings of culture by summarising the way this concept utilised: roots metaphors, formal philosophy, espoused values, shared meanings, habits of thinking, group norms, embedded skills, rules of the game, climate and observed behavioural regularities. Thus, the remarkable difference between interpretative and functionalist approaches is that interpretative approach treats an organisation as a culture, whereas functionalist approach considers an organisation has a culture (Reiman & Rollenhagen 2014). Despite the diversity in defining organisational culture, Guldenmund (2000, p. 21) summarised the overall characteristics of organisational culture, which "*is a relatively stable, multidimensional, holistic construct shared by (groups of) organisational members that supplies a frame of reference and which gives meaning to and/or is typically revealed in certain practices*".

Organisational culture is crucial for successful management (Mullins 2007). Organisational culture reflects through the way by which its members set objectives, manage the appropriate resources to obtain those objectives, and perform the specific tasks; and affects the way all members think, feel, make decisions and behave in response to the potential opportunities and threats (Thompson & Martin 2010). Accordingly, organisational culture arranges the scheme of informal rules which determine the way individuals act most of the time (Kennedy, AA 1982). Tharp (2009) summarised the ability of an organisational culture, which include: (1) to reduce the uncertainties by developing a typical method to understand issues, (2) to generate a sense of continuity, (3) to establish a sense of order in that individuals know what is expected, (4) to offer a vision of the future around which the company can rally, and (5) to provide a collective identity and a unity of commitment. Therefore, organisational culture is believed to have impacts on organisational performance (Kennedy, AA 1982; Schein 2010; Thompson & Martin 2010).

2.3.1.2 Composition of organisational culture

In efforts to outline the main features and levels of organisational culture, it has been shown that organisational culture manifests in a number of forms from invisible to visible compositions (Hofstede 2016; Schein 2010). The invisible manifestations can comprise value, beliefs and underlying assumptions (Hofstede 2016; Schein 2010). The visible compositions can involve symbols, heroes and rituals (Hofstede 2016); or artefacts, creations and behaviour norms (Schein 2010). According to Hofstede (2016), culture comprises multiple layers: the core layer is invisible and represented by the values and underlying assumptions; whereas the outer layer is visible and consists of rituals, heroes and symbols of the organisation. In addition, Hofstede (2016) refers the outer layers (i.e. rituals, heroes and symbols) as ‘practices’, which is more easily changed than the core layer (i.e. values and underlying assumptions).

A similar conceptualisation of organisational culture is provided by Schein (2010). According to Schein (2010), organisational culture comprises three noticeable layers, which include underlying assumptions, espoused values and artefacts. Underlying assumptions are recognised as the core layer of culture. They involve the prevailing assumptions of an organisation to guide the behaviour, cognition and attitude of employees. The middle layer is espoused values of organisation which shape the behaviours of employees. The surface layer is artefacts, which include physical manifestation (e.g. reporting and organisational documents, organisational celebrations and rituals, and slogans and logos) and overt routine behaviours of employees within an organisation (Schein 2010).

The studies of Hofstede (2016) and Schein (2010) have implications for research of organisational culture. First, since organisational culture is constituted and defined by multiple layers, mainly core layer (i.e. values and underlying assumptions) and outer layers (i.e. organisational practices), the investigation of organisational culture should involve examining the organisational practices and the values and underlying assumptions that govern those practices. Second, the visibility characteristic of the outer layers of organisational culture implies that organisational practices are more describable and measurable, and thus can be employed for assessing organisational culture. Third, as the values and underlying assumptions are recognised to govern organisational practices, the identification of the values and underlying assumptions in an organisation may help to offer guidance on the mechanisms, which improve and maintain organisational culture.

2.3.2 Safety culture concept

Organisational culture reflects shared behaviours, beliefs, attitudes and values (Williams, A et al. 1993). It also facilitates shared interpretations of situations and renders coordinated actions and interactions possible and meaningful (Alvesson 2012). Therefore, organisational culture can be used as a framework to understand how values, attitudes and beliefs about safety work are expressed and how they might influence directions that organisations take in respect of safety culture (Glendon and Stanton 2000, p. 201). Safety culture concept was first introduced in International Nuclear Safety Advisory Group (INSAG)'s Summary Report on the Post-Accident Review Meeting about Chernobyl Nuclear Accident in April 1986 and published by the International Atomic Energy Authority (IAEA 1991). IAEA (1991) provided the evidence of technology vulnerability, emphasised the need for better understanding of cultural aspects of safety, and explained that violations of operating procedures and organisational errors which contributed partly to the disaster were revealed to be evidence of a 'poor safety culture'. IAEA (1991) reported the definition of safety culture conceived by INSAG, which is "*assembly of characteristics and attitudes in organisations and individuals, which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance*" (p. 863). This definition accentuates two main points: (1) as safety culture is about characteristics and attitudes in organisations and individuals, positive safety culture requires good attitudes of individuals as well as proper management organised by organisations towards safety issues, and (2) the highest priority is assigned to safety in a positive safety culture (Choudhry et al. 2007). Since then, safety culture concept has been attracted much research attention in all industries (Choudhry et al. 2007; Guldenmund 2000; Reiman & Rollenhagen 2014; Wiegmann et al. 2004; Zohar 2010).

Defining the concept of safety culture is critical because it determines the mechanisms by which safety culture is operationalised, measured and developed in organisations (Cooper 2000). As a result, numerous safety culture definitions have been informed in the academic safety literature (Choudhry et al. 2007; Guldenmund 2000; Reiman & Rollenhagen 2014; Wiegmann et al. 2004; Zohar 2010).

According to Flin (2007), the most widely accepted definition of safety culture is "*The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management. Organisations with a positive culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures.*" (ACSNI 1993, p. 23). Based on ACSNI's (1993) definition, one of few definitions of construction safety culture abounded: "*The product of individual and group behaviours, attitudes, norms and values, perceptions and thoughts that determine the commitment to, and style and proficiency of, an organisation's system and how its personnel act and react in terms of the company's ongoing* *safety performance within construction site environments."* (Choudhry et al. 2007, p. 1008).

Notwithstanding the variation in approaches to defining safety culture, the similarities shared among those definitions is that they acknowledge safety culture as a subset of organisational culture, where the beliefs and values are typically associated with health and safety issues (Clarke 1999; Glendon & Stanton 2000). Based on the various definitions of safety culture, a set of commonly critical features among various industries was also identified. They include: (1) shared values, (2) concerned with formal safety matters and closely associated with the management and supervisory systems, (3) involvement of all members, (4) impacts on employees' work behaviour, (5) reflected in the willingness of an organisation to learn from accidents, incidents and errors, (6) indicated in the policies, procedures and systems of an organisation, and (7) stable, enduring and resistant to change (Wiegmann et al. 2004).

There have been debating regarding whether safety culture and safety climate are distinct or interchangeable terms. Whereas a number of researchers saw those terms as interchangeable, others have attempted to distinguish safety culture and safety climate concepts (Choudhry et al. 2007; Cox & Cox 1991; Guldenmund 2000; Mearns et al. 2003; Mohamed 2003; Wiegmann et al. 2004). Safety climate concept can be traced to the pioneering Zohar's (1980) study, in which safety climate was defined as a summary of *"perceptions that employees share about their work environment"* (p. 96). According to Wiegmann et al. (2004), the concepts of safety culture and safety climate share similarities in some aspects, which include*: "(1) safety climate is a psychological phenomenon that is usually defined as the perceptions of the state of safety at a particular time, (2) safety climate is closely concerned with intangible issues such as situational and environmental factors, and (3) safety climate is a temporal phenomenon, a 'snapshot' of safety culture, relatively unstable and subject to change"* (p. 124). Those above similarities make the concepts of safety culture and safety climate intermingled in practice, and thus it is accepted that safety climate can be served as an indicator of organisational safety culture (Reiman & Rollenhagen 2014; Teo & Feng 2009).

In light of the above, the relationship between safety culture, climate and management can be summarised. Kennedy, R and Kirwan (1998) noted that whereas safety culture is seen as a subset of the overall organisational culture, which determine how they act and react in relation to risks and risk control systems; safety climate and safety management (e.g. plans, procedures, process and policies) are at lower abstraction levels and are viewed to be a manifestation of the overall safety culture. Safety climate is in the form of political and symbolic aspects of the organisation and is a more tangible expression of safety culture, which in turn characterises and influences the implementation and effectiveness of safety management. Therefore, it is agreed that developing and maintaining a positive safety culture is crucial for improving organisational safety performance (Choudhry et al. 2007; Cooper 2000; Guldenmund 2000; Vecchio-Sadus & Griffiths 2004; Wiegmann et al. 2004; Zohar 2010).

2.3.3 Theoretical models of safety culture

There have been attempts to develop theoretical models of safety culture, which explain safety culture concept and determine the way by which safety culture can be measured and developed. There are two commonly used models of safety culture, including (1) component and layer models, and (2) triad models.

2.3.3.1 Component and layer models

This perspective utilises components and layers of culture to conceptualise safety culture. Reason (1997) outlined five components (or subcultures) of a safety culture. They include an informed culture, a reporting culture, a just culture, a flexible culture and learning culture. According to Reason (1997, p. 195), informed culture is "*current knowledge about the human, technical, organisational and environmental factors that determine the safety of the system as a whole*", reporting culture is "*reporting critical incidents, errors and near misses, particularly their own, in a climate of trust and without fear of reprisals*", just culture is "*understanding the delineation between unacceptable and acceptable behaviours*", flexible culture is "*the ability to reconfigure itself in the face of high-risk operations or certain kinds of emergency*", and learning culture is "*willingness and ability to understand and make changes based on safety information provided internally within the organisation and externally across the organisational interface*". Reason (1997) also argued that safety culture could be engineered based on breaking down and achieving these series of subculture. Nonetheless, hitherto, there is no empirical research on the validity and the interaction of the components of safety culture described above. Hence, based on Reason’s (1997) model, it is not clear on: (1) the mechanisms by which safety culture can be measured, and (2) the relationship between each component and other concepts of safety management (e.g. safety performance, safety behaviour, etc.) (Choudhry et al. 2007).

Guldenmund (2000) mapped the framework for safety culture which outlines three layers. The core layer consists of basic assumptions, which is about the nature of human relationship, human activity, human nature, space, time, and reality and truth (Guldenmund 2000). The middle layer comprises espoused values (i.e. justifications or attitudes towards safety measures, systems, people, and risks). The outer layer comprises particular manifestations of specific objects (e.g. personal protective equipment, safety training, inspections and posters, etc.). Accordingly, Guldenmund‘s (2000) model emphasises a linear sequence since the basic assumptions cause beliefs and value of people, which in turn affect human behaviours. Nonetheless, Cooper (2000) argued that the component and layer models of safety culture disregard the dynamic nature of culture because *“changing behaviour can also change attitude”* (Bandura 1986, p. 160). Guldenmund‘s (2000) layer model of safety culture was also criticised that the model is schematic and lacks the mechanisms to assess the concept of safety culture objectively (Choudhry et al. 2007).

2.3.3.2 Triad models

Triad models of safety culture are based on Bandura’s (1986) Social Cognitive Theory and Bandura and McClelland’s (1977) Social Learning Theory. Those theories explain psychosocial functioning with regard to triadic reciprocal causation, in which psychological factors of individuals, the contextual factors they are in and the behaviours they engage, are interacting determinants, influence each other bi-directionally (Bandura 1986; Bandura & McClelland 1977). Bandura (1986) postulated that people learn and reproduce safety behaviour by observing others. Moreover, people learn to primarily reciprocate safety behaviour that they believe will lead to positive reinforcement. It was also noted that the reciprocal influences between these factors do not coincide nor are of equal strength (Bandura 1986; Bandura & McClelland 1977).

Bandura's (1986) Social Cognitive Theory and Bandura and McClelland's (1977) Social Learning Theory offer a framework applicable for analysing safety culture for four main reasons. First, the prevalence of psychological, situational and behavioural factors indicated in those theories is precisely similar to the accident causation factors found by numerous studies (Abdelhamid & Everett 2000; Heinrich et al. 1980). Second, the dynamic nature of the relationships among those factors suits the measurement of human and organisational systems that operate in dynamic environments (Dawson 1992). Third, psychological, situational and behavioural factors offer the 'triangulation' methodology to measure and examine safety culture (Cooper 2000). Lastly, the framework provides with practical assessments and analyses for thoroughly investigating the multi-faceted and holistic nature of safety culture (Cooper 2000).

Based on Bandura's (1986) Social Cognitive Theory and Bandura and McClelland's (1977) Social Learning Theory, Geller (1994) proposed a 'Total Safety Culture' model which recognises the dynamic and interactive association between a person, environment and behaviour. In Total Safety Culture model, 'person' construct refers to psychological factors which include skills, knowledge, intelligence, abilities, motives and personality; 'environment' construct refers to managerial/environmental factors, which include procedures, operating, standards, heat/cold engineering, housekeeping, machines, tools and equipment; and 'behaviour' construct refers to actual safety-related behaviours, which include demonstrating 'actively caring', communicating, recognising, coaching and complying (Geller 1994) (See Figure 2.1). Geller (1994) further suggested ten principles to develop a total safety culture. They include: (1) the culture, not OSHA, should drive the safety process, (2) focus on process rather than outcomes, (3) focus on achieving success, instead of avoiding failure, (4) empowerment, self-esteem and belonging promote actively caring behaviours for safety, (5) behaviour-based and person-based factors determine success, (6) behaviour is directed by activators and motivated by consequences, (7) coaching and observing are main actively caring processes, (8) useful feedback occurs thorough behaviour-based and person-based coaching, (9) observation and feedback lead to safe behaviours, and (10) shift safety from a priority to a value.

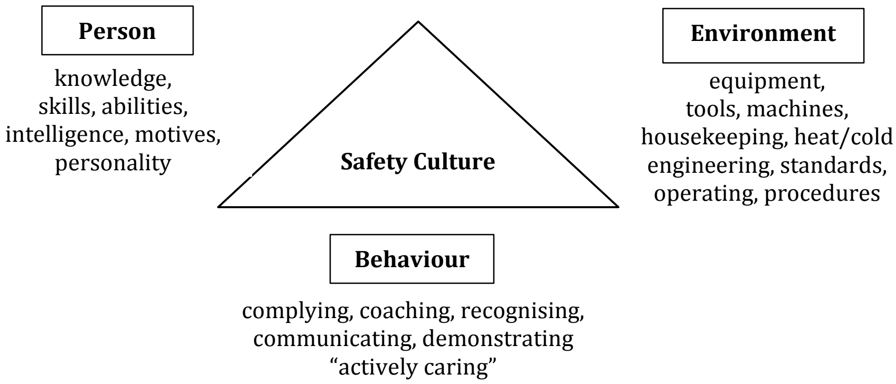


Figure 2.1: Total safety culture (Source: Geller, 1994)

Similarly, Cooper (2000) developed a reciprocal model of safety culture which comprises three components, namely internal psychological factors (how people feel), objective situational features (what the organisation has) and safety-related behaviours (what people do). Accordingly, Cooper's (2000) model and Geller's (1994) model are very similar in the components constructing safety culture. The only difference resides in the use of the term 'situation' in Cooper's (2000) model instead of 'environment' found in Geller's (1994) model. According to Cooper (2000), a reciprocal model of safety culture has its strength in allowing both the qualitative and quantitative aspects of safety culture to be explored. Psychological factors of safety culture can be assessed through a set of questions that measure people's beliefs, values, attitudes and perceptions; behaviours factors of safety culture can be assessed by outcome measures, self-report measures and/or peer observations; whereas situational factors of safety culture can be assessed through organisation's workflow systems, communication flows, control systems, management systems, operating procedures and policies (Cooper 2000).

Other researchers (Choudhry et al. 2007; Fang & Wu 2013) put forward to develop models of safety culture in the context of construction industry based on Geller's (1994) model and Cooper's (2000) model. Choudhry et al. (2007) proposed a model of construction safety culture, in which situation/environment construct is informed to reflect the situational aspects of the specific conditions and the organisation of a construction project. Another model presented by Fang and Wu (2013), which further clarifies the development of safety culture in construction projects and the particular interactive dynamism among the subcontractors, contractor and owner in a project team.

2.3.4 Traditional approach for achieving a positive safety culture

It is essential to develop a 'good' safety culture which enables organisations to gain resistance to safety risks, thereby improving safety performance. Table 2.1 shows a review of 24 studies, in which the indicators of safety climate/safety culture are presented. It is highlighted that most studies saw safety culture and safety climate concepts as interchangeable, and there is much variation in the number of indicators between studies. Accordingly to Zou (2010), seven dominant themes of indicators for a safety culture can be summarised. They include: (1) a safety knowledge database, (2) accountability and authority for safety and safe behaviour rewarded, (3) safety management systems in place, (4) extending safety management matters to all supply chain and stakeholders, (5) management commitment, (6) the belief that all accidents are preventable and unacceptable, and (7) beliefs, attitudes and commitment of employees to behave safety (Zou 2010).

Table 2.1: Safety culture/safety climate indicators

Source	Indicators
Zohar (1980)	• Safety training • Safety committee • Management attitudes • Safe promotion • Risk level at the workplace • Required work pace on safety • Safe conduct on social status • Safety officer
Dedobbeleer and Béland (1991)	• Management commitment • Worker involvement
Cox and Cox (1991)	• Personal scepticism • Safeness of work environment • Individual responsibility • Effectiveness of arrangement for safety • Personal immunity
Ostrom et al. (1993)	• Safety awareness • Teamwork • Pride and commitment • Excellence • Honesty • Communications • Leadership and supervision • Innovation • Training • Customer relations • Procedure compliance • Safety effectiveness • Facilities
Niskanen (1994)	• Work pressure • Supervision • Work value • Responsibility
Coyle et al. (1995)	• Maintenance and management issues • Company policy • Accountability • Training and management issues • Work environment • Policy and procedures • Personal authority • Training and enforcement of the policy
Lee (1995)	• Rules and procedure • Risk • Participation/ownership • Design
Donald (1995)	• Management/supervisor support • Information • Working procedures • Workgroup support • Work environment
HSE (1997)	• Reporting of accidents and near misses • Permit to work • Some obstacles to safe behaviour • Supervisor's role

Source	Indicators
	• Competence • Fellow worker influence • Personal role • Risk-taking behaviour and some contributory influences • Line management commitment • Organisational commitment and communication
Bytrom and Corbridge (1997)	• Management commitment • Organisational commitment and communication • Reporting accidents and near misses • Workmate's influence • Personal role • Risk-taking behaviour
Díaz and Cabrera (1997)	• Safety policy • Work pressure • Attitudes • Prevention strategies
Williamson et al. (1997)	• Management support • Safety system • Risk • Fatalism/optimism
Carroll (1998)	• Management support • Openness • Knowledge • Work practices • Attitudes
Flin et al. (2000)	• Management attitudes and behaviours • Safety system • Risk • Work pressure • Competence • Procedures/rules
Glendon and Litherland (2001)	• Communication and support • Adequacy of procedures • Work pressure • Personal protective equipment • Relationships • Health and safety rules
Mohamed (2002)	• Commitment • Communication • Health and safety rules and procedures • Supportive environment • Supervisory environment • Workers' involvement • Personal appreciation of risk • Appraisal of work hazards • Work pressure • Competence
Itoh et al. (2004)	• Motivation • Satisfaction with own competence • Awareness of operation • Morale • Satisfaction with manual and checklists • Satisfaction with safety management systems • Trust in management
Wiegmann et al. (2004)	• Organisational commitment • Management involvement • Employee empowerment • Reward systems • Reporting systems
Vecchio-Sadus and Griffiths (2004)	• Attitudes and behaviours • Management commitment

Source	Indicators
	• Employee involvement • Promotional strategies • Training and seminars • Special campaigns
Fang et al. (2006)	• Attitude and management commitment • Consultation and training • Supervisor's and workmate's roles • Risk-taking behaviour • Health and safety resources • Appraisal of health and safety procedure and work risk • Improper health and safety procedure • Worker's involvement • Workmate's influence • Competence
Choudhry et al. (2009)	• Management commitment and employee involvement • Procedure and work practices
Niu et al. (2016)	• Management commitment • Rules and procedures • Workers' involvement • Personal risk appreciation • Communication • Supervisory environment
Cheng, TM et al. (2016)	• Management commitment to safety • Perception of recreation safety rules • Fit between recreational environment and safety • Safety training for recreationists • Responsible managers • Emergency facilities • Caring • Altruistic safety behaviour
Zahoor et al. (2017)	• Management commitment and employees' involvement • Enforcement and promotion • Applicability of safety rules and safe work practices • Consciousness and responsibility

Although there are substantial efforts on traditional approaches for achieving a high level of safety culture, traditional safety management approaches are inadequate for organisations to ensure a state of workplace safety (Hollnagel 2008b). According to Hollnagel (2008b), traditional safety approaches emphasise on prevention and protection, which aim at eliminating hazards by preventing initiating events and/or by protecting against outcomes. Traditional safety approaches are developed based on the underlying assumptions that the workplace environment is free from unexpected events. That means: (1) the safety systems are well-designed and precisely maintained, (2) designers can foresee and anticipate every contingency, (3) procedures are complete and correct, and (4) employees behave as they are taught and as they are expected (Hollnagel 2008a). Accordingly, in order to prevent something from happening and ensure a state of safety, the effectiveness of traditional safety approaches is mainly dependent on the extent to which the safety risks are known or can be made known (Hollnagel 2008b). Hence, preventive and protective measures are useful for preventing known risks from occurring again (Hollnagel 2008b).

Today, it is widely acknowledged that accidents can occur as a result of a combination of a dysfunctional and an unexpected event or missing preventive and protective measures rather than to single failures in organisations (e.g. the organisational errors and violations of operating procedures) (Mitropoulos et al. 2005; Rasmussen 1997; Reason 1997). In consideration of the predictability and the origin of threats, and the potential to disrupt the organisation to the state of safety, Westrum (2017) argued that irregular threats and unexampled events are unusual and infrequent, and thus they cannot be managed in the traditional approaches of safety management (i.e. protective and preventive measures).

In the construction industry, as construction projects are unique and built in a changing and unstructured environment due to their inherent complexities (e.g. changes and uncertainties in designs, methods, production and economic pressures, technology, work tasks, quality and project team, etc.), safety risks on construction sites seem to be inevitable, changing and unforeseen (Zhou et al. 2015). As a result, there are many unexpected circumstances in which the needed protective and preventive safety measures are absent or existing safety measures are bypassed (Mitropoulos et al. 2005). Also, safety strategies (e.g. supervision, inspections, training, penalties, enforcement, motivation, etc.) emphasise liability and competency and aim at promoting workers' participation and compliance with safety (Mitropoulos et al. 2005). However, Hollnagel (2008b) argued that "*humans generally are generally seen as fallible and unreliable, as 'proved' by countless examples of 'human error'*" (p. 222).

In light of the above, a safety culture developed based on traditional safety management approaches can be effective in addressing known risks, but may not inadequate for organisations in responding all of the changing and unforeseen safety risks related to the complex nature of construction projects. In order to ensure a state of workplace safety, construction organisations should not only look to the past and take precautions against the accidents that have happened but also establish the capability to address potential new shapes of safety risks. A number of researchers advocated a need for moving towards a new perspective and techniques of safety management, which is found in resilience engineering (Bergström et al. 2015; Harvey et al. 2016; Pęciłło 2016).

2.4 Resilience engineering

2.4.1 Resilience concept

The concept of resilience was proposed by Holling (1973) in an ecological study to give insights into (1) a system (e.g. organisation, society or ecosystem) that persists in a state of stability, and (2) how these systems behave when they are stressed and move from this stability. Accordingly, resilience is considered as those features that enable an organisation to cope with, adapt to and recover from a disaster event (Buckle et al. 2000; Mallak 1998). There are numerous definitions of resilience existing in the literature. Table 2.2 summarises commonly cited definitions of resilience. These definitions reflect that: (1) resilience is 'an ability' or 'the capability' of an organisation to 'adapt/react, learn and anticipate' in order to address changes, variations, etc. (Pęciłło 2016), (2) resilience is a property of organisation, and (3) the development of organisational resilience is a continuing process (Woods & Hollnagel 2006). For examples, Woods (2017) defined resilience as the organisation's capability to create foresight, to recognise, to anticipate the changing shape of risk before adverse consequences happen. Becker et al. (2014, p. 7) considered resilience as an "*emergent property determined by society's ability to anticipate, recognise, adapt and learn from variations, changes, disturbances, disruptions and disasters that may cause harm to what human beings value*".

Table 2.2: Resilience definitions

Reference	Definition of resilience
Sheffi (2005)	The inherent ability to keep or recover a steady state, thereby allowing it to continue normal operations after a disruptive event or in the presence of continuous stress
McDonald (2006)	The properties of being able to adapt to the requirements of the environment and being able to manage the environments variability
Wreathall (2006)	The inherent ability of a system to adapt its functioning before and during disturbances, so that it can continue operations after a major mishap or in the presence of continuous stresses
Leveson et al. (2006)	The ability of systems to prevent or adapt to changing conditions in order to maintain (control over) system property
Vogus and Sutcliffe (2007a)	The ability of an organisation to absorb strain and improve functioning despite the presence of adversity
Chialastri and Pozzi (2008)	Refers to the broader definition of adaption, whether the system can handle variations that fall outside the design envelope
Sheridan (2008)	Aims at improving a systems capacity to cope with unexpected disturbances
Woods (2009)	Resilience, as a form of adaptive capacity, is a system's potential for adaptive action in the future when information varies, conditions change, or new kinds of events occur, any of which challenge the viability of previous adaptations, models, or assumptions
Becker et al. (2014)	Emergent property determined by society's ability to anticipate, recognise, adapt and learn from variations, changes, disturbances, disruptions and disasters that may cause harm to what human beings value
Wildavsky (2017)	The capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back
Woods (2017)	The capability of a system to create foresight, to recognise, to anticipate the changing

Reference	Definition of resilience
	shape of risk before adverse consequences happen
Hollnagel (2017)	The ability of a system or an organisation to react and recover from disturbances at an early stage, with minimal effects on dynamic stability
Westrum (2017)	Ability to prevent something bad from happening or the ability to prevent something bad from becoming worse, or the ability to recover from something bad once it has happened

Lengnick-Hall et al. (2011) also summarised two major aspects of the definitions of organisational resilience. The first aspect of organisational resilience emphasises *"an ability to rebound from unexpected, stressful, adverse situations and to pick up where they left off"*; whereas the second aspect stresses on *"an ability to effectively absorb, develop situation-specific responses to, and ultimately engage in transformative activities to capitalise on disruptive surprises that potentially threaten organisation survival"* (Lengnick-Hall et al. 2011, p. 244). It was also noted that the capacity of an organisation for resilience is embedded in a set of (1) individuals' abilities, skills and knowledge, (2) organisational routines and processes, and (3) organisational settings of adjustable and diversity integration, that enables to overcome the potentially threaten organisation survival (Beck & Lengnick-Hall 2016).

Organisational resilience is a multidimensional concept (Akgün & Keskin 2014; Lengnick-Hall et al. 2011). A review of the literature by Pillay et al. (2010) identified the three dimensions of organisational resilience, which include: (1) cognitive resilience, (2) contextual resilience, and (3) behavioural resilience. Cognitive resilience is an organisational capability that enables an organisation to notice shifts, interpret unfamiliar situations, analyse options, and figure out how to respond under the conditions that are disruptive, uncertain, surprising, and have the potential to jeopardise the organisation's long-term survival.

Cognitive resilience requires six specific employees' contributions: (1) expertise, (2) opportunism, (3) creativity, (4) conceptualising solutions that are novel and appropriate, (5) questioning fundamental assumptions, and (6) decisiveness despite uncertainty (Lengnick-Hall et al. 2011).

Behavioural resilience consists of the established behaviours and routines that enable an organisation to learn more about a situation, implement new routines, and fully use its resources. For behavioural resilience, employees are required to have contributions, which include: (1) taking actions before they are required to ensure that an organisation is able to benefit from situations that emerge, (2) practicing repetitive, over-learned routines that provide the first response to any unexpected, (3) combining originality and initiative to capitalise on an immediate situation, (4) sometimes following a dramatically different course of behaviour from that which is the norm for the organisation, and (5) devising unconventional, yet robust responses to unprecedented challenges (Lengnick-Hall et al. 2011).

Contextual resilience is the combination of interpersonal connections, resource stocks, and supply lines that provide the foundation for quick actions. Contextual resilience can be reflected through (1) sharing decision making widely, (2) sharing knowledge and information broadly, and (3) establishing interpersonal connections and resource supply lines that lead to the ability to act quickly (Lengnick-Hall et al. 2011).

2.4.2 Resilience engineering perspective of safety management

Resilience engineering approach has been recognised as a potential solution to the lack of effectiveness of traditional approaches in responding to the changing and unforeseen safety risks associated with the increasingly complex nature of sociotechnical systems (Pęciłło 2016). Unlike traditional risk management approaches, which consists of a posteriori improvement activities based on accident analysis and occupational risk assessment, resilience engineering is a proactive safety management approach that looks for ways to enhance the ability of organisations to explicitly monitor risks, and to make appropriate trade-offs between required safety levels and economic and production pressures (Woods 2003). The proponent of resilience engineering recognised that many adverse events could not be attributed to a breakdown or malfunctioning of components and normal system functions, but instead understood as the results of unexpected combinations of normal performance variability (Hollnagel 2011). Accordingly, an accident does not represent a failure of systems in dealing with risks but instead implies that the systems fail in adaptions necessary to cope with the real world complexity (Woods 2010). Therefore, whereas traditional approaches of safety management focus on 'what went wrong', resilience engineering approach recognises that the 'things that go right' are as important as 'things that go wrong' for safety performance improvement (Hollnagel 2011). In addition, whereas traditional approaches of safety management are based on hindsight, error tabulation and the calculation of failure possibilities; resilience engineering approach puts forwards developing an organisation's capability to create foresight, recognise and anticipate the changing shape of risks before adverse consequences occur (Woods & Hollnagel 2006).

A review by Bergström et al. (2015) summarised that there are two interconnected lines of reasoning for resilience engineering, which include: (1) resilience engineering is an increasingly adopted concept to cope with the growing complexity of socio-technical systems, and (2) resilience engineering is considered as an approach to address inherent risks and hazards, that emerge from this increasing complexity. The growing complexity in those systems leads to potentially disastrous failure modes and new shapes of safety risks, thereby forming a need for resilience engineering (Bergström et al. 2015; Lundberg & Rankin 2014; Shirali et al. 2013).

Identifying the threats to the state of safety that resilience protects against is crucial in providing implications for developing resilient systems (Westrum 2017). Westrum (2017) classified threats to the system into three types (i.e. regular threat, irregular threat and unexampled event). Regular threats are those that frequently happen enough for the system to develop a standard response and set resources aside for such situations. Irregular threats are described as 'low probability' but potentially catastrophic events. Irregular threats are not considered impossible, but the rarity of these events makes it impossible to develop a standard process. Unexampled threats are so unexpected that they push the respondents outside of their collective experience envelope (Westrum 2017).

The fundamental idea behind resilience engineering is that, in a world of limited resources, irreducible unpredictability and multiple conflicting goals, an organisation manages safety risks proactively and creates safety via four resilience processes (or capabilities), which includes anticipating (knowing what to expect), monitoring (knowing what to look for), responding (knowing what to do) and learning (knowing what can happened) (Hollnagel 2013; Pęciłło 2016; Shirali et al. 2015). Hollnagel (2016, p. 120) summarised four capabilities representing the resilient systems as follows:

- Responding (knowing what to do), that is, "*how to respond to the regular and irregular disruptions and disturbances through implementing a full and a ready set of responses or through adjusting normal functions. This is the ability to address the actual*" (Hollnagel 2016, p. 120). In order to respond to the threats, threats must be detected beforehand, identified in the events, recognised that the response is appropriate, and provided with required resources. Regarding the types of threat discussed above, Hollnagel (2016) suggested that this capability is feasible to address regular threats.

- Monitoring (knowing what to look for), that is, "*how to monitor something that is a threat or can become a threat in the near future. Monitoring must cover both that which happens in the environment and what happens in the system itself, i.e., system performance. This is the ability to address the critical*". Accordingly, in monitoring, a set of pre-defined indicators of regular threats are checked to see whether they change and whether they require a readiness to respond.

- Anticipating (knowing what to expect), that is, "*how to anticipate more developments, threats, and opportunities in the future, such as the potential changes, disturbances, pressures, and their consequences. This is the ability to address the potential*". The aim of anticipating is therefore to identify possible future events, conditions, or state changes that should be prevented or avoided. The major difference between monitoring and anticipating is that anticipating focuses on irregular threats, whereas the target of monitoring is regular threats.

- Learning (knowing what has happened), that is, "*how to learn from experiences, in particular, to learn the right lessons from the right experience. This is the ability to address the factual*". Hollnagel (2016) also noted that, in terms of learning, there is the difference between resilience engineering and traditional approaches of safety management: (1) resilience engineering extends learning experiences from both failures and successes, (2) resilience engineering seeks for the dependencies among functions and the variabilities of those functions rather than the relationships between causes and effects, and (3) learning in a resilient system is continuous and driven by a plan and strategy rather than by specific events.

In light of the above, resilience engineering theory has some implications for safety management. First, as resilience engineering theory is based on four resilience processes (i.e. responding, monitoring, anticipating and learning), the resilience processes (or capabilities) can be served as the theoretical basis for developing and implementing safety management practices for safety performance improvement in any workplace environments. Second, as a resilient organisation is characterised by those four capabilities, the level of organisational resilience can be determined based on the four resilience capabilities.

2.4.3 Application of resilience engineering in safety management

Resilience engineering has been advocated as a new safety management paradigm in order to address the complex nature of sociotechnical systems. The review of Righi et al. (2015) indicated that previous research of resilience engineering have contributed to the safety literature by focusing on developing: (1) theory of resilience engineering, (2) safety management tools, (3) identification and classification of resilience, (4) safety training, (5) analysis of accidents, and (6) risk assessment. Regarding safety management tools development, there has been a number of studies on the management and measurement of resilience. Komatsubara (2011) proposed a model of safety management to identify the situations in which resilience is required and its demanded resources. Other studies focused on developing the measurement of organisational resilience. Accordingly, the indicators for assessing organisational resilience level are identified (Azadeh et al. 2014; Dinh et al.

2012; Shirali et al. 2013; Shirali et al. 2012; Shirali et al. 2015). For examples, Shirali et al. (2013) identified six indicators for assessing organisational resilience. They include flexibility, preparedness, awareness and opacity, learning culture, just culture and top management commitment. Nonetheless, as those studies failed to address the relationship between organisational resilience and other concepts of safety management (e.g. safety performance, safety behaviour, etc.), it is not clear how resilience engineering perspective of safety management impacts on safety performance. Other studies put forwards to apply resilience engineering approach for measuring and improving safety management systems (Pęciłło 2016; Saurin & Carim Júnior 2011). However, in the construction industry, the findings by Pęciłło's (2016) empirical study failed to establish the relationship found between the implementation of safety management systems and either organisational resilience level or safety level.

2.5 Resilient safety culture

Studies (Akselsson et al. 2009; Shirali et al. 2016) advocated the concept of resilient safety culture for safety management. Resilient safety culture concept has emerged from a systemic view of safety and risk management in complex systems. Safety is the product of the operating state of an organisation, which changes dynamically in response to three types of pressure, including: (1) safety pressures that push the operating state away from the boundary of unacceptable safety risk, (2) least effort pressures that force the state away from the boundary of unacceptable workload, and (3) efficiency pressures that push the state away from the edge of economic breakdown. Because the environment is dynamic, the operating point moves continuously, thereby causing the level of risks also changes continuously. The risk of an accident increases when the distance from its operating position to the unacceptable safety risk boundary decreases (Cook & Rasmussen 2005).

In order to avoid accidents, Akselsson et al. (2009) considered safety culture as a counterforce which avoids its migration beyond the boundary of unacceptable performance. Since the precise location of the boundary of unacceptable safety risk is uncertain in practices, uncertainty about the location of the operating point and the dynamics of its movement may result in an unintentional crossing of the unacceptable safety risk boundary (Cook & Rasmussen 2005). Therefore, resilience is needed as the ability of an organisation to keep or recover quickly to a stable state, allowing it to continue operations during and after a major mishap or in the presence of significant continuous pressures (Wreathall 2006). Resilience engineering involves developing an organisation's capability to create foresight, to recognise, to anticipate the changing shape of risk before negative consequences happen (Woods & Hollnagel 2006). In view of the above, Akselsson et al. (2009, p. 4) defined resilient safety culture as *"an organisational culture that fosters safe practices for improved safety in an ultra-safe organisation striving for cost-effective safety management by stressing the resilience engineering, organisational learning and continuous improvements"*. Shirali et al. (2016) quantitatively evaluated the resilience safety culture in a petrochemical plant. In their study, resilient safety culture is developed by adopting principles of resilience engineering into safety culture model developed by Reason (1997). As a result, thirteen indicators representing the resilient safety culture were identified, which include competency, involvement of staff, accident investigation, safety management system, awareness, flexibility, management commitment, reporting culture, preparedness, risk assessment, learning culture, management of change and just culture. The results of Shirali et al.'s (2016) study enable the managers and policy makers to identify current weaknesses relating to resilient safety culture in their organisations.

2.6 Summary

Review of project complexity reveals that the construction project complexity is considered as the inherent characteristics of a project and results from the interaction of various factors with dynamic and uncertain properties. Project complexity could be categorised into three groups of factors, namely technical, organisational and environmental. Technical aspect of project complexity includes goals, scope, tasks and technology. Organisational aspect includes size, resources, project team and trust. Environmental aspect includes external stakeholders, location and market conditions. From a perspective of safety management, it is argued that increasing complexity of an organisation leads to an increase in changing and unforeseen safety risks, thereby making the organisation more vulnerable to accidents. Nonetheless, little empirical evidence was found in the literature to support this assumption.

The review of safety culture shows that safety culture is a subset of the overall organisational culture and that developing and maintaining a positive safety culture is crucial for improving safety performance in construction workplaces.

It is also indicated that although there are substantial efforts on traditional approaches for achieving a high level of safety culture, traditional safety culture approach may be inadequate for organisations to address all of the changing and unforeseen safety risks associated with the complex nature of construction projects.

The review of resilience engineering reveals that resilience engineering approach has been advocated as a potential solution to the lack of effectiveness of traditional approaches in responding to the changing and unforeseen safety risks associated with the increasingly complex nature of sociotechnical systems. Organisational resilience can be measured by three dimensions, namely cognitive, behavioural and contextual. From the resilience engineering perspective, an organisation manages safety risks based on four resilience processes (or capabilities) (i.e. responding, monitoring, anticipating and learning).

In applying resilience engineering approach in developing safety management tools, the previous research has made significant contributions in introducing resilience into workplace health and safety and developing the concept of resilient safety culture as a promising concept for addressing the limitation of traditional safety culture and achieving an ultra-safe organisation. Nonetheless, previous studies failed to: (1) examine the dimensions of resilient safety culture, which has been recognised as a multidimensional concept, (2) provide the guidance on how to improve and maintain resilient safety culture in organisations, and (3) explain how an organisation with a high level of resilient safety culture sustains their safety performance improvement under the changing complexity levels of its working conditions. Therefore, this study investigates the development of resilient safety culture in the construction environment by (1) identifying the dimensions of resilient safety culture of construction projects, (2) explaining how a resilient safety culture can be created in a construction organisation, and (3) examining the impact of resilient safety culture on safety performance under the changing complexity levels of construction projects. Insights on these three issues are likely to enhance our understanding of resilient safety culture concept and provide the theoretical basis for establishing an ultra-safe construction organisation, which is expected to achieve consistently high safety performance regardless of the changing complexity levels of its construction projects. In line with this, next chapter will integrate the three research objectives and the pertaining literature review for proposing research hypotheses and developing a conceptual model.

CHAPTER 3 THEORETICAL FRAMEWORK

3.1 Introduction

This chapter presents the theoretical framework for this research. The research objectives and literature review are integrated for proposing research hypotheses and developing a theoretical model.

3.2 Conceptualising resilient safety culture of construction projects

The review of safety culture theory indicates that triad models of safety culture developed by many researchers recognise psychological, situational and behavioural variables as three dimensions to measure organisational safety culture, and thus provide a useful framework for measuring and examining the reciprocal interactions between psychological, situational and behavioural safety-related factors for safety performance improvement in different settings (See Section 2.3). Specifically, the assessments of psychological, situational and behavioural dimensions of safety culture are practically useful for reflecting the strengths and weaknesses of safety management practices, thereby guiding the appropriate remedial actions. Triad models can also be used to provide insights into the relationships between each dimension and how each of these interacts with safety outcome measures (e.g. accident rates) (Choudhry et al. 2007; Cooper 2000; Fang & Wu 2013; Geller 1994).

The review of resilience engineering theory suggests that cognitive resilience, contextual resilience and behavioural resilience are three dimensions of organisational resilience (Lengnick-Hall et al. 2011; Pillay et al. 2010) (See Section 2.4). In addition, the resilience engineering approach suggests that a resilient organisation manages safety risks (i.e. regular threats, irregular threats and unexpected events) via four resilience capabilities (i.e. anticipating, monitoring, responding and learning) in order to ensure a state of workplace safety. Therefore, the resilience processes (or capabilities) can be served as the theoretical basis for developing and implementing safety management practices in any workplace environments. The level of organisational resilience can be determined based on the four resilience capabilities.

A comparison of the safety culture dimensions and organisational resilience dimensions reveals a similar factor structure of both concepts, and therefore it can be inferred that the concept of resilient safety culture can also be measured and examined under the framework of the psychological/cognitive, situational/contextual and behavioural factors. Resilience engineering theory enhances the concept of organisational safety culture to manage construction safety risks via four resilience capabilities (i.e. anticipating, monitoring, responding and learning).

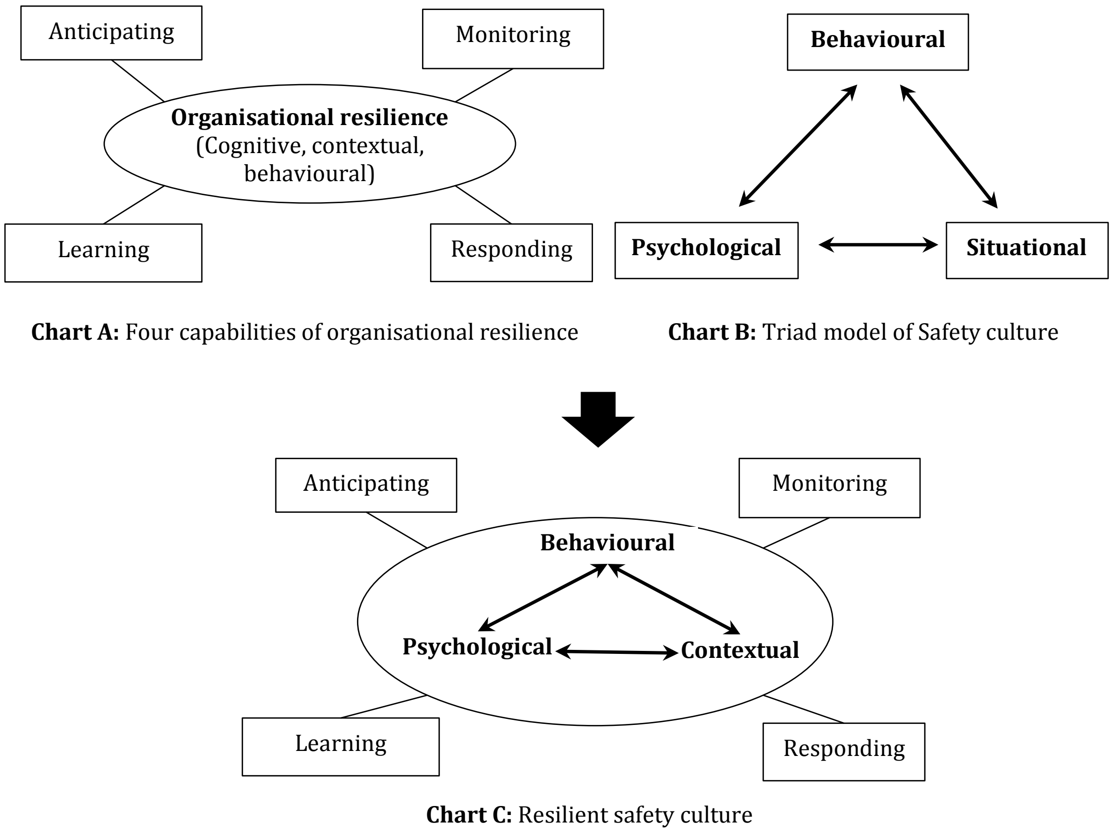


Figure 3.1: Integration of resilience engineering theory and safety culture theory for conceptualising resilient safety culture

In summarising the above literature review, Figure 3.1 depicts the integration of resilience engineering theory and safety culture theory for conceptualising resilient safety culture. Chart A presents the mechanisms by which a resilient organisation manages safety risks. Accordingly, organisational resilience (i.e. cognitive, contextual and behavioural resilience) is determined by its four capabilities (i.e. anticipating, monitoring, responding and learning). Chart B depicts three dimensions (i.e. psychological, situational and behavioural) for measuring safety culture of an organisation and examining the reciprocal interactions among those dimensions. Chart C integrates the approaches of resilient organisations' capabilities (Chart A) and measuring safety culture (Chart B). Therefore, in this study, resilient safety culture is defined as *an organisation's psychological/cognitive, situational/contextual and behavioural* *capabilities to 'anticipate, monitor, respond and learn' in order to manage safety risks and create an ultra-safe organisation.* Accordingly, resilient safety culture is characterised by the following three dimensions: (1) psychological resilience, (2) contextual resilience, and (3) behavioural resilience*.* Thus, hypothesis 1 is set out:

Hypothesis 1 – Resilient safety culture is characterised by psychological resilience, contextual resilience and behavioural resilience.

3.3 Drivers for resilient safety culture

Resilience engineering theory suggests that identifying the threats that resilience protects against provides implications for developing resilient systems (Westrum 2017). Westrum (2017) classified threats to the resilience system into three types: regular threat, irregular threat and unexampled event (See Section 2.4). Thus, in order to create an ultra-safe working environment characterised by resilient safety culture, it is necessary to systematically address the potential threats to the state of workplace safety.

Based on the review of existing theories and notions of safety in construction, it is indicated that the state of workplace safety in an organisation is impacted by 3 types of potential threats including project hazards (regular threats), human errors (irregular threats) and unexpected failures (unexampled events) (International Labour Office 1970; Kerr 1957; Reason 1990; Rochlin 1996). Therefore, drivers of resilient safety culture are identified by responding to the three types of potential threats based on the Latent Failure Model (Reason 1990), Human error theories (International Labour Office 1970; Kerr 1957) and High-Reliability Theory (Rochlin 1996).

3.3.1 Hazard prevention practice

Latent failure model (metaphorically called the Swiss cheese model) was developed by Reason (1990). According to this model, organisations make efforts to prevent accidents by defences (slides of 'cheese') in order not to allow the hazards become losses. The 'holes' in each 'slide of cheese' indicate that none of these defences is perfect. Therefore, when these 'holes' line up, accidents will occur. In contrast, in case that the line-up of 'holes' is stopped by one of these defences, accidents are prevented, namely incidents. In addition, Reason (1990) also used the term failures to refer to the imperfections of each defence, namely the latent and active failures. Latent failure refers to failures of an organisation that produce a negative effect, but its consequences are not activated until other enable conditions are met. Latent failures can include inadequate maintenance management, insufficient training, poor procedures, inappropriate materials, design failures, inadequate control and monitoring, poor planning and scheduling, inadequate communications and organisational deficiencies. Additionally, active failures are unsafe acts of workers, and its negative consequences are easily noticed (Reason 1993). The concept of 'defences' in Reason's (1990) latent failure model implies that project hazard is a type of potential threats to the state of workplace safety that needs to be detected and controlled by hazard prevention practice before they combine with unsafe behaviours of workers in order to prevent accidents in the workplaces. Thus, it is reasonably inferred that hazard prevention practice is one of the drivers of resilient safety culture. Therefore, hypotheses 2, 3 and 4 are set out:

Hypothesis 2 – Hazard prevention practice has a positive impact on psychological resilience.

Hypothesis 3 – Hazard prevention practice has a positive impact on contextual resilience.

Hypothesis 4 – Hazard prevention practice has a positive impact on behavioural resilience.

3.3.2 Error management practice

Rigby (1970) defined human error as any set of human actions that exceed some limit of acceptability. Human error theories consider human aspects as the main causes of accidents. Human error theories can be categorised into two main approaches including behaviour models and human factor models (Abdelhamid & Everett 2000). Behaviour models study the tendency of human to make errors under various situational conditions and identify human characteristics as the main cause of errors (e.g. accident proneness theory (International Labour Office 1970), goals freedom alertness theory (Kerr 1957) and motivation reward satisfaction theory (Petersen 1975)). Human factors models posit that extreme environment characteristics and overload of human physical and psychological capabilities are factors that contribute to human error (e.g. Ferrell's human error theory). Human error theories enhance Reason's (1990) latent failure model by providing the understandings of how active failures (or unsafe acts of workers) occur within hazardous working environments. Those theories imply that human error is a type of potential threats to the state of workplace safety that needs to be managed by error management practice in order to prevent accidents in the workplaces. Thus, it is reasonably inferred that error management practice is one of the drivers of resilient safety culture. Therefore, hypotheses 5, 6 and 7 are set out:

Hypothesis 5 – Error management practice has a positive impact on psychological resilience.

Hypothesis 6 – Error management practice has a positive impact on contextual resilience.

Hypothesis 7 – Error management practice has a positive impact on behavioural resilience.

3.3.3 Mindful organising practice

Although Reason's (1990) latent failure model acknowledges that none of 'defences' are perfect, it does not explain how failures at different layers of 'defence' come into existence. Accidents still occur since unexpected failures are produced without awareness. The high-reliability theory may address the limitation of Reason's (1990) latent failure model by enhancing the organisation's capability of anticipating and controlling the unexpected failures. High-reliability theory began with studies exploring a distinct and special class of organisations, which operate in hazardous conditions (LaPorte & Consolini 1991; Rochlin 1996). Accordingly, the term 'high-reliability organisation' refers to those organisations that successfully avoid such failure while providing adaptive organisational forms under an increasingly complex environment (Weick et al. 2008). From the most effective practices in high-reliability organisations and accident investigations, high-reliability theory assumes that mindfulness is the key concept for organisations to sustain their safety performance (Weick et al. 2008). Mindfulness is defined as a conceptual mechanism allowing organisations to maintain continuing awareness, recognise what should receive attention and inform how to process given the information gathered (Weick et al. 2008). The state of mindfulness is created by mindful organising practice, which includes preoccupation with failure, sensitivity to operations, reluctance to simplify interpretations, deference to expertise and commitment to resilience (Sutcliffe 2011; Weick et al. 2008). High-reliability theory implies that unexpected failure is a type of potential threats to the state of workplace safety that needs to be managed by mindful organising practice in order to prevent accidents in the workplaces. Thus, it is reasonably inferred that mindful organising practice is one of the drivers of resilient safety culture. Therefore, hypotheses 8, 9 and 10 are set out:

Hypothesis 8 – Mindful organising practice has a positive impact on psychological resilience.

Hypothesis 9 – Mindful organising practice has a positive impact on contextual resilience.

Hypothesis 10 – Mindful organising practice has a positive impact on behavioural resilience.

3.4 Resilient safety culture, project complexity and safety performance

3.4.1 Project complexity and safety performance

Normal Accident Theory (NAT) assumes that accidents involve the unanticipated interaction of a multitude of events in a complex system rather than as a result of a few or a number of component failures. Accordingly, Perrow (1994) identified two interacting variables that specify a space, which fully characterises accidents, namely coupling and complexity. NAT postulates that the more tightly coupled and complex a system is, the more vulnerable it is to accidents. Interactions are the reciprocal actions among elements of the system. The interactions are linear or complex. Linear interactions are those in expected and familiar, visible and understandable. In contrast, complex interactions are those of unfamiliar sequences, or unplanned and unexpected sequences and either not visible or not immediately comprehensible (Perrow 1994).

NAT implies that the inherent changing and unforeseen shape of safety risks of construction projects are positively associated with the complexity level of the project. The review of project complexity indicates the three project complexity dimensions, namely technical, organisational and environmental (See Section 2.2). Therefore, hypotheses 11, 12 and 13 are set out:

Hypothesis 11 – Technical complexity has a negative impact on safety performance.

Hypothesis 12 – Organisational complexity has a negative impact on safety performance.

Hypothesis 13 – Environmental complexity has a negative impact on safety performance.

3.4.2 Resilient safety culture and safety performance

The use of triad model of safety culture for examining resilient safety culture concept in this study is theoretically supported by Bandura's (1986) Social Cognitive Theory and Bandura and McClelland's (1977) Social Learning Theory. Specifically, the prevalence of psychological, behavioural and contextual dimensions indicated in those theories is precisely similar to the accident causation factors found by numerous studies (Abdelhamid & Everett 2000; Heinrich et al. 1980). In addition, the dynamic nature of the reciprocal relationships among those dimensions influencing organisational goal achievements (e.g. influence of any dimensions on goal achievements may not be simultaneously exerted by other two dimensions) suits the measurement of human and organisational systems that operate in dynamic environments (Dawson 1992). Cooper (2000) further asserted that triad model provides a framework to establish: (1) whether or not the reciprocal relationships between the three dimensions hold in different settings, and (2) under what conditions do the relationships alter. Therefore, the triad model could be used for examining: (1) the relationships between each dimension of resilient safety culture and safety performance (e.g. accident rates), and (2) the reciprocal interactions between these dimensions on safety performance. The following hypotheses are set out:

Hypothesis 14 – Psychological resilience has a positive impact on safety performance.

Hypothesis 15 – Contextual resilience has a positive impact on safety performance.

Hypothesis 16 – Behavioural resilience has a positive impact on safety performance.

Hypothesis 17 – Safety performance is impacted by the interaction between psychological resilience and contextual resilience.

Hypothesis 18 – Safety performance is impacted by the interaction between behavioural resilience and contextual resilience.

Hypothesis 19 – Safety performance is impacted by the interaction between behavioural resilience and psychological resilience.

3.4.3 Interactions of project complexity and resilient safety culture on safety performance

As discussed earlier, the inherent increasing complexity of construction projects is associated with more changing and unforeseen shape of safety risks of construction projects, thereby being hypothesised to have a negative impact on safety performance. Resilient safety culture aims to develop an ultra-safe organisation which is characterised by continuous improvements of safety performance and the capability of creating foresight, recognising and anticipating the changing shape of safety risks in the complex sociotechnical systems. It is possible that, in those construction projects with higher levels of resilient safety culture, organisations have better capabilities to manage safety risks, thereby mitigating the adverse impact of project complexity on safety performance. Based on this proposition, the following hypotheses are set out:

Hypothesis 20 – The impact of project complexity on safety performance becomes weaker when there is a higher level of psychological resilience.

Hypothesis 21 – The impact of project complexity on safety performance becomes weaker when there is a higher level of contextual resilience.

Hypothesis 22 – The impact of project complexity on safety performance becomes weaker when there is a higher level of behavioural resilience.

3.5 Conceptual model for resilient safety culture

The hypotheses developed in Sections 3.2, 3.3 and 3.4 are integrated into a conceptual model for resilient safety culture. The main variables and their hypothesised relationships are indicated in the conceptual model (See Figure 3.2).

First, the model describes how resilient safety culture is measured. Figure 3.2 indicates that resilient safety culture could be studied by its three dimensions for empirical testing in this study: (1) psychological resilience, (2) contextual resilience, and (3) behavioural resilience (hypothesis 1). The measurement method reflects the definition of resilient safety culture by integrating the approaches of measuring safety culture and resilient systems. The measurement of resilient safety culture dimensions can be found in Section 4.3.1.1.

Second, the model describes how resilient safety culture can be created in a construction organisation by systematically responding to the potential threats that resilience protects against. Figure 3.2 shows that hazard prevention practice, error management practice and mindful organising practice are three distinct safety management approaches that systematically address the potential threats (i.e. project hazards, human errors and unexpected failures) to the state of construction workplace safety and drive the development of resilient safety culture. Accordingly, hazard prevention practice has positive impacts on three dimensions of resilient safety culture (hypotheses 2, 3 and 4); error management practice has positive impacts on three dimensions of resilient safety culture (hypotheses 5, 6 and 7); mindful organising practice has positive impacts on three dimensions of resilient safety culture (hypotheses 8, 9 and 10). Hazard prevention practice could be characterised by ten dimensions, which include safety policy, site safety organisation, safety meeting, safety inspection, safety training, safety promotion, risk assessment and hazard analysis, personal protection program, hazard control program and management support. Error management practice could be characterised by four dimensions, which include learning from errors, thinking about errors, error competence and error communication. Mindful organising practice could be characterised by five dimensions, which include preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience and deference to expertise. The measurements of hazard prevention practice, error management practice and mindful organising practice can be found in Sections 4.3.1.2, 4.3.1.3 and 4.3.1.4, respectively.

Third, the model describes how safety performance is impacted by resilient safety culture and project complexity. It is shown in Figure 3.2 that technical project complexity, organisational project complexity and environmental project complexity have negative impacts on safety performance (hypotheses 11, 12 and 13). Resilient safety culture dimensions have positive impacts on safety performance (hypotheses 14, 15 and 16). Safety performance is impacted by the interactions among three dimensions of resilient safety culture (hypotheses 17, 18 and 19). The impact of project complexity on safety performance is moderated by three dimensions of resilient safety culture (hypotheses 20, 21 and 22). The measurements of project complexity and safety performance can be found in Sections 4.3.1.5 and 4.3.1.6, respectively.

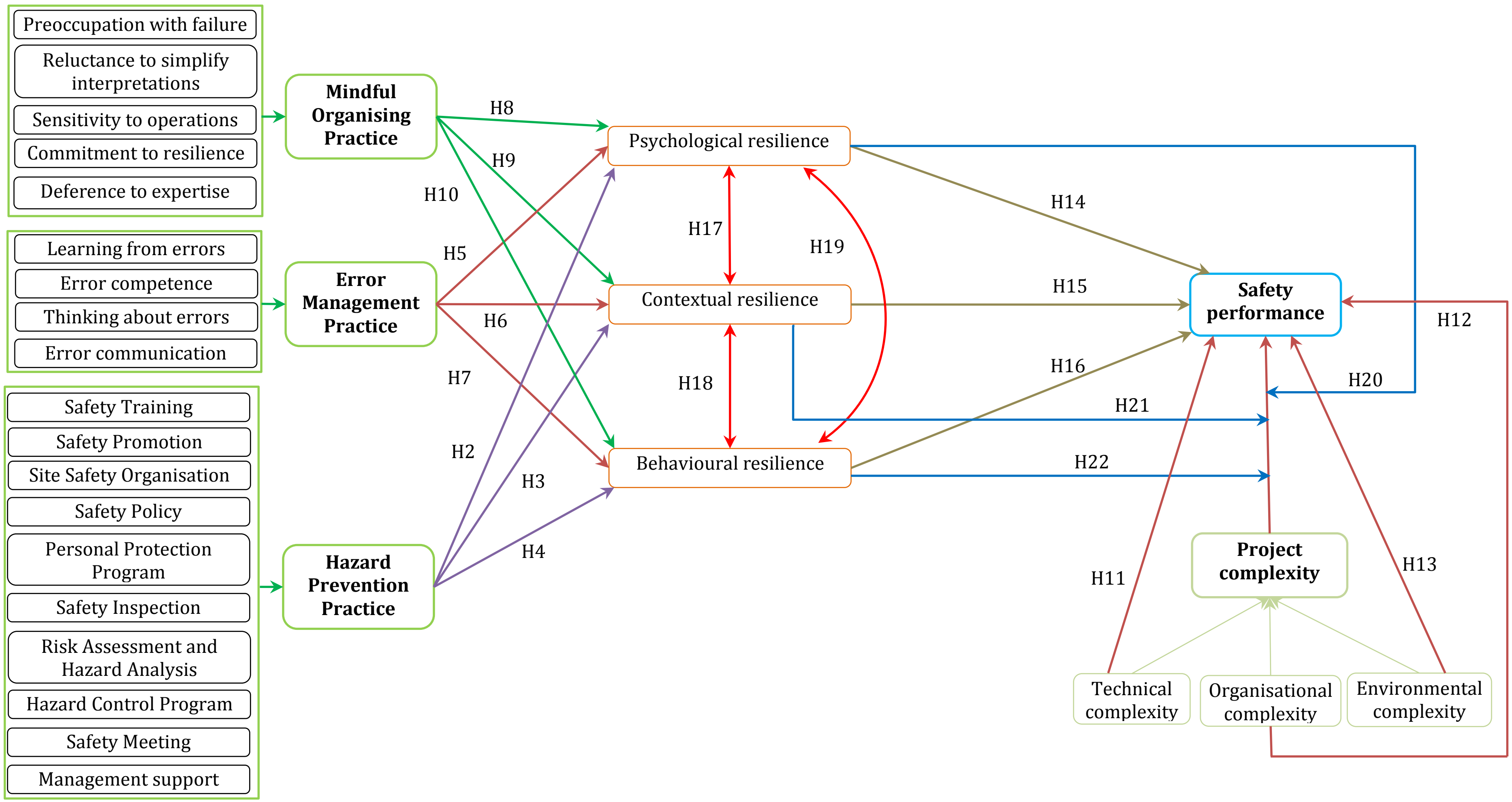


Figure 3.2: Conceptual model for resilient safety culture

3.6 Summary

In this chapter, a conceptual model for resilient safety culture was developed based on the safety culture theory, resilience engineering theory, latent failure model, human error theory, high-reliability theory and normal accident theory. Based on safety culture theory and resilience engineering theory, the conceptual model proposes a measurement method for resilient safety culture of construction projects. Based on latent failure model, human error theory and high-reliability theory, the conceptual model and its hypotheses explain how resilient safety culture can be created in a construction organisation by systematically responding to the potential threats that resilience protects against. Based on the implications of normal accident theory, the conceptual model and its hypotheses depict the interactive effects of project complexity and resilient safety culture on safety performance of construction projects.

CHAPTER 4 RESEARCH METHODOLOGY

4.1 Introduction

This chapter presents the research methodology of this research. Justifications for selecting a particular method over other methods are provided in the corresponding sections. Section 4.2 describes a research design. Section 4.3 focuses on data collection. Section 4.4 specifies data analysis methods.

4.2 Research design

A research design is a plan, structure and strategy of an investigation so conceived as to obtain answers to research problem and questions (Kerlinger & Lee 2000). Research design has its two primary functions, which include: (1) to conceptualise an operational plan to conduct various procedures and tasks required in order to complete the research, and (2) to ensure that these procedures and tasks are suitable to obtain valid, objective and accurate answers to the research questions (Kumar 2005). Creswell (2014) proposed that the plan for conducting a study involves the intersection of philosophical assumptions the researcher brings to the research; research design that related to the philosophical assumptions; and specific methods of data collection, analysis and interpretation. Thus, next sections present a systematic process to select the appropriate research design for this study: (1) the literature review on philosophical foundation and relevant methodological approaches (Section 4.2.1), (2) the selection of an appropriate methodological approach (Section 4.2.2), and (3) the selection of a particular study design pertaining to the chosen methodological approach for this study (Section 4.2.3).

4.2.1 Review of research philosophy and methodological approach

In a specific research design, the philosophical foundation for finding solutions to the research problem needs to be selected (Creswell 2014; Fellows & Liu 2015). The selection of philosophical foundation helps to explain why specific methodological approaches are appropriate for conducting a particular study (Creswell 2014).

Ontology and epistemology are two areas of philosophical assumptions and principles which underpin various research designs (Neuman 2013). Ontology deals with the nature of being, or what exists (i.e. what is out there to be known?). The central question is whether the reality of investigation exists independently or is the product of consciousness (Fellows & Liu 2015). These two contrasting positions of ontology refer to constructivism and objectivism (Bryman 2015). Constructivism asserts that social phenomenon and their meanings are continually being achieved by social actors, and thus be viewed as products of social interaction and constant state of revision (Bryman 2015). In contrast, objectivism asserts that social phenomenon and their meanings exist independently from social actors. Accordingly, social phenomenon and their meanings, which are experienced, exist independently or separately from actors (Bryman 2015).

Epistemology concerns the creation of knowledge and concentrates on the identification of the most valid methods to reach the truths (Neuman 2013). Thus, the central question of an epistemological matter is whether the social world can be studied with the same ethos, procedures and disciplines as the natural sciences (Bryman 2015). There are two contrasting epistemological positions, namely positivism and interpretivism (Bryman 2015). Positivism advocates the principles of the natural sciences methods to the study of social reality, which emphasise establishing causal laws, empirical observations and value-free research (Bryman 2015; Neuman 2013). Interpretivism, on the other hand, advocates that a strategy is requested to acknowledge the distinctions between the objectives of the natural sciences and individuals, thereby demanding researchers to comprehend the subjective meaning of social actions (Bryman 2015).

Different philosophical assumptions and principals underpin different research methodological approaches. There are three typical research methodologies adopted in social research, which include qualitative, quantitative and mixed methods (Creswell 2014). Quantitative approach is characterised by collecting quantitative data, adopting a deductive approach to the relationship between research and theory (i.e. identifying theories, generating hypotheses, collecting data, testing the hypotheses for confirmation and revising theories), incorporating the norms and practices of the natural science approach and positivism of epistemological position to explain a social phenomenon, and exhibiting the view of social reality as an external and objective reality (Bryman 2015). The characteristics of qualitative approach are emphasising words instead of qualification in the data collection and analysis, predominantly adopting an inductive approach to the relationship between research and theory (i.e. making observations, discovering patterns and generating theories), adopting an interpretivism of epistemological position to understand the social reality, and exhibiting the view of social world as products of social interactions (Bryman 2015). The differences between quantitative and qualitative approaches are summarised in Table 4.1.

Table 4.1: Fundamental differences between quantitative and qualitative approaches (Source: Bryman, 2015)

	Quantitative	**Qualitative**
Principal orientation to the role of theory in relation to research	Deductive, testing theory	Inductive, generation of theory
Epistemological orientation	Natural science model, in particular positivism	Interpretivism
Ontological orientation	Objectivism	Constructionism

In addition, the rationale underpinning the mixed methods approach is that the adoption of either quantitative or qualitative approach only cannot produce accurate answers to all of the research problem and objectives, and that collecting various types of data offers better insights into a research problem than either quantitative or qualitative data alone (Kumar 2005).

4.2.2 Selection of methodological approach for this study

The selection of research methodological approach should depend on the research problem and research objectives (Creswell 2014; Fellows & Liu 2015;

Kumar 2005). In this study, the research problem calls for investigating the development of resilient safety culture in responding the changing and unforeseen safety risks related to the complex nature of construction projects and achieving a sustained improvement of safety performance in the construction environment (See Section 1.4 for research aim and objectives). Accordingly, in terms of ontological positions, the phenomenon under investigation of this study was amenable to the objectivism as resilient safety culture, safety performance and project complexity were assumed to be social realities existing externally and objectively from the researcher. In terms of epistemological positions, the phenomenon under investigation of this study was approving for objectivism as it is assumed resilient safety culture, safety performance and project complexity as social realities, which can be understood through the adoption of suitable methods.

In terms of objectives of a study, research is categorised as exploratory, descriptive, explanatory and correlational (Kumar 2005). The aim of an exploratory research is to investigate phenomena and recognise variables and develop hypotheses for future studies (Fellows & Liu 2015). A descriptive study aims to systematically describe a phenomenon of interest or attitudes towards an issue (Kumar 2005). An explanatory research attempts to explain the causal relationship between two aspects of a phenomenon (Fellows & Liu 2015; Kumar 2005). A correlational research aims to establish the existence of a relationship between two or more aspects of a phenomenon (Kumar 2005). In this study, the objectives imply that this study can be categorised as a correlational research, which sought: (1) to quantify resilient safety culture (See Objective 1 in Section

1.4), (2) discover and establish the relationships between drivers of resilient safety culture and resilient safety culture dimensions (See Objective 2 in Section 1.4), and (3) discover the relationships between resilient safety culture, safety performance and project complexity (See Objective 3 in Section 1.4).

Taken together, implications of the positivism and objectivism for finding solutions to the research problem and the correlational type of study for achieving research objectives, therefore, favoured the adoption of a quantitative approach to fulfil the research aim and objectives in this study. The appropriateness of the use of a quantitative approach and its underpinning positivist view in this research was further reinforced by the apparent dominance of the positivism and quantitative research approaches in construction management research. The findings by Dainty's (2008) study indicated that, in construction management research, quantitative approach is the most popular research methodology (71%), followed by mixed methods approach (11.2%), review papers (9.4%) and qualitative approach (8.4%).

4.2.3 Selection of a research design for this study

After selecting the research methodological approach, the research design within the chosen research methodological approach should be considered in order to provide direction for specific research methods (Creswell 2014). There are two main research designs employed in conducting quantitative research approach, namely experiments and surveys (Creswell 2014). Experiments aim to determine whether a particular treatment affects an outcome. To fulfil this aim, a particular treatment is provided to one group, whereas it is withheld to another group, and then the performance of both groups related to a predetermined outcome is analysed and compared (Creswell 2014). A standard form of an experiment method includes (1) participants, (2) materials, (3) procedures, and (4) measures (Creswell 2014). In terms of participants in an experiment, participants can be chosen randomly (true experiment) or non-randomly (quasi-experiment). With the true experiment, each individual of the population has an equal chance of being selected, guaranteeing that the sample will be representative of the population. A quasi-experiment, in contrast, eliminates the probability of systematic differences among participants' characteristics that could influence the outcomes so that any differences in outcomes can be attributed to the experimental treatment (Keppel et al. 1992). In terms of materials in an experiment, a pilot test of the materials should be discussed, and any training for administering the materials in a standard way should be provided to the experimental group. This is to ensure that materials can be administered without variability to the experimental group (Creswell 2014). In terms of experimental procedures, the types of experimental design and what is being compared in the experiment need to be identified (Creswell 2014). In terms of measures, there are two types of threats to the validity of an experiment: (1) internal validity threats (i.e. experiences of the participants, treatments, or experimental procedures), and (2) external validity threats (i.e. interactions between selection and treatment, between setting and treatment, and between history and treatment) (Creswell 2014).

Although an experiment can powerfully test and focus evidence about causal relationships, an experimental design was considered inappropriate for the context of this study due to its artificial characteristics (e.g. it simplifies the complex social by controlling the situation of the research and purposely incorporating relevant variables while removing variables without a causal importance for a hypothesis) as suggested by Neuman (2013). The specific reasons are:

- Experimental design is suitable for research problems that have a narrow scope or scale (Neuman 2013). In this study, the scope of research and unit of analysis is building construction projects in Vietnam, in which the construction process often takes from several months to several years, and is generally very high cost (See Section 1.7 for the scope of research and unit of analysis).

- Experimental design requires isolating and targeting one or a few causal variables (Neuman 2013). Thus, it is inappropriate to achieve the research objectives in this study, which require examining the relationships among multiple variables in a wide range of construction projects.

- In this study, the research problem indicates the interactions of psychological, contextual and behavioural safety-related factors under the actual conditions of construction projects during the construction process, which require the consideration and observation in real life rather than in the laboratory.

The surveys, on the other hand, aim to produce a numeric description of opinions, attitudes, or trends of a population by investigating a sample of that population. To fulfil this aim, data are obtained using questionnaires, or structured interviews on more than one case and at a single point in time to obtain a set of quantitative data pertaining to two or more variables, which are then examined to identify the patterns of association (Bryman 2015). Survey research was considered suitable for this study for following reasons:

- The objectives of this research shows that this study encountered the magnitude of variation in all of the variables (i.e. resilient safety culture, project complexity, safety performance, hazard prevention practice, error management practice and mindful organising practice), which can only be established when more than one case (e.g. construction projects) are examined.

- The hypotheses of this research imply that this study sought to establish variation between cases (construction projects) in order to examine the patterns of association among variables (i.e. between drivers of resilient safety culture and resilient safety culture dimensions; among resilient safety culture, safety performance and project complexity) based on the implications of theories (See Chapter 3 for the development of hypotheses). Thus, it was essential to obtain data at a single point in time, and the information of variables was gathered using predominantly quantitative data.

4.3 Data collection

4.3.1 Operationalisation of research variables

The conceptual model presented in Section 3.5 indicates that there are six major variables in this research. They are resilient safety culture, hazard prevention practice, error management practice, mindful organising practice, project complexity and safety performance. This section focuses on the operationalisation of the research variables in order to allow them to be observed empirically. Accordingly, for each research variable, the corresponding section presents a literature review on its concept and a specification of its measurable scale items.

4.3.1.1 Resilient safety culture

Based on hypothesis 1, the concept of resilient safety culture could be studied by its three dimensions for empirical testing in this study: (1) psychological resilience, (2) contextual resilience, and (3) behavioural resilience. A resilient organisation manages its workplace safety risks (i.e. regular threats, irregular threats and unexpected events) via its four capabilities (i.e. anticipating, monitoring, responding and learning). Thus, each dimension of resilient safety culture could be evaluated using the measurable scales, which are actual safety practices implemented on construction sites reflecting all four resilience capabilities (Hollnagel 2013; Pęciłło 2016; Shirali et al. 2015). Table 4.2

summarises previous studies, in which the four resilience capabilities are presented. Accordingly, the four resilience capabilities are conceptualised as below.

- Anticipating: the capability of an organisation to identify the potential threats to the state of safety that should be prevented or avoided.

- Monitoring: the capability of an organisation to check the pre-defined indicators of regular threats to see whether they change and whether they require a readiness to respond.

- Responding: the capability of an organisation to respond to the regular and irregular threats via implementing a set of responses or via adjusting normal functions.

- Learning: the capability of an organisation to take lessons from experiences, in particular how to learn useful lessons from the experiences of success and failure.

Table 4.2: Four resilience engineering processes of safety management

Studies	Anticipating	Responding	Learning	Monitoring
dos Reis et al. (2008)	✓	✓	✓	
Johansson and Lindgren (2008)	✓			
Macchi et al. (2011)	✓	✓	✓	✓
Dinh et al. (2012)	✓	✓		
Rigaud and Martin (2013)	✓	✓	✓	✓
Gecco et al. (2013)	✓		✓	
Shirali et al. (2013)	✓	✓	✓	✓
Rankin et al. (2013)	✓	✓	✓	✓
Shirali et al. (2015)	✓	✓	✓	✓
Azadeh et al. (2015)	✓	✓	✓	✓
van der Beek and Schraagen (2015)	✓	✓	✓	✓
Pęciłło (2016)	✓	✓	✓	✓
Shirali et al. (2016)	✓	✓	✓	✓

In this study, the measurement items of the three dimensions of resilient safety culture were developed based on previous studies. Consequently, psychological resilience was measured with 14 measurement items, contextual resilience was measured with 14 measurement items, and behavioural resilience was measured with 13 measurement items. Sample measurement items are:

- Psychological resilience (anticipating capability): Everyone on site acknowledged that unexpected hazardous events (i.e. unobserved hazardous conditions and unintentional unsafe behaviours) could occur anytime and anywhere.

- Contextual resilience (responding capability): The project was provided with sufficient resources (financial, technical and human) appropriate to achieve health and safety targets related to observed hazards.

- Behavioural resilience (responding capability): Site management and supervisors paid attention to not sending people to work sites which involved physical and mental harm.

4.3.1.2 Hazard prevention practice

There are two aspects to the control and management of construction safety hazards: (1) the preventive control measures to limit hazard entry (e.g. reducing probability of hazards' occurrence), and (2) the precautionary control measures to limit hazard movement (e.g. reducing the severity of hazard if it occurs) (Carter & Smith 2006). Carter and Smith (2006) also noted that the basic assumption for management of construction hazards is that the hazards were identified in the first place. Based on this assumption, the subsequent measures include estimating the possibility of a hazard's occurrence, evaluating the risk related to the hazard based on the severity and frequency estimations, and responding to the hazard by carrying out appropriate control (Carter & Smith 2006). Hazard prevention practice can also be classified into two groups, namely hard and soft (Kanki 2010). Hard group of hazard prevention practice refers to technical measures such as engineered safety appliances, physical obstacles, or alarming systems, etc., whereas the soft group of hazard prevention practice is dependent on the personnel such as regulation, checking, training and supervision, etc. (Kanki 2010). A workplace safety literature review shows that hazard prevention practice could be characterised by ten dimensions, which include: safety policy, site safety organisation, safety meeting, safety inspection, safety training, safety promotion, risk assessment and hazard analysis, personal protection program, hazard control program and management support (Cheng, EWL et al. 2015; Choudhry & Fang 2008; Choudhry et al. 2008; Hinze & Gambatese 2003; Ho et al. 2000; Tam & Fung IV 1998; Tam et al. 2004). These hazard prevention practices are listed in Table 4.3. Each dimension is discussed as follows.

Table 4.3: Hazard prevention practices identified in previous studies

Studies	Jaselskis et al. (1996)	Sawacha et al. (1999)	Ho et al. (2000)	Abudayyeh et al. (2006)	Choudhry et al. (2008)	Rajendran and Gambatese (2009)	Fernández-Muñiz et al. (2009)	Vinodkumar and Bhasi (2010)	Esmaeili and Hallowell (2011)	Cheng, EWL et al. (2015)	Yiu et al. (2017)
Safety policy	-	✓	✓	-	✓	-	✓	-	-	✓	✓
Site Safety Organisation	-	-	✓	-	✓	✓	-	-	-	✓	✓
Risk Assessment and Hazard Analysis	-	-	✓	-	✓	✓	✓	✓	✓	-	✓
Safety Inspection	✓		✓	-	✓	✓	-	-	✓	✓	✓
Hazard Control Program	-	✓	✓	-	✓	-	✓	-	-	-	✓
Personal Protection Program	-	✓	✓	-	✓	-	✓	-	-	-	✓
Safety Meeting	-	✓	-	-	✓	✓	✓	✓	✓	✓	-
Safety Training	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Safety Promotion	-		✓	-	✓	-	✓	-	-	✓	-
Management support	✓	✓	-	✓	✓	✓	-	✓	✓	✓	-

- **Safety policy (H1).** Development of a safety policy has been widely recognised as critical for addressing hazards and reducing accidents in the workplaces (Choudhry et al. 2008; Fernández-Muñiz et al. 2009; Teo et al. 2005; Yiu et al. 2017). Safety policy of an organisation is a *"system of codified decisions established by an organisation to support the safety and health functions within the organisation. Setting safety policies is when a manager develops standing safety decisions applicable to repetitive problems that may affect the safety of the organisation"* (McKinnon 2013, p. 81). The written safety policy provides the specific safety requirements for a construction project, which can include the extent to which safety is a priority, the degree to which employees are consulted on health and safety issues, and the practicality of identifying hazards and implementing safety plans, procedures and instructions (Cheng, EWL et al. 2015; Glendon & Stanton 2000). Consequently, the implemented safety policy can (1) promote safe working conditions (Hill & Bowen 1997; Whittington et al. 1992) and (2) reduce the ignorance of safety practices, violation of safety rules and the adoption of unsafe behaviours (Rodrigues et al. 2015). In this study, safety policy was measured with three measurement items, which were derived from previous studies (Choudhry et al. 2008; Fernández-Muñiz et al. 2009; Rajendran & Gambatese 2009). A sample measurable item is "*Safety policy clearly states the importance of health and safety requirements as equally important as any other objectives*".

- **Site safety organisation (H2).** Site safety organisation include outlining the structure of the organisation, the describing individual safety responsibilities and presenting an organisational chart (Ho et al. 2000). The aim of site safety organisation is to assure the compliance with OSH standards, codes and legislation (Yiu et al. 2017). Thus, for each project, developing a site safety organisation could be useful for safeguarding workers from work-related hazards and preventing accidents (Cheng, EWL et al. 2015). In this study, site safety organisation was measured with four measurement items, which were derived from previous studies (Cheng, EWL et al. 2015; Choudhry et al. 2008; Yiu et al. 2017). A sample measurable item is: *"Everyone on site is clearly assigned their roles and responsibilities in order to eliminate or reduce the risks of hazards".*

- **Risk assessment and hazard analysis (H3).** Hazard analysis and risk assessment can be initiated by examining the activities related to a construction process, recognising potentially hazardous situations which can result in an injury, and assessing the probability and severity of all hazards of a specific activity (Hallowell & Gambatese 2009; Jannadi, OA & Almishari 2003). Thus, the implementation of hazard analysis and risk assessment can offer contractors with an identification of the risk level of construction activities, thereby allocating safety measures in a more efficient manner (Pinto et al. 2011). In this research, hazard analysis and risk assessment were measured with three measurement items, which were derived from previous studies (Choudhry et al. 2008; Fernández-Muñiz et al. 2009; Rajendran & Gambatese 2009). A sample measurable item is *"Workplace and task hazards in the project were clearly identified prior to execution."*

- **Safety inspection (H4).** Safety inspection refers to the identification of hazardous conditions for the modification of such conditions as appropriate and/or at regular intervals (Cheng, EWL et al. 2015; Yiu et al. 2017). A safety inspection aims to identify uncontrolled hazardous exposures to the construction workers, violations of safety standards or regulations, or unsafe behaviours (Hallowell & Gambatese 2009). Neal et al. (2000) noted that when the inspection is frequent enough to make workers feel pressure on unsafe acts, the motivation for comfort and convenience can decline, and in turn, the safety motivation will increase, so as to influence on the attitude of workers. Thus, the frequency and thoroughness of safety inspection contribute to the reduction of onsite hazards and workers' unsafe behaviour (Tam et al. 2004). In this study, safety inspection was measured with three measurement items, which were derived from previous studies (Choudhry et al. 2008; Fang et al. 2004). A sample measurable item is *"Conditions related to work tasks are examined at regular intervals".*

- **Hazard control program (H5).** Hazard control program aims to eliminate hazards using the process control before exposing workers to any adverse working conditions (Yiu et al. 2017). Hazard control program is vital for safeguarding workers from work-related hazards (Fernández-Muñiz et al. 2009; Ho et al. 2000; Sawacha et al. 1999). In this study, hazard control program was measured with four measurement items, which were derived from previous studies (Choudhry et al. 2008; Yiu et al. 2017). A sample measurable item is *"Appropriate plant, machine & equipment for each work task were provided".*

- **Personal protection program (H6)** Personal protection equipment (PPE) not provided, and not using provided personal protection equipment are among root causes of construction accidents (Chan et al. 2008; Tam et al. 2004; Toole 2002). The implementation of personal protection program refers to the degree to which the organisation is concerned with designing, issuing, using, and enforcing and monitoring PPE (Glendon & Stanton 2000). In this study, personal protection program was measured with four measurement items, which were derived from previous studies (Choudhry et al. 2008). A sample measurable item is *"The provision of personal protective equipment complies with safety plan".*

- **Safety meeting (H7). S**afety meetings are crucial for communicating safety matters to all parties involved in the project (Tam et al. 2004). In those meetings, communication and information sharing are associated with the frequency and methods of emphasising knowledge and the importance of safe work (e.g. informing potential hazards in the workplace, new or revised work instructions and safety rules, work tasks, and safety incidents experienced by other employees or organisations). In this study, safety meeting was measured with four measurement items, which were derived from previous studies (Choudhry et al. 2008; Rajendran & Gambatese 2009). A sample measurable item is "*Toolbox talks are planned and delivered to everyone on site".*

- **Safety training (H8).** The fundamental difference between safe employees and those who often experience injuries is that safe employees are able to recognise hazards and hazardous actions and understand the consequences (Toole 2002; Vredenburgh 2002). All workers should be provided with safety training about the hazards related to their work tasks (Choudhry & Fang 2008). Safety training typically begins with worker orientation and continues as workers need to become more informed about specific aspects of the work they are doing (Hinze & Gambatese 2003). Accordingly, the content of a safety training program may involve reviewing task-specific and project-specific hazards, methods of safe work behaviour, safety and health goals, and company policies, etc. (Hallowell & Gambatese 2009). Thus, it is widely accepted that safety training is crucial in improving awareness, knowledge, ability, skills, and attitudes of employees in order to prevent hazards and safety risks (Hinze & Gambatese 2003; Silva et al. 2004; Vredenburgh 2002; Zohar 1980). In this study, safety training was measured with four measurement items, which were derived from previous studies (Choudhry et al. 2008; Fernández-Muñiz et al. 2009;

Silva et al. 2004). A sample measurable item is *"All workers receive basic general safety training".*

- **Safety promotion (H9).** Safety promotion is promoting safety behaviour and engaging employees in decision-making processes by rewards/punishments, developing an advertising campaign or consulting them about their wellbeing (e.g. safety posters and stickers) (Cheng, EWL et al. 2015; Fernández-Muñiz et al. 2009). A well-designed safety promotion is characterised by high visibility level in the organisation and offering recognition (Vredenburgh 2002). The use of safety promotion can enhance reporting hazards, awareness and self-protection action among workers (Cohen, A et al. 1979; Vinodkumar & Bhasi 2010). In this study, safety promotion was measured with three measurement items, which were derived from previous studies (Choudhry et al. 2008; Vinodkumar & Bhasi 2010). A sample measurable item is *"Safety warning signs, posters and bulletin boards are provided sufficiently and clearly visible on site".*

- **Management support (H10).** Management support (or management commitment) is a major factor reducing the frequency of fatalities and injuries in the job site (Jaselskis et al. 1996; Sawacha et al. 1999; Vinodkumar & Bhasi 2010). Hofmann et al. (1995) noted that safety support of the management are observable activities as a part of the management, and must be demonstrated via their behaviours and words. In this study, management support was measured with four measurement items, which were derived from previous studies (Choudhry et al. 2008; Vinodkumar & Bhasi 2010). A sample measurable item is *"Site management and supervisors act as safety role models for all workers".*

4.3.1.3 Error management practice

There are two types of unsafe behaviour, namely violations and errors (Health and Safety Executive 2009; Rasmussen 1983; Reason et al. 1990). Violations are different from errors since they involve a conscious intention to break the rules that describe the safe or approved method of executing a particular task; as opposed to errors, which are unintentional made by individuals (Reason et al. 1990). There is also a difference in the psychological pathway to errors and violations. Violations are found in relation with social-psychological factors such as attitudes, beliefs, norms and practices (Lawton 1998). Helmreich (2000) also stated that violations come from a culture of poor procedures, perceptions of invulnerability, or non-compliance. In contrast, errors are closely related to cognitive failure such as information processing and skills (Lawton 1998). Helmreich (2000) argued that errors happen due to human limitations such as poor interpersonal communications, fatigue, imperfect information processing workload, fear, cognitive overload and flawed decision making.

The concept of error management was proposed by Frese (2008). Error management was regarded as the supplemented strategy to prevention approach. Whereas the prevention approach attempts to avoid and prevent violations from happening, error management refers to organisational practices related to communicating about errors, to sharing error knowledge, to helping in error situations and to quickly detecting and handling errors (Frese 2008; van Dyck et al. 2005). A workplace safety literature review shows that error management practice could be characterised by four dimensions including learning from errors, thinking about errors, error competence and error communication (Casey & Krauss 2013; Cigularov et al. 2010; van Dyck et al. 2005).

- **Learning from errors (E1).** The primary purpose is to reduce the repeated errors or the adverse outcomes of errors in the future (Carroll et al. 2002). van Dyck et al. (2005) summarised that learning occurs when people are encouraged to learn from errors, when they think about errors meta-cognitively, and when the negative emotional impact of errors is reduced. In this study, learning from errors was measured with three measurement items, which were derived from previous studies (Casey & Krauss 2013; Cigularov et al. 2010; van Dyck et al. 2005). A sample measurable item is *"Workers readily accept feedback about how to avoid and/or correct errors".*

- **Error competence (E2).** Error competence refers to knowledge or capability of individuals to deal immediately with errors (Rybowiak et al. 1999). In this study, error competence was measured with three measurement items, which were derived from previous studies (Casey & Krauss 2013; Cigularov et al. 2010; van Dyck et al. 2005). A sample measurable item is *"When an error occurs, workers on site know how to correct it".*

- **Thinking about errors (E3).** Errors are used for exploration and experimentation in order to develop a better and more sophisticated understanding of a particular situation that caused an error to occur (Dormann & Frese 1994). In this study, thinking about errors was measured with three measurement items, which were derived from previous studies (Casey & Krauss 2013; Cigularov et al. 2010; van Dyck et al. 2005). A sample measurable item is *"After an error occurs, it is analysed thoroughly".*

- **Error communication (E4).** Error communication refers to individuals' decision to talk openly errors to co-workers and supervisors or report through official incident-reporting systems (Edmondson 2000; Pfeiffer et al. 2010). Due to error communication, the knowledge from error learning allows workers to detect and deal with errors in hazard situation effectively (Cigularov et al. 2010). In this study, error communication was measured with four measurement items, which were derived from previous studies (Casey & Krauss 2013; Cigularov et al. 2010; van Dyck et al. 2005). A sample measurable item is *"When workers on site make errors, they ask others for advice on how to continue".*

4.3.1.4 Mindful organising practice

A literature review on workplace safety shows that mindful organising practice could be characterised by five dimensions, which include preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience and deference to expertise (Sutcliffe 2011; Weick et al. 2008).

- **Preoccupation with failure (M1).** Preoccupation with failure is directing attention and effort to a proactive and pre-emptive analysis of potential novel sources of conditions that can produce the unexpected (LaPorte & Consolini 1991; Rochlin 1996). This means that employees actively and continuously search for surprises and indicators of failure (Ford 2018). In this study, preoccupation with failure was measured with four measurement items, which were derived from previous studies (Sutcliffe 2011; Vogus & Sutcliffe 2007b). A sample measurable item is *"Minor project hazards and their risks of harm are given as much attention as major project hazards".*

- **Reluctance to simplify interpretations (M2).** Reluctance to simplify interpretations is *"deliberately questioning assumptions and received wisdom to create a more complete and nuanced picture of current situations"* (Sutcliffe, KM, p. 139). Accordingly, employees do not take the past as an infallible guide to the future, but rather actively seeking divergent viewpoints that question received wisdom, uncover blind spots and detect changing demands (Sutcliffe & Weick 2011). In this study, reluctance to simplify interpretations was measured with four measurement items, which were derived from previous studies (Sutcliffe 2011; Vogus & Sutcliffe 2007b). A sample measurable item is *"When workers confronted with unfamiliar safety instructions/procedures/rules and working conditions, they discussed with others".*

- **Sensitivity to operations (M3).** Sensitivity to operations is creating and maintaining an up-to-date understanding of the distributed tasks and expertise so that these are appropriately utilized in the face of unexpected events (Sutcliffe & Weick 2011). This requires: (1) a strong contact between employees to make sure inconsistencies, and problems are quickly recognised and treated, and (2) a number of adjustments are made in order to prevent the compounding of failures (Sutcliffe 2011). In this study, sensitivity to operations was measured with four measurement items, which were derived from previous studies (Sutcliffe 2011; Vogus & Sutcliffe 2007b). A sample measurable item is *"Site management and supervisors constantly monitor the workloads and take actions to reduce them when they become excessive".*

- **Commitment to resilience (M4).** Commitment to resilience is developing capabilities to cope with, contain and bounce back from mishaps that have already occurred, before they worsen and cause more serious harm (Sutcliffe 2011). The capabilities for resilience can be achieved through an extensive action repertoire, which is developed based on learning from negative feedback and ad hoc networks, varied job experiences, training and simulation that allow for rapid pooling of expertise to handle unanticipated events (Sutcliffe 2011). In this study, commitment to resilience was measured with four measurement items, which were derived from previous studies (Sutcliffe 2011; Vogus & Sutcliffe 2007b). A sample measurable item is *"Workers receive training on how to act in emergency situations (i.e. injury, damage to properties, incident…)".*

- **Deference to expertise (M5).** Deference to expertise occurs when collective pools the necessary expertise and utilises it by allowing people with the best expertise in managing the problem at hand to make decisions, regardless of formal rank in the face of an unexpected event (Roberts et al. 1994). In this study, deference to expertise was measured with four measurement items, which were derived from previous studies (Sutcliffe 2011; Vogus & Sutcliffe 2007b). A sample measurable item is *"In regarding important health and safety issues, site management delegate an authority to make final decisions to the safety manager (or who is most qualified on health and safety)".*

4.3.1.5 Project complexity

Based on the literature review (See Section 2.2), the overall project complexity could be characterised by three dimensions, which include technical, organisational and environmental factors (Bosch-Rekveldt et al. 2011).

Technical project complexity could be characterised by four parameters (i.e. goals, scope, tasks, and technology); organisational project complexity could be characterised by four parameters (i.e. size, resources, project team and trust); whereas environmental project complexity could be characterised by three parameters (i.e. external stakeholders, location and market conditions) (Baccarini 1996; Bosch-Rekveldt et al. 2011; Lu et al. 2015; Luo et al. 2016; Nguyen et al. 2015).

- **Technical complexity (TC).** Technical project complexity was characterised by four parameters, which include: (1) goal (Luo et al. 2016), (2) scope (Bosch-Rekveldt et al. 2011; Nguyen et al. 2015), (3) tasks (Bosch-Rekveldt et al. 2011; Lu et al. 2015; Luo et al. 2016), and (4) technology (Baccarini 1996; Luo et al. 2016; Nguyen et al. 2015). In this study, technical project complexity was measured with sixteen measurement items reflecting the uncertainty and change associated with the aforementioned parameters. A sample measurable item for 'goal' is *"The project goals are changed very often during the construction stage".*

- **Organisational complexity (OC).** The organisational aspect of project complexity were characterised by four parameters, which include: (1) size, (2) resources (Bosch-Rekveldt et al. 2011; Luo et al. 2016), (3) project team (Bosch-Rekveldt et al. 2011; Luo et al. 2016), and (4) trust (Bosch-Rekveldt et al. 2011). In this study, organisational project complexity was measured with nine measurement items reflecting the uncertainty and change associated with the aforementioned parameters. A sample measurable item for 'project team' is *"There are often replacements of contractors during the construction phase of the project".*

- **Environmental complexity (EC).** The environmental aspect of project complexity were characterised by three parameters, which include: (1) external stakeholders (Bosch-Rekveldt et al. 2011; Luo et al. 2016; Nguyen et al. 2015), (2) location (Luo et al. 2016; Xia & Chan 2012), and (3) market conditions (Bosch-Rekveldt et al. 2011; Luo et al. 2016). In this study, environmental project complexity was measured with six measurement items reflecting the uncertainty and change associated with the aforementioned parameters. A sample measurable item for 'location' is *"The project was located in complicated geological conditions".*

4.3.1.6 Safety performance

There are two types of measure of safety performance for construction projects, namely reactive measures (after an accident event occurred) and proactive measures (before an accident event occurred). From the reactive perspective, safety performance can be measured by recordable incidents, injuries and near misses. The reactive measures are most appropriate for the purpose of comparison with another organisation or across the industry or the evaluation of past safety effort (Cooper & Phillips 2004). From the proactive perspective, safety performance can be measured by safety participation and safety compliance. According to Neal et al. (2000), safety participation relates to promoting the safety program, helping co-workers, demonstrating initiative and putting effort into improving safety in the workplace; whereas safety compliance refers to individuals' conducting work in a safe manner and adhering to safety procedures. Safety participation and safety compliance can be measured by safety inspections, questionnaire surveys, or observations of behaviours in the workplace. The purpose of proactive measures is that they provide a risk assessment on the safety aspect of a construction project. However, the disadvantage of this method is that the data obtained from proactive measures only can be collected in on-going projects (Neal et al. 2000).

The selection of safety performance measures depends on the resources availability and purpose of measuring. In this study, reactive measure of safety performance (i.e. accident rate) was chosen because: (1) the objective and design of this research indicate that the accident rate enables the comparison of safety performance among construction projects, and (2) the report of accident is required by law in Vietnam, the records of injuries and accidents are available for all completed construction projects in Vietnam. Accordingly, to measure safety performance, the formula for calculating Recordable Incident Rate (IR) is given below:

Recordable Incident Rate (Jaselskis et al. 1996):

$$IR = \frac{\text{Number of OSHA recordable cases} \times 200000}{\text{Number of employee labor hours worked}}$$

In the formula, the 200000 employee hours worked reflects a 100-person crew working 40 hours per week for 50 weeks.

4.3.2 Data collection instrument

Constructing a research instrument is important because the findings and conclusions of the research are dependent on the types of information gathered, whereas the collected information is based entirely on the questions delivered to the respondents (Kumar 2005). Thus, after determining the information required (See Section 4.3.1 for the definition and operationalisation of the research variables), a data collection instrument was designed to collect the necessary information for this study.

In this study, the Likert scale was selected over other scales (i.e. Guttman scale and Thurstone scale) because: (1) it is the most comfortable scale to construct and administer and is the most widely used (Kumar 2005), and (2) it is easy to understand and thus facilitate the respondents' answering process (Bernard 2012). In developing a Likert scale, odd-numbered scale was chosen because odd-numbered scale can provide a neutral position associated with the respondents' attitude towards the issue under the study; whereas there is no neutral option in even-numbered scales, which may influence outcomes by classifying the responses into two different categories (e.g. agree or disagree, and low or high) (Feng 2011). Coupled with this, the number of points on a categorical scale is decided based on: (1) how finely the researcher wants to measure the intensity of the attitude in question, and (2) the capacity of respondents to make fine distinctions (Kumar 2005). In this study, a five-point Likert scale, instead of a three, seven or nine-point, was adopted because: (1) although seven or nine-point scales tend to collect more discriminating information, it is argued that respondents do not actually discriminate carefully enough in their responses to make these scales valuable, (2) three-point scale offer little information on the intensity of the respondents' attitude in a typical question (Feng 2011). Therefore, the use of a five-point Likert scale was adopted in this study. A data collection instrument for this study is presented in Appendix E, which comprises eight sections:

- **Section A:** Project information and personal information. This section collects the general details on the characteristics of the construction project (e.g. location, duration, year of completion, total man-days worked for the project and project grade, etc.) and respondents (i.e. education background, work experience).

- **Section B:** Safety performance. This section requires respondents to provide information about safety performance of the project, as measured by Recordable Incident Rate. The questions include the number of fatal deceased workers, injured workers who are permanently disabled, injured workers who are temporarily disabled and minor injuries.

- **Section C**: Project complexity. This section aims to collect information about complexity level of their construction project. Based on the actual conditions of the project during the construction phase, the respondents were required to indicate the level of your agreement with each of the statements found in this section using a five-point Likert scale: 1 – Strongly disagree, 2 – Disagree, 3 – Neutral, 4 – Agree and 5 – Strongly agree.

- **Section D:** Resilient safety culture. This section collections information relating to resilient safety culture of the project. Based on the actual safety practices which were implemented in their completed construction projects, respondents were required to indicate the level of their agreement on a five-point Likert scale (between 1 = 'Strongly disagree' and 5 = 'Strongly agree') for each of statements found in each section.

- **Section E:** Hazard prevention practice. This section obtains information on the safety activities, which aim to address safety risks of inherent project hazards. In this section, respondents were required to indicate the level of their agreement on a five-point Likert scale (between 1 = 'Strongly disagree' and 5 = 'Strongly agree') for each of statements found in each section.

- **Section F:** Mindful organising practice. This section obtains information about safety activities, which manage the unexpected failures/events/situations in the construction workplaces. Based on the actual safety practices which were implemented in their completed construction projects, respondents were required to indicate the level of their agreement on a five-point Likert scale (between 1 = 'Strongly disagree' and 5 = 'Strongly agree') for each of statements found in each section.

- **Section G:** Error management practice. This section was designed to collect information on safety activities, which aim to reduce the likelihood of unintentional unsafe behaviours of construction workers. Based on the actual safety practices which were implemented in their completed construction projects, respondents were required to indicate the level of their agreement on a five-point Likert scale (between 1 = 'Strongly disagree' and 5 = 'Strongly agree') for each of statements found in each section.

- **Section H:** Consultation for the completion of the response. This section has one question referring the 'types of project positions' that respondents consulted with when completing their questionnaires (e.g., site manager, site safety manager, site supervisor and site safety officer).

4.3.3 Data collection method

After constructing the data collection instrument, the next step of the research process is to select the suitable data collection method. Data can generally be obtained from two main sources: (1) primary sources, and (2) secondary sources (Kumar 2005). Primary sources are those where researcher firsthand collect information from the respondents for the particular purpose of the study, whereas all sources, where the information required has been already available, are called secondary sources (Kumar 2005).

In this study, the data collection instrument indicates that both primary and secondary sources of data are required (See Section 4.3.1 and Appendix E for data collection instrument). Primary sources of data include project complexity (See Section C of Appendix E), resilient safety culture (See Section D of Appendix E), hazard prevention practice (See Section E of Appendix E), mindful organising practice (See Section F of Appendix E), error management practice (See Section G of Appendix E) and consultation for the completion of response (See Section H of Appendix E). Secondary sources of data include information about construction project characteristics (See Section A of Appendix E) and safety performance (See Section B of Appendix E) as it requires the provision of project records. In the next sections, potential data collection methods pertaining to each source of data were discussed and followed by the selection of suitable data collection method for this study.

4.3.3.1 Primary sources of data

Since this study is categorised as non-experimental quantitative research (See Section 4.2.3), a survey is appropriate to collect primary data for this study as suggested by Creswell (2014). According to Bryman (2015), there are two types of survey, which include a structured interview (i.e. telephone and face-to-face) and a self-completion questionnaire (i.e. postal, collective and online). Interviewing is a prominent data collection strategy, in which two or more individuals interact person-to-person with a specific purpose in mind (Kumar 2005). A structured interview is a form of an interview, in which the researcher reads out a prearranged set of questions, using the same order and wording of questions as detailed in a data collection instrument (Kumar 2005). The goal of a structured interview is to ensure that the responses of interviewees can be aggregated by providing the same identical cues to all interviewees (Bryman 2015).

A questionnaire is a written list of questions, which are completed by respondents. Accordingly, respondents are required to read and understand the information pertaining to the questions and write down the answers (Kumar 2005). The questionnaire and structured interview, therefore, are similar in many aspects. The difference between a questionnaire and a structured interview is that there is no interviewer in a questionnaire, who asks the questions and records the answers of respondents, and thus respondents must records answers themselves (Bryman 2015).

There are advantages of the questionnaire over the structured interview. First, the questionnaire is cheaper to administer as there is no need for the cost of travel and/or telephone for each interview. Second, it takes a longer time for an interview to be completed as there is a need for the presence of an interviewer to ask the questions and record the answers. Third, since an interviewer is not present when a questionnaire is completed, there are no effects of an interviewer on the answers of respondents (i.e. tendency to exhibit social desirability of the answers and to under-report those facts which are sensitive when an interview is present). Fourth, the questionnaire is more convenient for respondents to select the suitable time to answer a questionnaire at their own pace. Fifth, as there is no interaction between interviewer and respondents, questionnaire method offers greater anonymity, which is an important issue when there are sensitive questions required (Bryman 2015; Kumar 2005). Nonetheless, there are also remarkable disadvantages of the questionnaire in comparison to the structured interview, which include: (1) no chance to probe respondents to elaborate an answer, (2) no help provided for respondents if they have trouble answering the questions, (3) high risk of missing data, and (4) low response rate (Bryman 2015).

4.3.3.2 Secondary sources of data

Secondary sources are data, which has already been obtained and kept by an individual or an organisation (Kumar 2005). Examples of secondary sources include mass media, government or quasi-government publications, personal records, organisational records, and earlier research (Kumar 2005; Yin 2009). Kumar (2005) noted that validity and reliability, personal bias, availability and format are some issues, which need to be considered when choosing the secondary sources of data. In terms of validity and reliability, information collected from an official purpose is more reliable and valid than that gathered for a personal purpose. In terms of personal bias, the information obtained from personal purpose (i.e. diary, magazine and newspaper) is less exact and objective than that collected from organisational and academic reports. It is also essential to ensure that the required information is available and in the appropriate format before proceeding the study further (Kumar 2005).

4.3.3.3 Selection of data collection method for this study

In terms of primary data in this study, the choice between a questionnaire and a structured interview should be taken into account the advantages and disadvantages of the two methods. According to Kumar (2005), the fundamental criteria for this selection are the socioeconomic-demographic characteristics of the population and the nature of an investigation. In this research, a questionnaire was considered appropriate for collecting data for the following reasons:

- The sampling frame of this study comprises building projects which were located in the five largest cities in Vietnam (See Section 4.3.4 for sampling). It was indicated that the potential respondents are scattered over a wide geographical area, and thus interviewing would expensive and time-consuming to obtain primary data.

- As the data collection instrument indicates that all of the questions used to collect primary data are closed questions (See Sections C, D, E, F, G, and H in Appendix E). That means once it was ensured that there are no problems that potential respondents have in understanding the questions, the presence of the researcher for supporting them is not necessary. Also, the use of questionnaire method could eliminate the effects of an interviewer on the answers of respondents (e.g. tendency to meet social desirability relating to their actual safety practices), and thus would increase the likelihood of collecting accurate information.

In terms of secondary data in this research, a questionnaire was used to collect organisational records pertaining to information about construction project characteristics (See Section A in Appendix E) and safety performance (See Section B in Appendix E). This is because:

- It is required by law in Vietnam that all information related to the construction projects (i.e. health and safety, quality, time and cost, etc.) are recorded and kept by project managers. Thus, information about construction project characteristics and safety performance are available and can be provided by project managers.

- Information about safety performance (i.e. the number of fatalities, injuries, and accidents, etc.) was acknowledged as sensitive. Thus, the use of questionnaire method could eliminate the effects of an interviewer on the answers of respondents (e.g. under-report the safety records).

Taken together, the project managers were targeted for data collection in this study because: (1) project manager is a compulsory position for all construction projects in Vietnam, and (2) the project manager works full-time during the construction stage of the project, has an overall understanding of the project and holds all project records.

Among a questionnaire method, there are three ways to administer: (1) postal questionnaire, (2) collective questionnaire, and (3) online questionnaire. Accordingly, a questionnaire can be: (1) sent through the post to the respondents (postal questionnaire), (2) designed in a form of a website with the aid of an appropriate program for potential respondents to assess and respond (online questionnaire), or (3) answered by respondents assembled in a place (collective questionnaire) (Bryman 2015). A postal questionnaire was inappropriate to obtain data in this research as the addresses of potential respondents were not available for sending the questionnaire by mail. Thus, collective and online questionnaire were chosen, which are described in detail in data collection procedure (See Section 4.3.8).

4.3.4 Pilot study

It is necessary to test a data collection instrument before using it for actual data collection (Kumar 2005). In this study, a pilot test was carried out: (1) to identify the problems in understanding the way the questionnaire was worded and the appropriateness of the meaning it communicated to capture the necessary data for the research, (2) to examine whether the questionnaire was ambiguous among different respondents, (3) to inspect whether there was a different interpretation of the questionnaire between respondents and researcher, (4) to estimate the completion time, and (5) to obtain data collection experiences.

The selection of experts involved in this pilot study was met two requirements. First, they had a good relationship with the researcher in order to ensure that they have dedicated their time and efforts to giving feedback, making feedbacks more reliable. Second, the experts were involved in site management of construction projects to ensure that the group of people in the pilot study was similar to the population in actual data collection, making the feedbacks were more valid and valuable. Consequently, a total of six experts agreed to participate in the pilot study. It is noted that all experts had extensive working experience ranging from 10 years' experience to 25 years' experience in the construction industry.

The pilot study included two phases. In the first phase, preliminary questionnaires were sent to the experts via email. The experts were required to read the data collection instrument carefully and give their comments concerning the following issues: (1) comprehensibility and clarity of instructions, wordings, statements and questions (2) appropriateness of the questions to the context of Vietnamese construction industry, (3) any other potential questions could be added to the questionnaire, (4) possibility of providing information pertaining to the questions, and (5) other comments. Based on the experts' feedback, the questionnaire was then amended and finalised: (1) some unclear statements were changed, and (2) overlapping items were deleted. In addition, it was noted by the experts that questionnaire was relatively lengthy, and required at least 25 minutes to complete all the questions.

In the second phase, the revised questionnaire was designed in the form of an online survey with the aid of Qualtrics survey software for following reasons:

- It is a subscription-based software for collecting data to optimise research in various areas such as website feedback, employee evaluations, concept testing, product, and customer satisfaction and loyalty. This software is advantageous in its features: (1) creating, testing and modifying surveys instantly with no coding required, (2) automatically building reports which easily export to another format (e.g. word, powerpoint, or pdf) in order to create presentations, (3) sending customised email invitations to the respondents, tracking their progress, and preventing fraud and abuse of survey, and (4) providing various distribution channels (e.g. mobile site, website, QR codes, offline surveys).

- It is suggested and attested by a number of researchers in handbooks of conducting surveys (Smith & Albaum 2006; Sue & Ritter 2011). There are some types of support provided by the Qualtrics community and team on how to use this software.

After designing an online survey, six experts were then invited to test the online survey. The six experts were required to provide their comments concerning the following issues: (1) the technical problems which potentially interrupt and/or impair the completion of response, (2) suggestions to make the online survey more user-friendly. Based on the experts' feedback, several amendments were made to the online survey: (1) restructuring the survey, (2) adding the expression of encouragement and the 'percentage of completion' notice on the survey website, (3) providing multiple-access to a half-done response, and (4) automatically sending notice email to remind the respondents of their uncompleted responses. Those modifications were expected to improve the quality of the responses, and the interest and willingness of respondents.

4.3.5 Reliability and validity issues

4.3.5.1 Validity and reliability of a research instrument

The validity of an instrument is defined as *"the extent to which an empirical measure adequately reflects the real meaning of the concept under consideration"* (Babbie 1989, p. 133). Validity can be assessed by: (1) comparing the result of the operational definition with the results of other measures with which it should or should not be related, or (2) subjectively evaluating whether an operational definition measures what it is intended to do (Singleton et al. 1993). There are four types of validity in quantitative research, which include: (1) face validity, (2) content validity, (3) criterion validity (i.e. concurrent and predictive validity), and (4) construct validity (i.e. convergent and discriminant validity (Neuman 2013). Face validity refers to the degree by which each indicator or measurable scale on the research instrument must have a logical connection with an objective. Content validity refers to the extent to which the indicators or measurable scales cover all areas of the conceptual definition of a construct. Content validity involves three steps, which include: (1) to specify the content in the definition of a construct, (2) to sample from all aspects of the definition, and (3) to develop one or more measurable scales that involve all aspects of the definition (Neuman 2013). Criterion validity includes two subtypes of validity: concurrent validity is estimated by how well an instrument compares with another assessment concurrently completed, while predictive validity refers to the extent to which an instrument predicts an outcome. Construct validity also comprises two types: convergent validity is judged by how well the indicators or measurable scales of one construct converge, whereas discriminant validity is judged by how well indicators of different constructs diverge (Kumar 2005; Neuman 2013). Construct validity is determined through the statistical procedures (Kumar 2005).

In this study, the content validity of the research instrument was established and assured through:

- The design and selection of measurable scales pertaining to research variables used in this study (i.e. hazard prevention practice, error management practice, mindful organising practice, resilient safety culture, project complexity and safety performance) were based upon an extensive review of pertinent literature. Thus, the content validity of the research instrument used in this study was theoretically established (See Section 4.3.1 for operationalisation of research variables).

- A pilot study was carried out to pre-test the research instrument before using it for actual data collection (See Section 4.3.4 for a pilot study). During the pilot test, the research instrument was checked and revised to assure that each construct is well represented by its measurable scales in the context of Vietnamese construction industry.

Reliability of a research instrument concerns the degree of its consistency and stability (Kumar 2005). There are three types of reliability: (1) stability reliability, (2) representative reliability, and (3) equivalence reliability (Neuman 2013). Stability reliability is judged by the degree by which the measure achieves the same response when applied in different periods of time. Representative reliability refers to the degree by which a measurable scale produces the same response when applied to different subpopulations (e.g. different ages, races and genders). In addition, equivalence reliability, which is adopted when a construct is measured with multiple indicators, refers to the extent to which a measure yield consistent results across different indicators (Neuman 2013).

In this study, the reliability of the research instrument was established and assured through:

- All constructs in this study were clearly defined and conceptualised to ensure that the meanings of all constructs and questions in the research instrument were consistent: (1) for each respondent over different time periods, (2) among different respondents, and (3) between researcher and respondents.

- As single-item measures are less stable than multiple-item measures, most constructs of this study were measured by multiple measurable scales, which follow the principle of triangulation (i.e. hazard prevention practice, error management practice, mindful organising practice, resilient safety culture and project complexity).

- A five-point Likert scale was adopted to design a research instrument in this study, which is more understandable to the respondents, produces more detailed information, and thus be more reliable than other scales (See Section 4.3.1 for the selection of data collection method).

- A pilot study was adopted, which aimed to assure that the research instrument is comprehensive and clear under the group of people similar to the study population before applying the final version of research instrument in the actual data collection (See Section 4.3.4 for the pilot study).

4.3.5.2 Validity and reliability of research data

According to Neuman (2013), the reliability of research data concerns with the extent to which the observations about the real phenomenon or an event are internally and externally consistent. Internal consistency refers to *"data that are* *plausible given all that is known about a phenomenon or an event and eliminating common forms of human deception. External consistency refers to data that have been verified or cross-checked with other, divergent sources of data."* (Neuman 2013, p. 455). In this study, some potential threats to reliable research data were identified and addressed.

- *Respondent's mood:* It is acknowledged that a change in respondents' mood when answering the questions in a questionnaire may influence the reliability of collected data (Kumar 2005). In this study, the change in respondents' mood was anticipated to emerge due to: (1) some questions required recollection of unfavourable events (e.g. injuries and accidents) which may cause personal distress (See Section B in Appendix E), and (2) the questionnaire was relatively lengthy (e.g. completion time of around 25 minutes) (See Section 4.3.4 for estimating completion time). Thus, those type of potential threats were mitigated in this study by providing respondents with (1) notification that the participation in the survey is voluntary and, that participants are free to discontinue their participation without giving a reason at any time (See Section 4.3.8 for data collection procedure), (2) the hotline of a popular Community Health Support centre, the researcher and the Western Sydney University Human Research Ethics Committee, for any instructions, supports, or psychological help (See Section 4.4.8.1 for details), and (3) multiple access to a half-done response with the aid of Qualtrics survey software (See Section 4.3.4 for details).

- *Regression effect of an instrument:* it is noted by Kumar (2005) that, during the completion of a response, a change in respondent's opinion towards answers can affect the reliability of collected data. Thus, in order to mitigate the impact of this threat, respondents were encouraged to review and revise their recorded responses.

- *Intentional and/or unintentional acts by respondents:* There are four types of threats to the accuracy of research data, which are caused by respondents (i.e. misinformation, evasions, lies and fronts) (Neuman 2013). In this study, the aforementioned potential threats were controlled by following precautions: (1) careful selection of appropriate respondents (i.e. only project managers were selected as the targets of the research design), (2) project managers were encouraged to consult other project management positions (i.e. site managers, site safety managers, etc.) when completing the questionnaire, (3) the data collection procedure ensures the voluntary nature of participation in the questionnaire, anonymity of respondents and confidentiality of participants' responses in order to prevent intended lies and deceptions, and (4) assuring the comprehensiveness and clarity of the research instrument in terms of its instructions, statements and questions in order to avoid unintended error made by respondents when answering the questionnaire.

According to Fellows and Liu (2015), the validity of research data concerns: (1) obtaining a sample which is appropriate to represent the population under investigation with sufficient confidence, and (2) the applicability of the results drawn from testing a sample to the population. In this study, the validity of research data was established through (1) determining sample size requirement with an anticipated response rate to attain the desired precision of collected data (See Section 4.3.6 for determination of sample size), and (2) the principles of random sampling to avoid bias when selecting a sample (See Section 4.3.7 for sampling).

4.3.6 Determination of sample size

It is crucial to determine the minimum sample size in order to ensure that: (1) the results of the statistical method have adequate statistical power and are robust, and (2) the model is generalisable (Hair et al. 2016). As the structural equation modelling technique with partial least-squares was applied to test the hypotheses suggested in this study, the sample size is determined as suggested by many researchers (e.g. Wixom and Watson (2001), Aibinu et al. (2008) and Tompson et al. (1995)): (1) 10 times the greatest number of formative measurement items used to measure a single construct, or (2) 10 times the greatest number of structural paths directed at a particular construct in the structural model.

In this study, the PLS-SEM models developed to test the research hypotheses indicate that all measurement items used to measure its corresponding constructs are under reflective mode (See Section 4.4.3 for SEM models specification). Thus, the former formula is not suitable to determine the minimum sample size in this study. In terms of the latter formula, the maximum number of structural paths in those SEM models was estimated at 3. Accordingly, the minimum sample size of 30 (being 10 x 3) was considered.

In addition, PLS-SEM requires considering the sample size against the background of the model and data characteristics. In other words, the required sample size should be determined by means of power analyses based on the part of the model with the highest number of predictors (Marcoulides & Chin 2013). Cohen, J (1992) provided a framework to determine the minimum sample size requirements based on three parameters (i.e. the minimum R^2, significance levels, and assumed level of statistical power of 80%, and a specific level of the complexity of the PLS path model). Adopting Cohen, J (1992)'s framework to this study, the mininum sample of 53 was considered to achieve a statistical power of 80% for detecting R^2 values of at least 0.25 (with a 1% probability of error). Taken together, the minimum sample size of 53 was considered adequate for the modelling purposes in this study.

4.3.7 Sampling

Sampling is the process of selecting a subgroup (or a sample) from a bigger group (or a sampling frame) as the basis for estimating the prevalence of an unknown piece of information relating to the bigger group (Kumar 2005). The aim of sampling is: (1) to offer a practical means, which enable the data collection and processing components of a study to be conducted, and (2) to ensure that the sample is representative (Fellows & Liu 2015).

This research applied the principles of random sampling as the sampling strategy. In random sampling, each sample in the sampling frame has an equal and independent chance of being selected (Fellows & Liu 2015). Equality means that the possibility of selection of each sample in the sampling frame is the same, whereas independence means that the selection of a sample is independent of the selection of another sample (Kumar 2005).

In this study, sampling included two stages. The first stage was building a sampling frame for this study. Based on the research aim and objectives, building projects in Vietnam were identified as the study population. A list of building projects, which were registered with the Construction Department of the five largest cities in Vietnam (i.e. Ha Noi, Hai Phong, Da Nang, Ho Chi Minh and Can Tho) and completed within the last three years, was identified and used to build the sampling frame for this study. This is because: (1) Vietnam can be divided into three regions (North, Central and South). Each region has its largest cities, including North (e.g. Ha Noi City and Hai Phong City), Central (Da Nang City) and South (e.g. Ho Chi Minh City and Can Tho City), and (2) most of the Vietnamese building construction projects are located in these cities (See Figure 4.1 for the distribution of sampling projects). Therefore, the geographical distribution of the five largest cities and its high proportion to the population of building projects in Vietnam make them representative for the population and were selected as the sampling frame. Consequently, a list of 2004 building construction projects was identified and used as a sampling frame for this study.

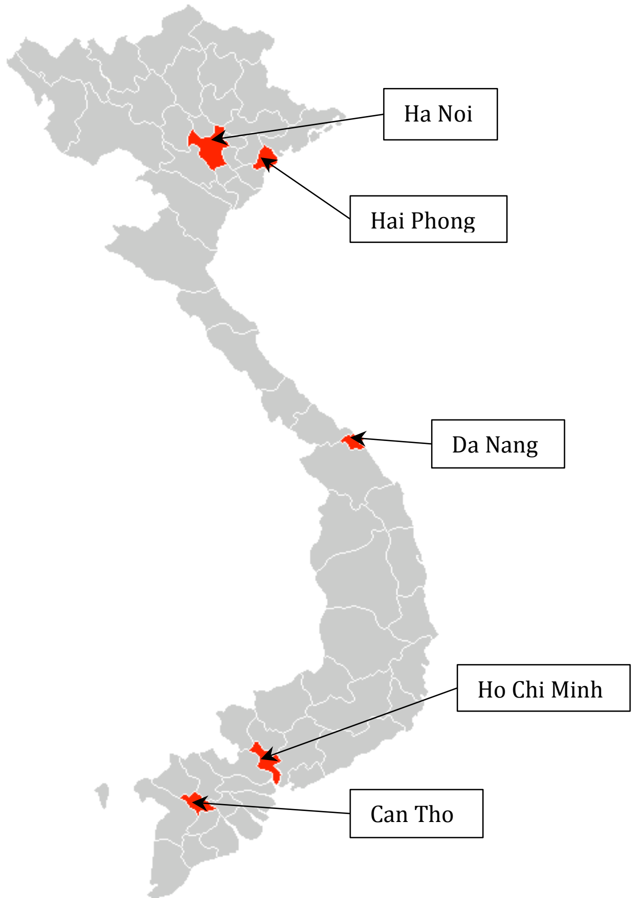


Figure 4.1: Five largest cities in Vietnam

The second stage was randomly selecting the building projects from the sampling frame in order to invite them to participate in the research. When estimating the number of samples to be selected from the sampling frame, it is essential to take into account the anticipated response rate in order to receive sufficient expected responses (Fellows & Liu 2015). Nonetheless, as Fowler (2013) noted that there is no agreement on the standard for a minimum acceptable response rate, it is necessary to reference construction safety research. Recent studies (Cigularov et al. 2010; Feng et al. 2015; Teo & Feng 2011; Teo et al. 2005) indicated that the response rate of a questionnaire method is relatively low (e.g. from 15% to 30%). In addition, the minimum sample size requirement for this study is determined as 53 (See Section 4.3.6 for determination of sample size). Thus, a minimum sample of 360 is necessarily randomly selected for participation invitation as a response rate of 15% was expected.

4.3.8 Data collection procedure

Data collection stage was conducted from 10th April 2017 to 9th July 2017. The data collection procedure involved three steps, which are detailed below:

The first step was collecting the contact information (i.e. name, telephone number and email) of a project manager of each randomly selected project in the sampling frame. Consequently, the information pertaining to the project managers of 438 building projects was collected through the websites of the main contractors' project and yellow pages.

In the second step, an invitation letter was sent to the project managers, and a phone call was made (if appropriate) in order to invite them to participate in this research. The invitation email mainly includes the introduction of this research and the detailed description of what the participation involves, and the link access to the online survey (See Appendix B for the invitation letter). It was also emphasised in the invitation email that the potential participants are welcomed to contact with the researcher via telephone, email or private face-to-face meeting for discussing the research further. Once the potential participants agreed to participate in the research, they would have access to the online survey through the link given.

Step three involves reading the participation information sheet, providing the consent and answering the online questionnaire carried out by the respondents with the aid of Qualtrics survey software. On the survey website, the participants were asked to read the participation information sheet and provide their agreement by choosing *'Yes, I have read and understood this participation information'* to access to the participant consent form (See Appendix C for participation information sheet). In the consent form webpage, participants were asked to read and provide their consent by choosing *'I agree to participate in this study'* in order to access to the questionnaire (See Appendix D for the consent form). The respondents were then requested to answer all questions in the questionnaire (See Appendix E for the questionnaire). Accordingly, the questionnaire comprises seven sections. Section A (project and personal information) and section B (safety performance) require respondents to extract their organisational records to answer. Section C (project complexity), section D (resilient safety culture), section E (hazard prevention practice), section F (mindful organising practice), and section G (error management practice) require respondents rate their level of agreement on the statements found in those sections. Section H (consultation for the completion of response) asks to indicate the people by whom the respondents consulted with when they complete the questionnaire.

There were also cases that the potential respondents requested face-to-face meetings for further information about the research and followed by an acceptance of participation. In such situations, potential respondents could choose one of two forms of response: (1) a paper-based questionnaire or (2) an online questionnaire. Whether a paper-based questionnaire or an online questionnaire was selected by the potential respondents, they were required to read the participation information sheet, provide the consent and answer the questionnaire sequentially.

During the data collection process, some measures were taken in order to encourage the potential respondents to participate in this research: (1) explaining the purpose of the study and their contribution to the completion of this study, (2) assuring them in invitation emails (and verbally if possible) that all information provided will be treated with strict confidentiality, and that their identities will remain anonymous throughout the research as their names and organisation's details will not be required to provide (See Section 4.3.9.1 for ethical issues relating to anonymous and confidentiality issues), (3) explaining the aid of Qualtrics survey software for data collection, and (4) promising that the research findings will be shared with the respondents. Eventually, out of the 438 building projects contacted, 115 project managers responded to the questionnaire, representing a response rate of 26.2% (See Section 4.3.10 for the characteristics of the sample).

4.3.9 Ethical considerations

Conducting a research study could raise ethical matters (Bouma & Ling 2004). The Collins Dictionary (1979) defines ethical as *"in accordance with principles of conduct that are considered correct, especially those of a given profession or group".* In this study, ethical issues could concern three parties: the respondents, the researcher and the sponsoring organisations. This research program was awarded ethics approval by the Western Sydney University Human Research Ethics Committee, with ethics approval number H12023 (See Appendix A for Letter of Human Research Ethics Approval). Accordingly, a number of ethical considerations were addressed in the data collection stage.

4.3.9.1 Ethical issues concerning research participants

The first ethical issue concerns the probability of causing harm to participants. According to Bailey (1978, p. 384), harm includes *"not only hazardous medical experiments but also any social research that might involve such things as discomfort, anxiety, harassment, invasions of privacy, or demeaning or dehumanising procedures"*. As no environmental experiments were performed, there was no risk of environmental harm found in this study. Nonetheless, it was anticipated that there are minor discomforts to participants since the questions require recollection of unfavourable events (e.g., injuries, accidents) which may cause personal distress. Based on its intellectual merit, this research was expected to justify the minor discomforts as it could benefit both the participants and the wider community. The expected benefit was that participants have a chance to reflect on their actual safety practices which were implemented on their construction projects, thereby improving safety performance in their portfolio. Both these minor discomforts and benefits of the participation were clearly explained to participants in the participant information sheet. Additionally, in order to mitigate the discomforts, the respondents were provided with the hotline of a popular Community Health

Support centre, for any psychological help. An alternative option was to contact the researcher and the Western Sydney University Human Research Ethics Committee via telephone or email for any further instructions, or supports.

The second ethical consideration is the consent process. It is unethical to obtain information without the knowledge and expressed willingness and informed consent of participants (Kumar 2005). In this study, the consent process was designed to ensure that: (1) the participants are competent to give consent; sufficient information is provided for participations' decision-making and (2) the consent is voluntary. Accordingly, participants were informed of the nature of their participation through the invitation letter and participant information sheet prior to providing their consent, thereby accessing to the survey. Potential participants were informed that participation in the survey is voluntary and, that participants are free to discontinue their participation without giving a reason at any time. The potential participants were also encouraged to contact the researcher via telephone, emails or face-to-face meetings to discuss further on the information and involvement in the research project. The online survey was designed to ensure that respondents are required to read the information sheet and provide their consent to access the questionnaire.

Another ethical issue concerns the anonymity and confidentiality. It is crucial to ensure the anonymity of respondents in all stages of the research program (Kumar 2005). In this study, the anonymity of respondents was controlled through the data collection procedure. Any discussion on this research and participation was conducted via mail or telephone or private face-to-face meetings between participants and researchers. Further, as the provision of consent and completion of a questionnaire were both conducted online by participants, individuals' decisions to participate in this research are unidentified by the other participants. In addition, the confidentiality of participants' responses was emphasised in invitation letter, participant information sheet, participant consent form and verbally if possible. Of particular emphasis was the data gained in this study could be published, but no individual could be identified in any way. Therefore, anonymity and confidentiality were achieved for all respondents.

4.3.9.2 Ethical issue concerning the researchers

An ethical issue relating to the researchers is about the use of information. According to Kumar (2005), it is unethical to use the information in a way that directly or indirectly affects the respondents adversely. In this study, data collected by the researcher about participants is not identifiable and is used solely for the purpose of research.

4.3.9.3 Ethical issue concerning the sponsoring organisations

In terms of sponsoring organisations, it is unethical to impose any controls and restrictions, which make the research findings to meet sponsoring organisations' financial interests (Kumar 2005). This study is jointly sponsored by the Ministry of Education and Training, Vietnam and Western Sydney University with the project identification P00022974. Nonetheless, it was acknowledged that both funding providers have no financial interests in the outcomes of this research, and there are no controls and restrictions on the publication of results from this research.

4.3.10 Characteristics of sample

4.3.10.1 Response

Out of the 438 building projects contacted, 115 project managers responded to the questionnaire, representing a response rate of 26.2%. A number of invalid and unreliable questionnaires were identified and removed due to: (1) short response duration determined by Qualtrics survey software (5 responses), (2) incompleteness (6 responses), (3) the same choice for all required questions (8 responses), and (4) inconsistency in the answers for duration of the project and total man-days worked for the project (18 responses). After excluding invalid questionnaires, the information of 78 completed building projects was input into a database.

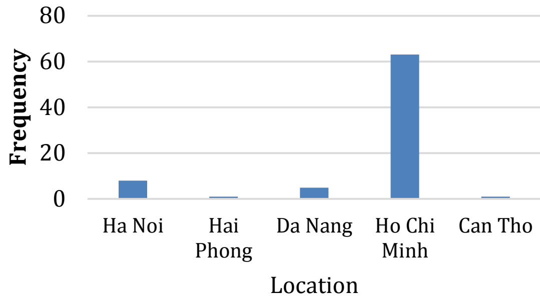
4.3.10.2 Sample profile

The characteristics of the sample projects are described in Table 4.4. The profile of the projects suggests that the sample projects were mainly located in Ho Chi Minh City (80.8%). This may be attributable to the fact that the majority of the projects in the sampling frame were located in Ho Chi Minh City (55%). In term of the duration of projects, the sample projects were categorised into 4 groups, which include less than 12 months (21.8%), from 12 to 24 months (48.7%), from 25 to 36 months (15.4%) and over 36 months (14.1%). Seventy-one point eight per cent of the sample projects were from the civil sector, and 28.2% of the projects were from the industrial sector. The project grade comprises grade IV (6.4%), grade III (9.0%), grade II (25.6%) and extraordinary (17.9%). In relation to contract size of the projects, the data were collected from all 4 determined groups of contract value, which include level C (14.1%), level B (26.9%), level A (46.2%) and important national level (12.8%). Therefore, the profile of the projects indicates that whereas the data were obtained from various locations and across the whole range of building projects, the focus of data collection was on civil buildings (71.8%) and located in Ho Chi Minh City (80.8%).

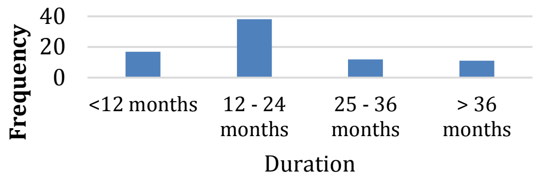
Table 4.4: Characteristics of sample projects

Profile	Frequency	Percentage
Location		
Ha Noi	8	10.3
Hai Phong	1	1.3
Da Nang	5	6.4
Ho Chi Minh	63	80.8
Can Tho	1	1.3

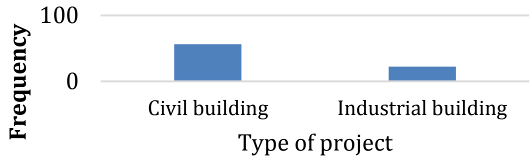
Histogram



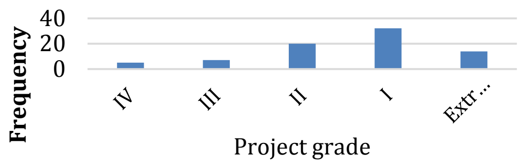
Profile	Frequency	Percentage
Duration		
< 12 months	17	21.8
12 -24 months	38	48.7
25 -36 months	12	15.4
> 36 months	11	14.1



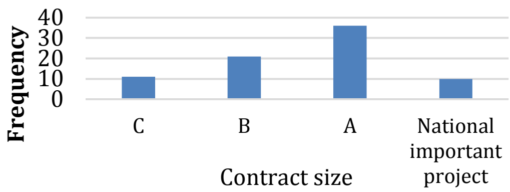
Profile	Frequency	Percentage
Type of project		
Civil	56	71.8
Industrial	22	28.2



Profile	Frequency	Percentage
Project grade		
IV	5	6.4
III	7	9
II	20	25.6
I	32	41
Extraordinary	14	17.9



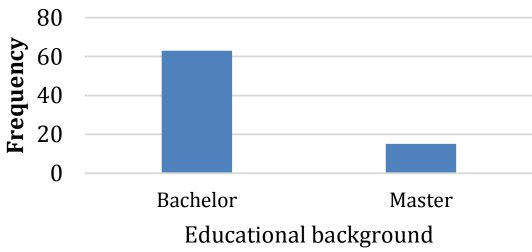
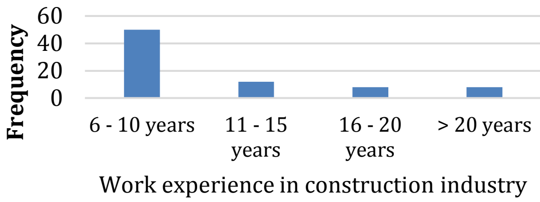
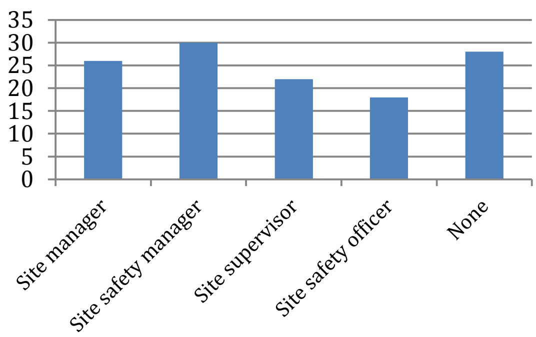
Profile	Frequency	Percentage
Contract size		
C	11	14.1
B	21	26.9
A	36	46.2
Important national project	10	12.8



4.3.10.3 Respondents profile

The respondents' demographics are reported in Table 4.5. The profile of respondents indicates that 80.8% of the respondents held a bachelor's degree, whereas 19.2% of respondents held a master's degree. All respondents had more than six years of experience in the construction industry. In relation to the consultation rate when answering the questionnaires, 64.1% of responses were consulted by other positions of site management, whereas 35.9% of responses were not consulted. As the validity of the study is directly associated with the participants and their responses, the extensive working experience, high education level of the respondents, their position as a project manager and a high consultation rate (64.1%) may enhance the validity and reliability of the research data.

Table 4.5: Demographics of respondents

Profile	Frequency	Percentage	Histogram
Educational background			
Bachelor	63	80.8	
Master	15	19.2	
Work experience			
6 - 10 years	50	64.1	
11 - 15 years	12	15.4	
16 - 20 years	8	10.3	
> 20 years	8	10.3	
Consults			
Site manager	26	33.3	
Site safety manager	30	38.5	
Site supervisor	22	28.2	
Site safety officer	18	23.1	
None	28	35.9	

'None': no consultation was undertaken by the respondents.

4.4 Data analysis methods

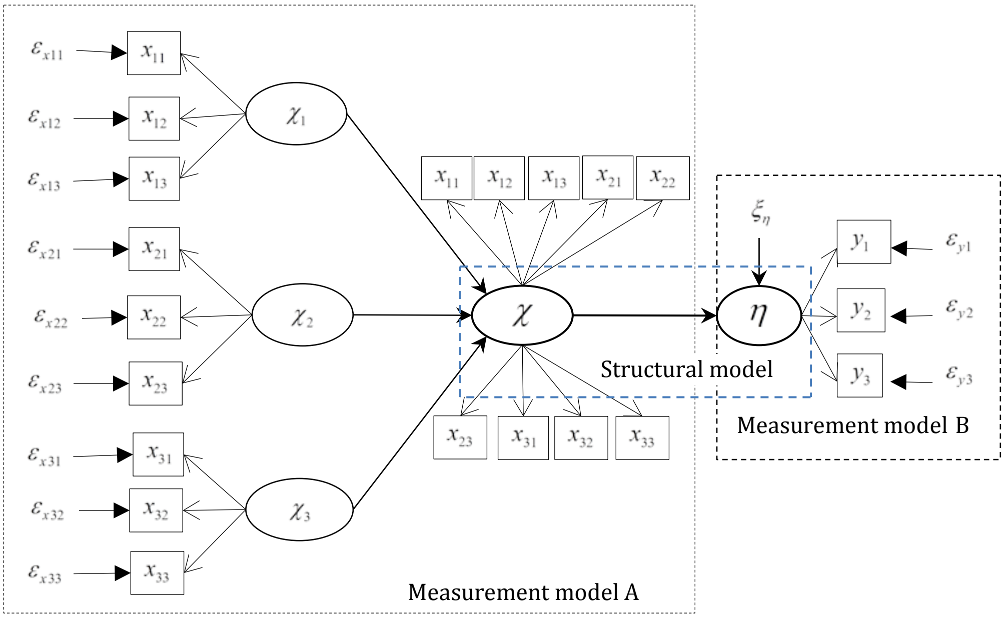
This section presents the analytical methods used for analysing data in this study. It begins with reviewing the structural equation modelling (SEM) technique (Section 4.4.1). It is followed by the justification for the selection of PLS-SEM approach for this study (Section 4.4.2). This section ends with the details of PLS-SEM process (Section 4.4.3).

4.4.1 Structural equation modelling (SEM)

SEM is seen as a general model encompassing a set of multivariate statistical approaches to empirical data (e.g. multiple regression, analysis of covariance, analysis of variance, confirmatory factor analysis and path analysis, etc.) (Bowen & Guo 2011). For social research, SEM has often been used as an approach for analysing data, which combines simultaneous regression equations and factor analysis (Ecob & Cuttance 1987). This modelling technique has been attracted widespread attention from construction safety management researchers such as Wu et al. (2016), Sunindijo and Zou (2012), Vinodkumar and Bhasi (2010) and Feng et al. (2017).

SEM is characterised by its abilities: (1) to estimate multiple and interdependence relationships, and (2) to present unobserved constructs in these relationships and account for measurement error in the estimation process (DiLalla et al. 2000). In SEM, there are predicted (dependent) constructs and predictor (independent) constructs. Predicted constructs are unobserved latent variables. Predictor constructs are unobserved latent variables that are used to predict dependent constructs. Both predicted and predictor constructs are measured by their corresponding observed variables, namely indicators or measurement items. In this research, the terms 'predicted constructs/latent variables' and 'dependent constructs/latent variables' are used interchangeably, the terms 'predictor constructs/latent variables' and 'independent constructs/latent variables' are used interchangeably, and the terms 'measurement items' and 'indicators' are used interchangeably.

Figure 4.2 depicts an example of a structural equation model, which comprises two main elements: (1) a structural model, and (2) measurement models. The structural model presents the relationship between predictor construct (χ) and predicted construct (η). A structural error (ξ_{η}) for predicted construct (η) in a structural model is the variance of this construct that is not explained by its predictor construct (χ). There are also measurement model A and B of the constructs χ and η, respectively, which represent the relationship between the constructs and the measurement items. Specifically, in measurement model A, χ is a second-order predictor construct, which can be defined and represented by three first-order components (i.e. χ_1, χ_2 and χ_3). All first-order constructs (i.e. χ_1, χ_2 and χ_3) are measured by reflective measurement items (i.e. x_{ij}). Each observed measurement item (x_{ij}) has a measurement error labelled ε_{xij}. In terms of measurement model B, predicted construct η is defined and measured by reflective measurement items (i.e. y_1, y_2 and y_3). Each measurement item has its measurement error term (ε_{yi}).



Note:

χ : second-order predictor construct

χ_i : first-order predictor constructs

η : dependent predicted construct

ε : measurement error

x_i : measurement items of predictor construct

y_i : measurement items of predicted construct

ξ_η : structural error (or error of prediction)

→ reflective effect between observed and latent variables

→ causal effect between predictor and predicted constructs

→ direct effect of error

Figure 4.2: An example of a structural equation model

SEM allows a series of analyses by combining the two sub-models described above into a unified model, thereby enabling the assessment of the adequacy of the entire model towards the observed data (Hwang & Takane 2004). Accordingly, in this study, SEM was adopted for data analysis for following reasons:

- The hypotheses of this study indicate the presence of multiple constructs (i.e. resilient safety culture, project complexity, hazard prevention practice, error management practice and mindful organising practice) (See Chapter 3 for the conceptual model and hypotheses development).

Nonetheless, based on a review of pertinent literature, it was showed that those constructs are latent variables, which comprise various sub-components and corresponding measurement items (See Section 4.3.1 for operationalisation of research variables). Thus, it was required to examine the relationships among hypothesised latent variables and their corresponding observed variables (or confirming the factor structure of those latent variables) before performing the substantive analyses. Above issue can be solved by confirmatory factor analysis function of measurement models in SEM (Bowen & Guo 2011; Hoyle 2012).

- The hypotheses of this study also concern with an examination of multiple structural relationships between constructs identified in this study based on various theories (i.e. safety culture theory, resilience engineering theory, Latent failure model, human error theory, high-reliability theory and normal accident theory). This issue can also be solved by path analysis function of the structural model in SEM (Hair et al. 2006; Hair et al. 2016).

- In addition, the use of SEM facilitates those tests (i.e. relationships between latent variables and corresponding measurement items, and relationships between latent variables) to conduct simultaneously (Chin 1998; DiLalla et al. 2000).

4.4.2 Selection of PLS-SEM approach for this study

There are two general approaches to SEM characterised by two distinctive ways of conceptualising latent variables: covariance-based SEM (CB-SEM) and component-based SEM (also called partial least squares (PLS-SEM)) (Hwang & Takane 2004). CB-SEM considers the latent variables as common factors that explain the covariation between its corresponding measurement items, whereas PLS-SEM uses proxies to present the latent variables of interest (Hair et al. 2016). The differences between CB-SEM and PLS-SEM approaches are summarised in Table 4.6 below:

Table 4.6: Comparison of the two SEM approaches

Criterion		CB-SEM	PLS-SEM	Sources
Data characteristics	Sample size	Recommendations range from 200 to 800 cases	Recommendations range from 30 to 100 cases	(Chin & Newsted 1999; Fornell & Bookstein 1982)
	Distribution	Normally distributed and independent observation (parametric)	No distributional assumptions (non-parametric)	(Hwang & Takane 2004; Wang & Wang 2012)
Model characteristics	Relationships between constructs and measurement items	Only with reflective measurement models	Formative and reflective measurement models	(Chin & Newsted 1999; Hair et al. 2016)
	Relationships among constructs	Allow circular relationships	No circular relationships	(Chin & Newsted 1999; Hair et al. 2016)
	Model complexity	Only small complexity (e.g., less than 100 indicators)	Allow large complexity (e.g., more than 100 indicators)	(Chin & Newsted 1999; Fornell & Bookstein 1982; Hair et al. 2016)
Algorithm properties	Objective	Parameter accuracy	Prediction accuracy	(Hwang & Takane 2004)
	Parameter estimates	Consistent	Consistent at large	(Chin & Newsted 1999; Hwang & Takane 2004)
	Latent variable score	Indeterminate	Determinate	(Hair et al. 2016; Hwang & Takane 2004)

Based on the comparison of the two SEM approaches, it is highlighted that the selection of SEM approach for a specific study should consider three main issues: (1) data characteristics, (2) model characteristics, and (3) algorithm properties. In terms of data characteristics, CB-SEM approach requires the observations to be normally distributed and independent, and a large sample size data; whereas PLS-SEM approach does not require a large sample size nor normality assumption of data distribution. In terms of model characteristics, whistle CB-SEM approach only allows reflective measurement models and low level of complex structural models; PLS-SEM approach works efficiently with reflective and formative measurement models and can handle highly complex structural models. In terms of algorithm properties, CB-SEM approach adopts the maximum likelihood estimation and aims to minimise the difference between the sample covariance and those predicted by the model for theory development and testing; PLS-SEM approach, in contrast, adopts least square estimation and aims to maximise the variance explained for constructs and parameter estimates for predictive purposes (Chin & Newsted 1999; Fornell & Bookstein 1982; Hair et al. 2016; Hwang & Takane 2004; Wang & Wang 2012).

In this study, PLS-SEM approach was selected to analyse data for following reasons:

- Due to low response rate in the construction industry, the sample size (N = 78) is not too large (See Section 4.3.10 for characteristics of the sample). In addition, the data are non-normally distributed (See Section 5.2 for the characteristics of data). Therefore, the use of CB-SEM approach was inappropriate for this study as it requires a large sample size and a normality distribution of data. The PLS-SEM approach, in other way, works efficiently with a small sample size and does not require the data to be normally distributed.

- The operationalisation of research variables indicates that the SEM models will be specified with a high complexity level. Specifically, most of the constructs are operationalised at higher levels of abstraction. For example, error management practice is defined and represented by four components: learning from errors, thinking about errors, error competence and error communication. Each component of error management practice is measured by a number of indicators. Accordingly, the total number of measurement items found in this study is large (approximately 140 items).

- The hypotheses of this study imply that the study sought for predicting the target constructs (i.e. psychological resilience, contextual resilience, behavioural resilience and safety performance). In addition, the research objectives (i.e. to examine the interactive impacts of resilient safety culture dimensions on safety performance of construction projects, and to examine the moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance of construction projects) require to determine the latent variables scores prior to subsequent analyses. For example, in order to examine the moderating effects of psychological resilience on the relationship between project complexity and safety performance of construction projects (See hypothesis 20), latent variables scores of project complexity and psychological resilience are required to be determined in order to create the interaction term and examine the impact of interaction term on safety performance (See Table 4.9 for details). Therefore, the use of PLS-SEM more appropriate than CB-SEM for this study because whereas the former approach provides the results of latent variables scores; the latter does not.

4.4.3 PLS-SEM process

There are four critical issues associated with the application of PLS-SEM, which include: (1) model properties, (2) data, (3) PLS-SEM algorithm, and (4) model evaluation (Hair et al. 2012; Ringle et al. 2012). Thus, to fulfil the research aim and objectives, PLS-SEM modelling process of this study comprises four steps (See Figure 4.3). Step 1 is specifying the structural models and measurement models. Step 2 is preparing and examining the data after they have been collected to ensure that the results from applying PLS-SEM are valid and reliable. Step 3 is running the PLS-SEM algorithm to estimate PLS-SEM models. Step 4 is evaluating the measurement models and structural models specified in this study.

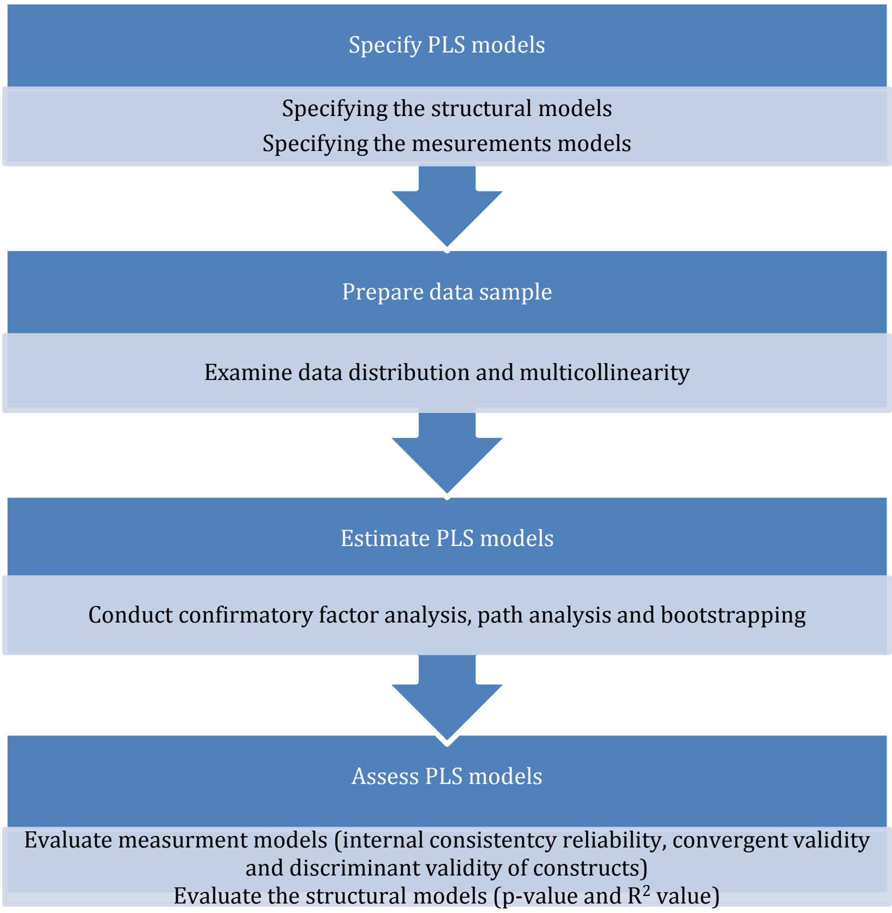


Figure 4.3: PLS-SEM process

In the above process, SmartPLS (v. 3.2.7), a statistical software (Ringle et al. 2015), was used to execute the PLS-SEM models specified in this research for following reasons:

- It has been developed by scholars at the School of Business, the University of Hamburg, Germany under the leadership of PLS experts and IT professionals (e.g. Prof. Dr Christian Ringle, Dipl Wiinf Sven Wende and Dr Jan Michael Becker). This software provides the necessary algorithms and techniques to estimate the models specified in this study.

- It has been widely applied across various areas (Ringle et al. 2015). In construction safety management research, the effectiveness of this software has been attested by a number of studies (Hong et al. 2018; Ramli et al. 2014; Subramaniam et al. 2016).

- There are some types of support which provide instructions on how to use this software to conduct research and obtain solutions such as a web-based discussion forum and books (e.g. a primer on partial least squares structural equation modelling by Hair et al. (2016) and advanced issues in partial least squares structural equation modelling by Hair et al. (2017)).

4.4.3.1 PLS-SEM specification

Based on the hypotheses and conceptual model developed in this study, PLS-SEM models were specified. Each of the specified PLS-SEM models consists of two elements: (1) a structural model which presents the relationships between predictor and predicted constructs, and (2) measurements models which present the relationships between those constructs and their corresponding measurement items (Hair et al. 2016).

(1) Modelling the relationship between hazard prevention practice, error management practice, mindful organising practice and resilient safety culture dimensions

In responding to the objectives 1 and 2 of this study (i.e. to identify the dimensions of resilient safety culture of construction projects and to identify the drivers of resilient safety culture (See Sections 3.2 and 3.3), the PLS-M1 is developed and shown in Figure 4.4. In PLS-M1, hazard prevention practice, error management practice and mindful organising practice are three independent latent variables. Psychological resilience, contextual resilience and behavioural resilience are three dependent constructs. The relationships between independent constructs and dependent constructs are established by arrows. Accordingly, the arrows indicate that independent constructs predict dependent constructs (e.g. the constructs on the left predict the constructs on the right side of the figure). In addition, the relationships between each construct and their corresponding measurement items of the PLS-M1 are formed and detailed in: (1) measurement model 1 (e.g. relationship between hazard prevention practice and its indicators) (See Figure 4.5), (2) measurement model 2 (e.g. relationship between error management practice and its indicators) (See Figure 4.6), (3) measurement model 3 (e.g. relationship between mindful organising practice and its indicators) (See Figure 4.7), (4) measurement model 4 (e.g. relationship between psychological resilience and its indicators) (See Figure 4.8), (5) measurement model 5 (e.g. relationship between contextual resilience and its indicators) (See Figure 4.9), and (6) measurement model 6 (e.g. relationship between behavioural resilience and its indicators) (See Figure 4.10).

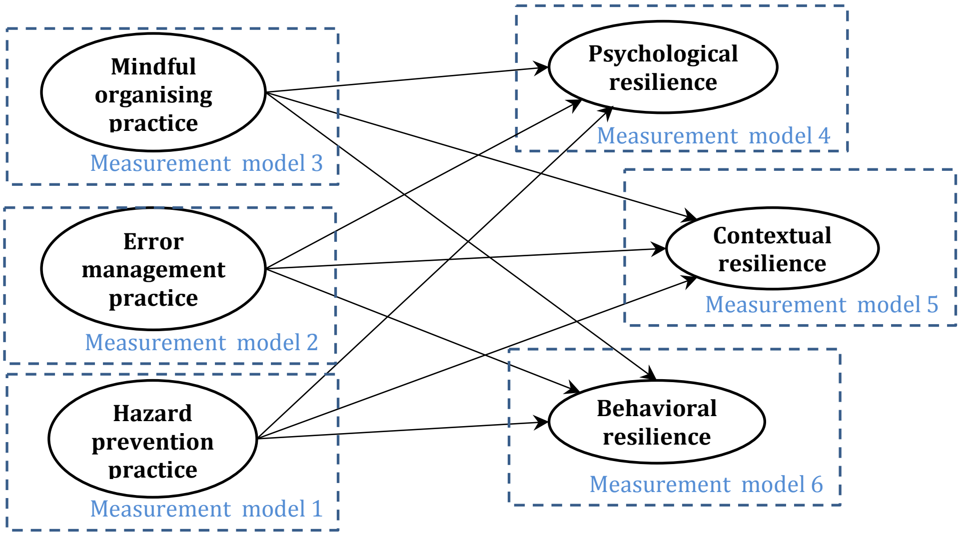


Figure 4.4: PLS-M1 formulated to examine the relationships between hazard prevention practice, error management practice, mindful organising practice and resilient safety culture dimensions

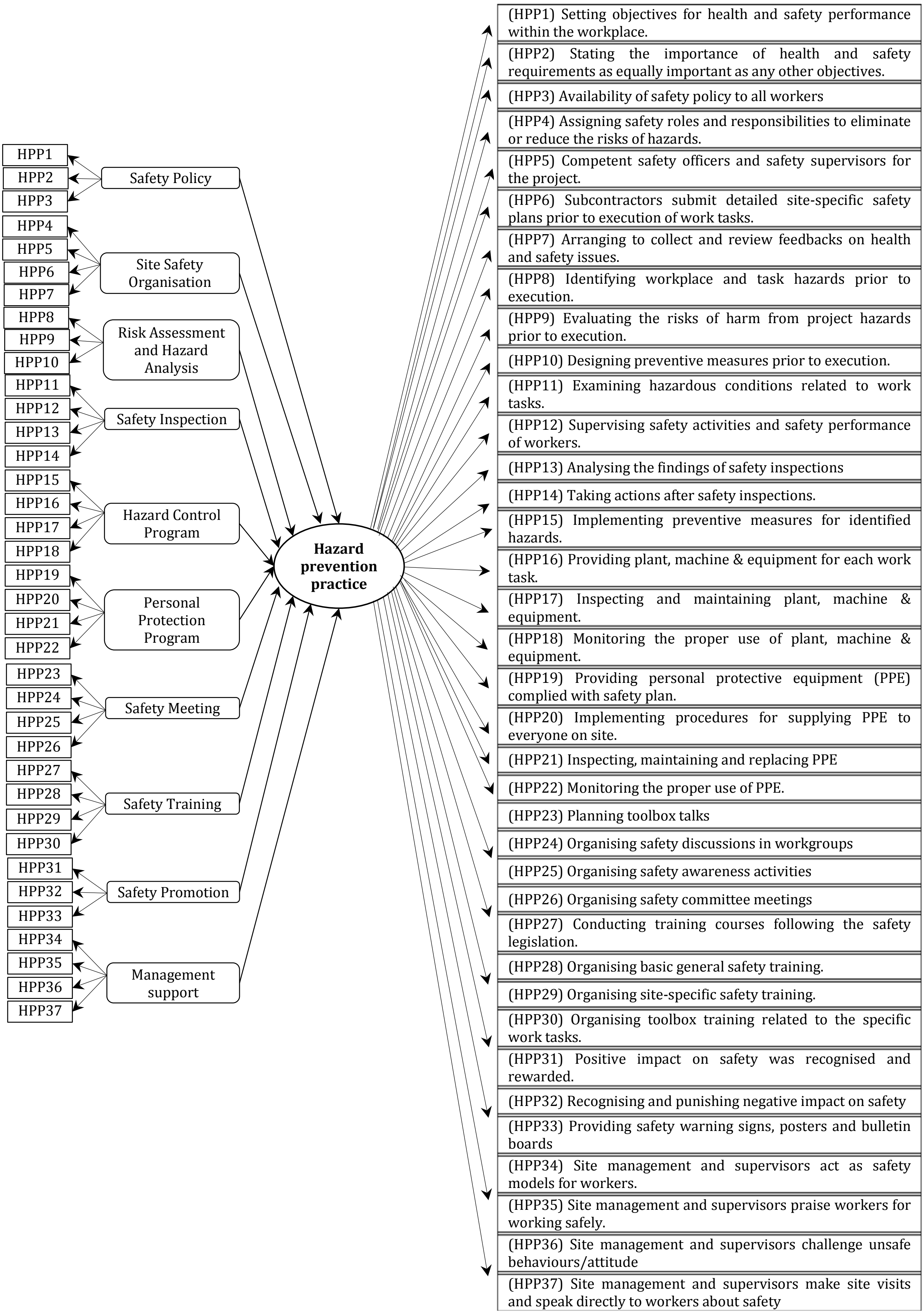


Figure 4.5: Measurement model 1 (Hazard prevention practice and indicators)

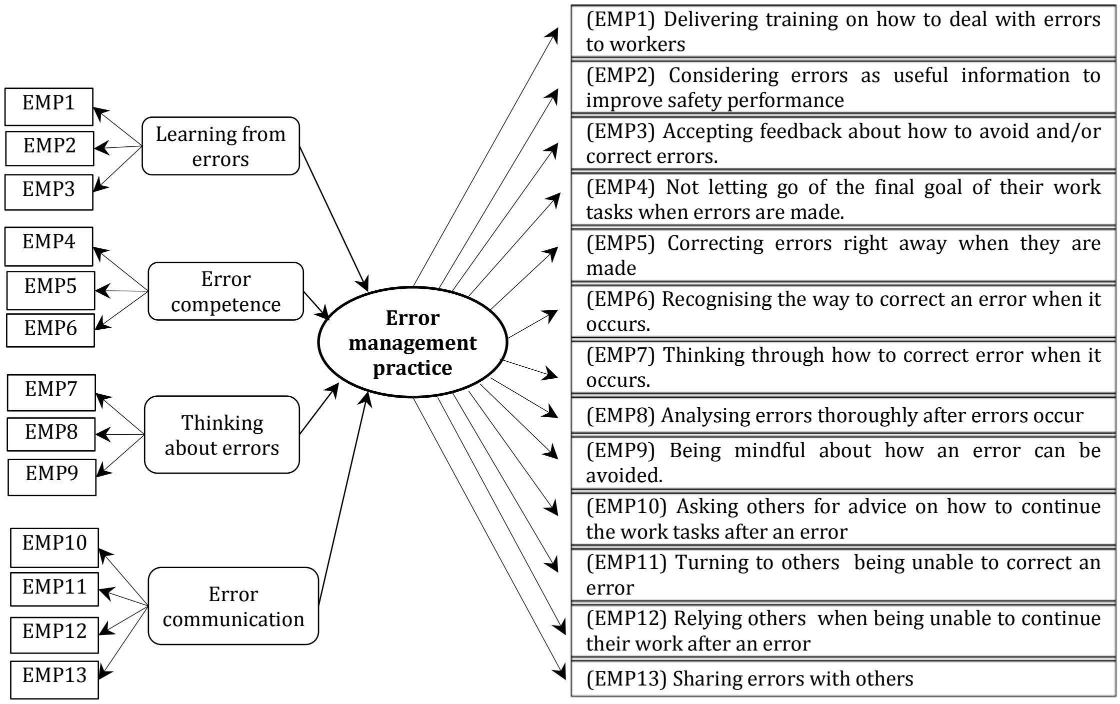


Figure 4.6: Measurement model 2 (Error management practice and indicators)

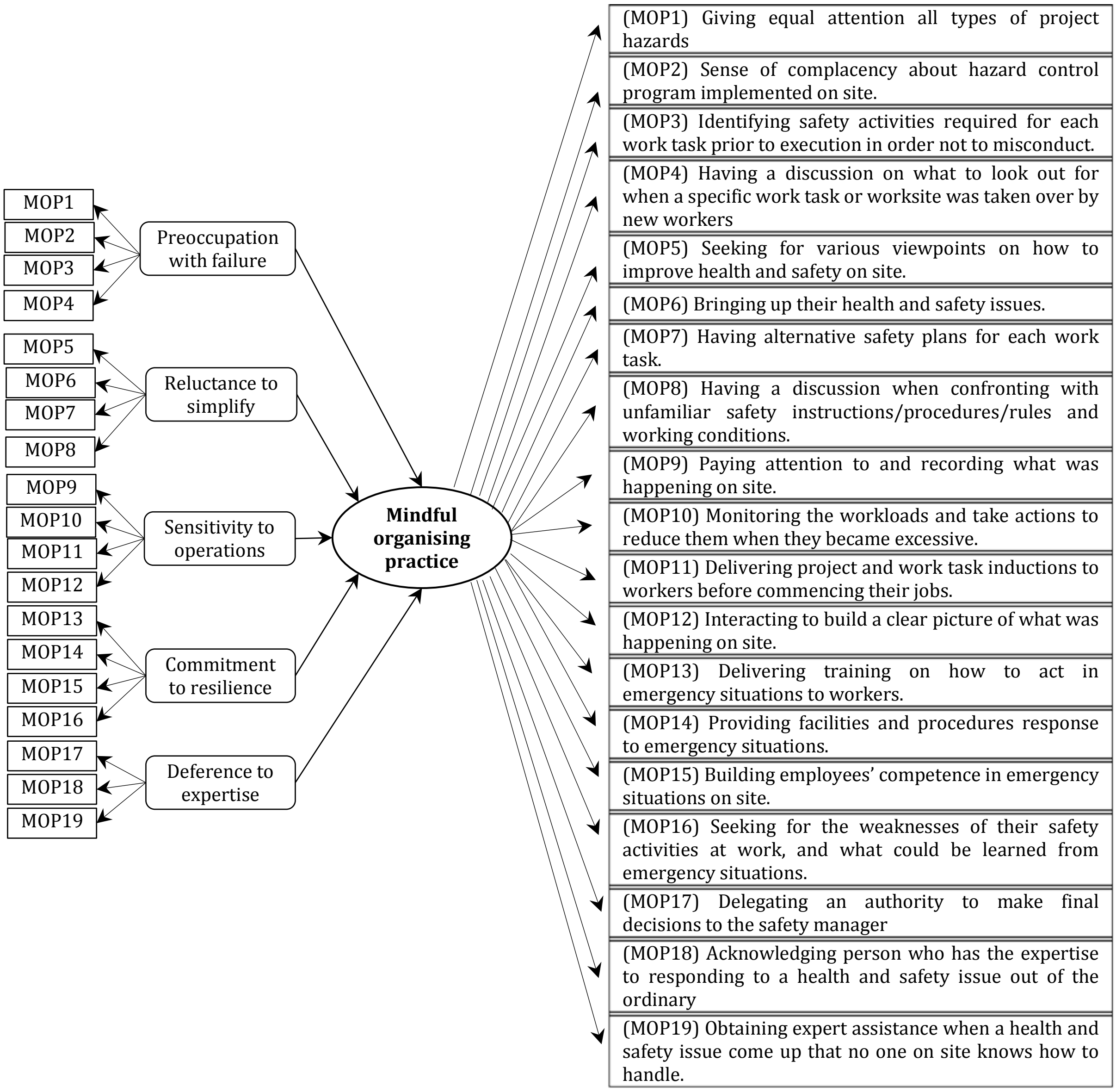


Figure 4.7: Measurement model 3 (Mindful organising practice and indicators)

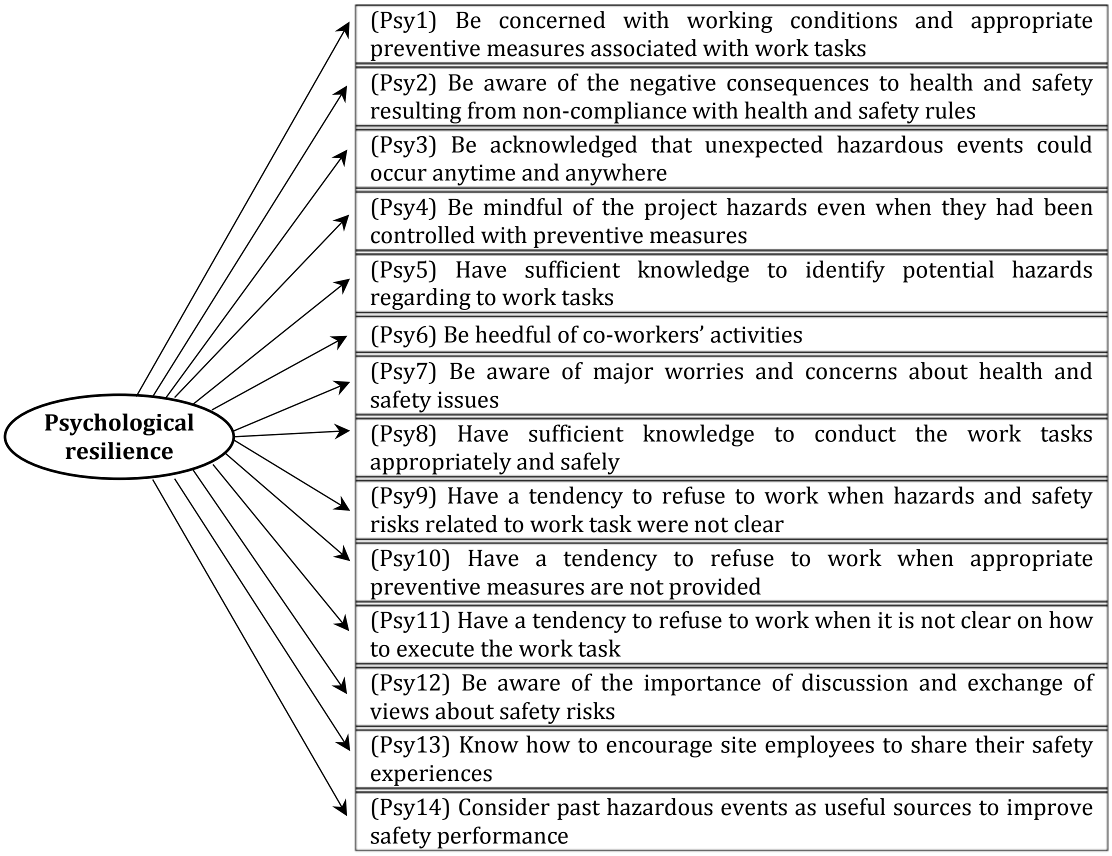


Figure 4.8: Measurement model 4 (Psychological resilience and indicators)

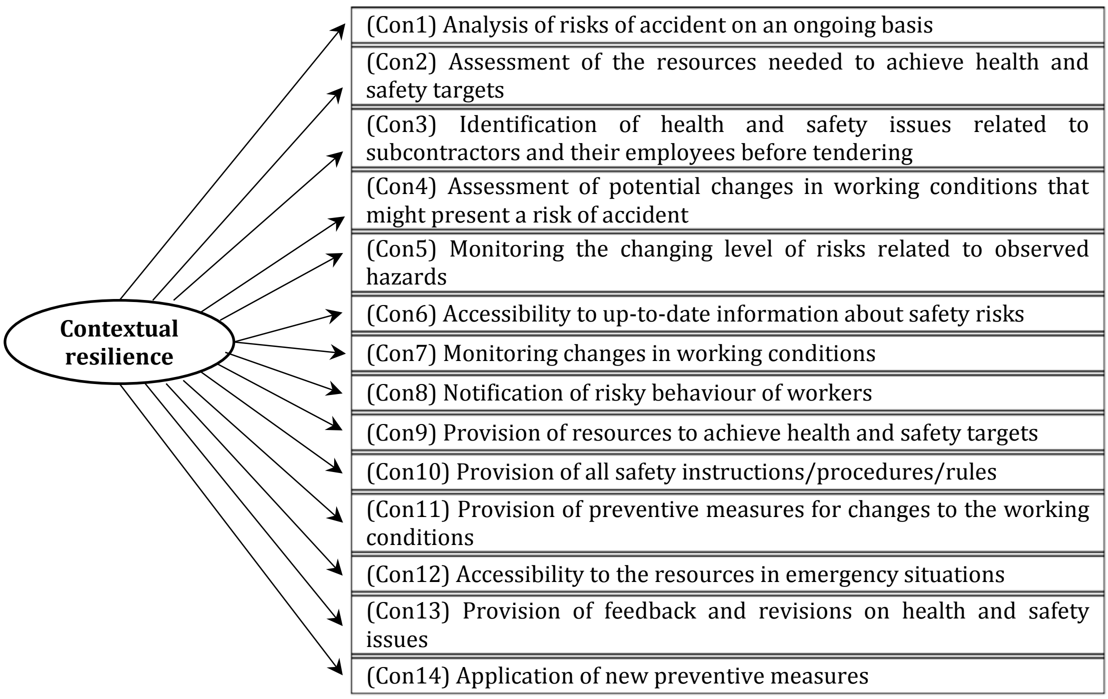


Figure 4.9: Measurement model 5 (Contextual resilience and indicators)

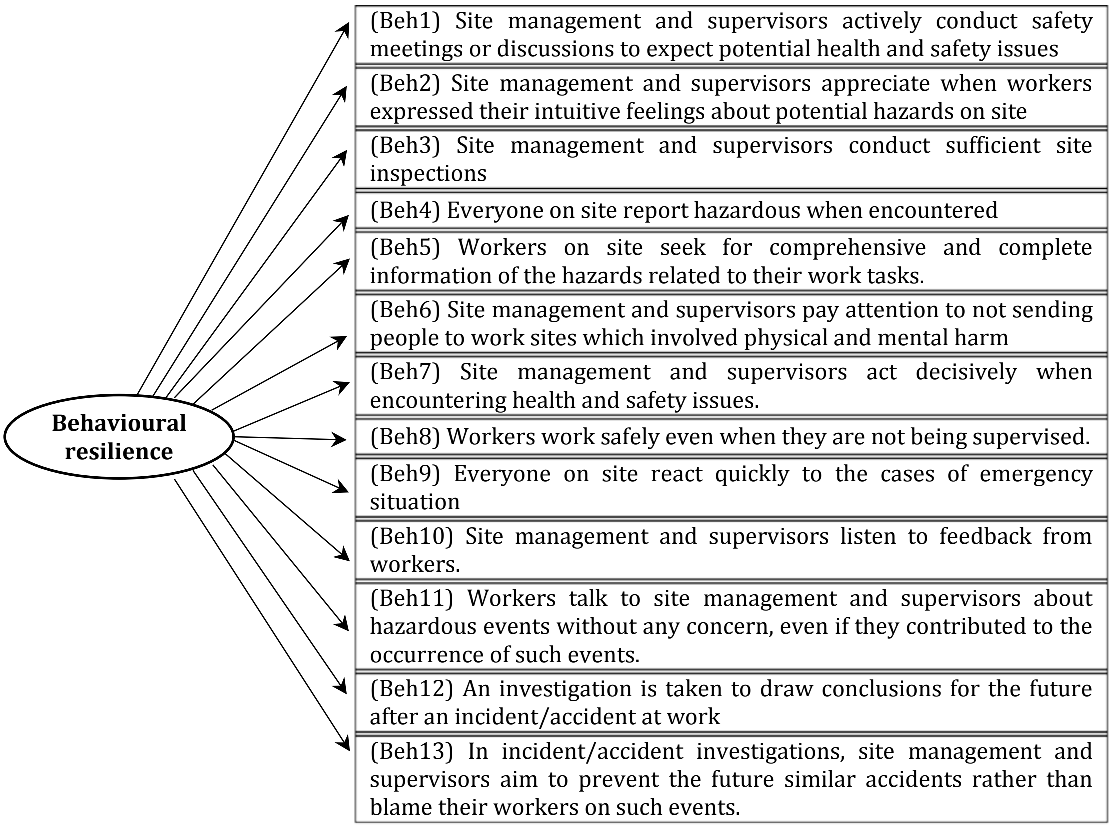


Figure 4.10: Measurement model 6 (Behavioural resilience and indicators)

(2) Modelling the relationship between project complexity dimensions and safety performance

In responding to the objectives 3 and hypotheses 11, 12 and 13 of this study (i.e. to examine the impacts of project complexity dimensions on safety performance of construction projects measured by incident rate) (See Section 3.4); the PLS-M2, PLS-M3 and PLS-M4 are developed and shown in Figure 4.11 (technical complexity and safety performance), Figure 4.12 (organisational complexity and safety performance) and Figure 4.13 (environmental complexity and safety performance), respectively.

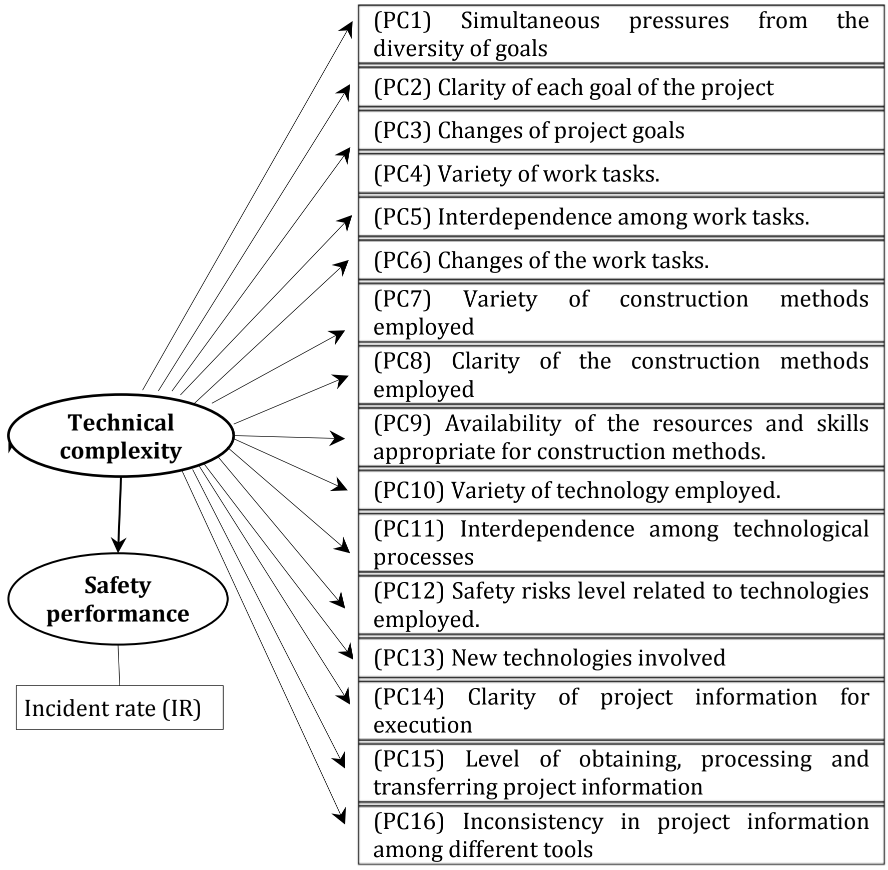


Figure 4.11: PLS-M2 formulated to examine the relationship between technical project complexity and safety performance

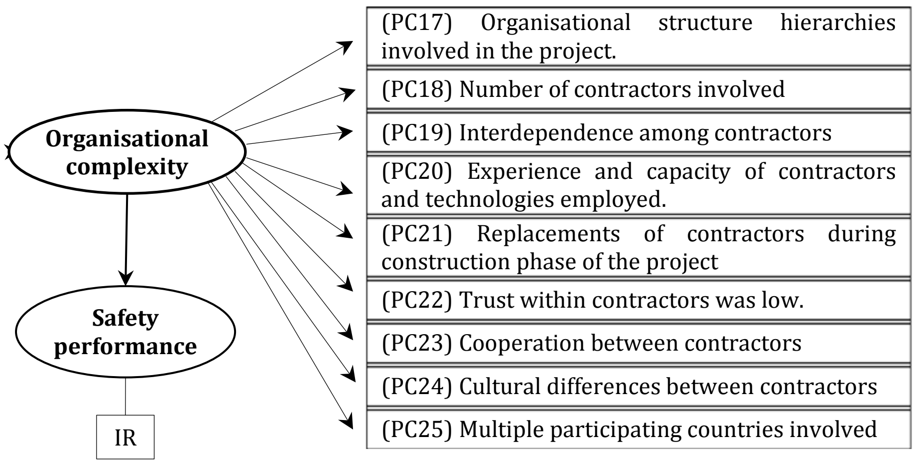


Figure 4.12: PLS-M3 formulated to examine the relationship between organisational project complexity and safety performance

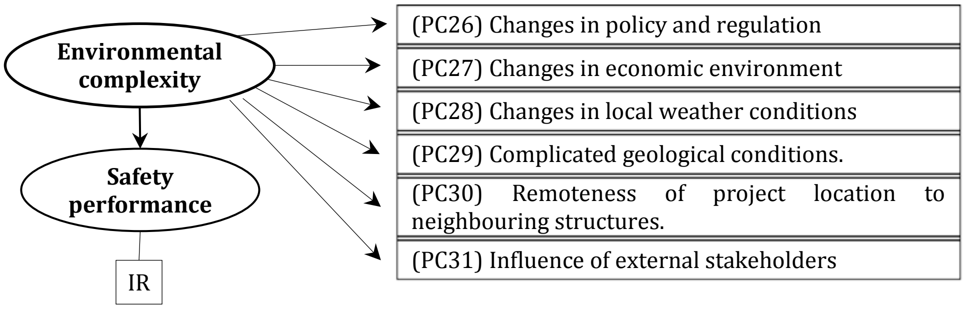
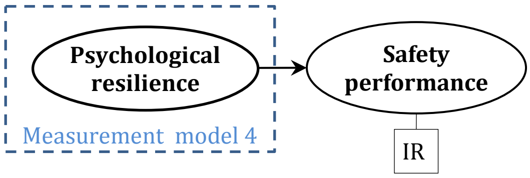
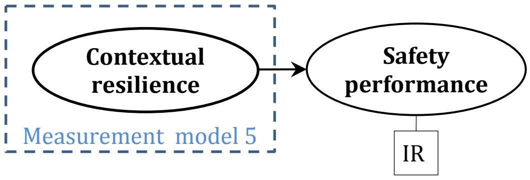
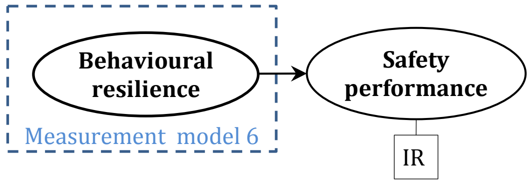


Figure 4.13: PLS-M4 formulated to examine the relationship between environmental project complexity and safety performance

(3) Modelling the relationship between resilient safety culture dimensions and safety performance

In responding to the objectives 3 and hypotheses 14, 15 and 16 of this study (i.e. to examine the impacts of resilient safety culture dimensions on safety performance of construction projects) (See Section 3.4); the PLS-M5, PLS-M6 and PLS-M7 are developed and shown in Table 4.7.

Table 4.7: PLS-M5, PLS-M6 and PLS-M7 formulated to examine the relationship between resilient safety culture dimensions and safety performance

Hypotheses	**PLS models**	**Structural models**	**Measurement models**
H14	PLS-M5		See measurement model 4 (Figure 4.8) for the relationship between psychological resilience and its indicators
H15	PLS-M6		See measurement model 5 (Figure 4.9) for the relationship between contextual resilience and its indicators
H16	PLS-M7		See measurement model 6 (Figure 4.10) for the relationship between contextual resilience and its indicators

In addition, in responding to the objectives 3 and hypotheses 17, 18 and 19 of this study (i.e. to examine the interactive impacts of resilience safety culture dimensions on safety performance of construction projects) (See Section 3.4), the PLS two-stage approach of moderating effects was adopted in this study for following reasons:

- Moderation model is created to examine whether a third variable could directly affect the relationship between the dependent and independent variables. In the moderation model, a moderator interacts with the independent variable to predict the dependent variable (Tharenou et al. 2007). Thus, the moderating effect occurs when a moderator changes the strength and/or the direction of a relationship between the dependent and independent variables in a model (Hair et al. 2016). In this study, the hypotheses 17, 18 and 19 imply that this study sought for determining whether or not the relationship between any dimensions of resilient safety culture on safety performance is influenced by the other two dimensions, which include: (1) the relationship between psychological resilience and safety performance is affected by contextual resilience, (2) the relationship between behavioural resilience and safety performance is affected by contextual resilience, and (3) the relationship between psychological resilience and safety performance is affected by behavioural resilience.

- There are three main approaches for creating the interaction term of moderating effects: (1) product indicator approach, (2) orthogonalising approach, and (3) two-stage approach (Hair et al. 2016). The product indicator approach involves multiplying each indicator of the moderator variable with each indicator of the independent variable (Chin et al. 2003). Orthogonalising approach was developed by Little et al. (2006) to address two issues, which are the results of the standardisation of variables as implemented by product indicator approach. In addition, a two-stage approach was proposed by Chin (2003), which exploits the advantages of PLS-SEM in estimating latent variable scores. In the selection of an appropriate approach for a specific research objective, Hair et al. (2016) noted that, whereas procedure of product indicator approach is not recommended in PLS-SEM due to its inevitable introduction of collinearity in the path model, orthogonalising approach is preferred when the primary concern is minimising estimation bias and producing prediction accuracy, two-stage approach is applied to determine whether or not the moderator exerts a significant effect on the relationship between independent and dependent variables. In this study, the objective 3 and hypotheses 17, 18 and 19 indicate that this study concerns with whether or not the relationship between any dimensions of resilient safety culture on safety performance is significantly influenced by the other two dimensions.

Rigdon et al. (2010) summarised the two stages of two-stage approach (See Figure 4.14). The first stage is to obtain the scores of the latent variables (LVS) in the main effects model (i.e. without the interaction term). In stage two, the latent variable scores of the independent variable and moderator variable from stage one are multiplied in order to generate a single-item measured used to measure the interaction term, whereas other latent variables are represented by means of single items of their latent variable scores from stage one.

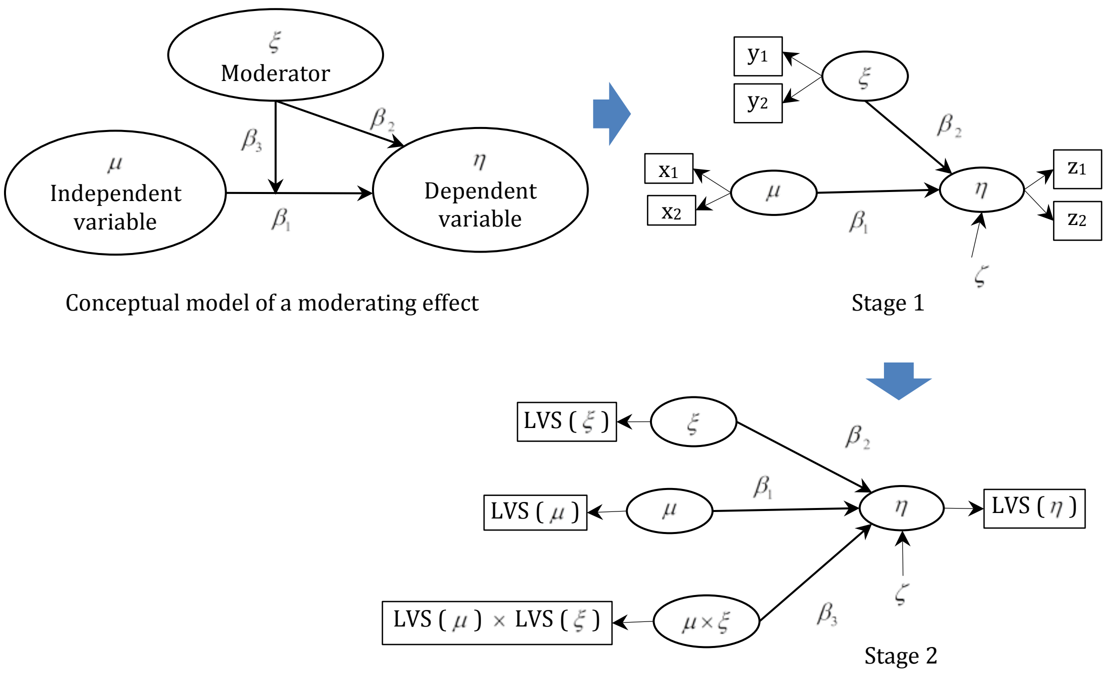
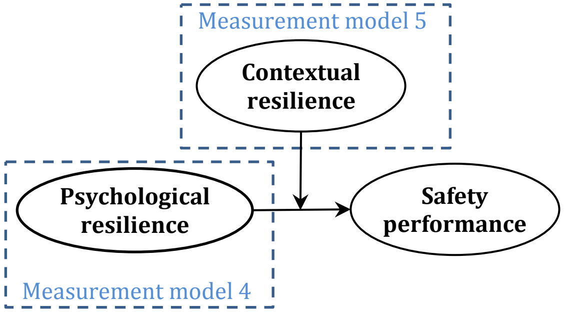
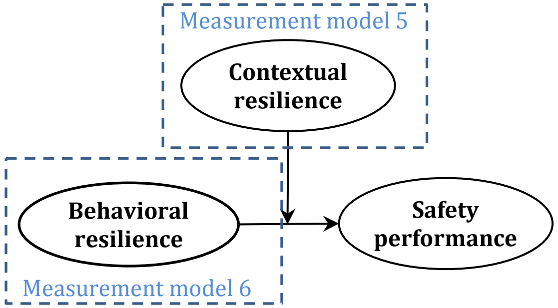
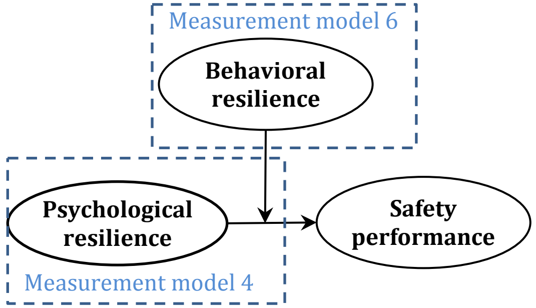
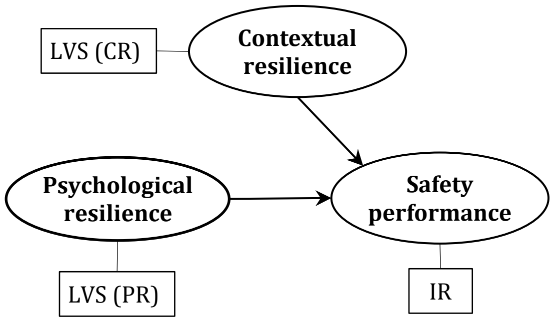
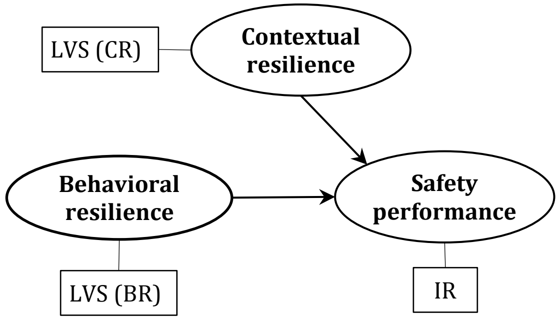
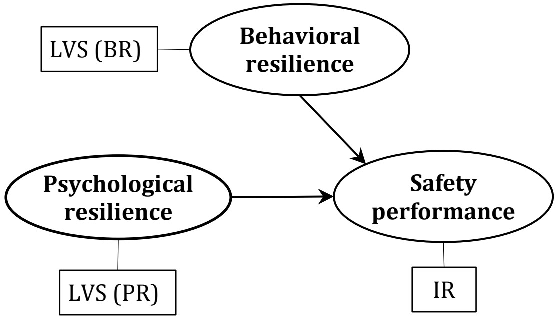
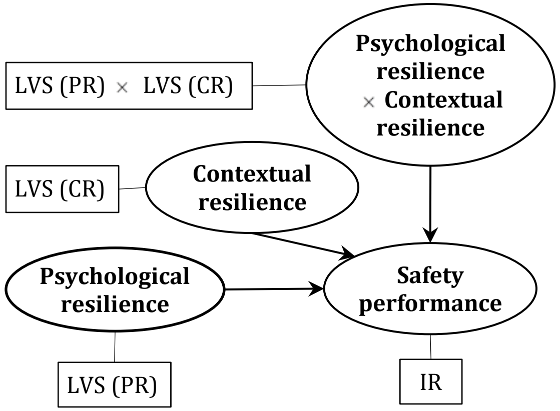
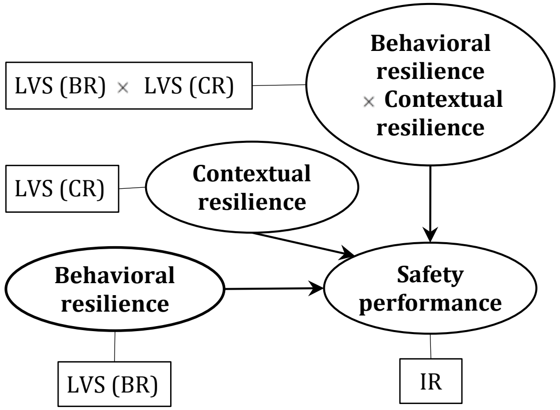
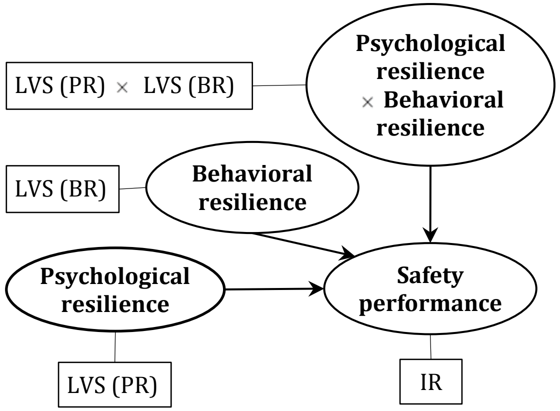


Figure 4.14: A two-stage approach of moderating effect adapted from Rigdon et al. (2010)

In this research, to examine the interaction between resilient safety culture dimensions on safety performance, PLS-M8, PLS-M9 and PLS-M10 were developed and shown in Table 4.8. For example, in responding to hypothesis 17, PLS-M8 was developed. In this model, contextual resilience (a moderator) was hypothesised to change the strength and/or the direct relationship between psychological resilience (independent variable) and safety performance (dependent variable) (See a conceptual model of PLS-M8 in Table 4.8). In the first stage of this model, the scores of contextual resilience and psychological resilience, which are LVS (CR) and LVS (PR) respectively, were obtained. In the second stage, an interaction term (Psychological resilience x Contextual resilience) was developed by multiplying the latent variable scores of psychological resilience and contextual resilience.

Table 4.8: PLS-M8, PLS-M9 and PLS-M10 formulated to examine the interactive impacts of resilient safety culture dimensions on safety performance

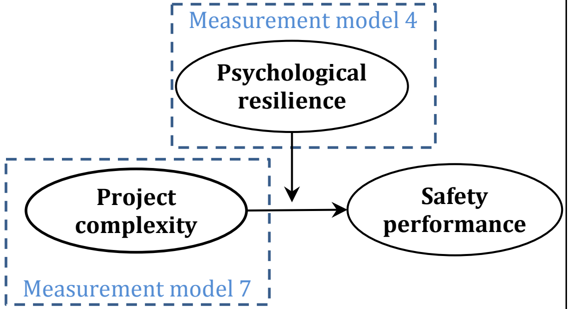
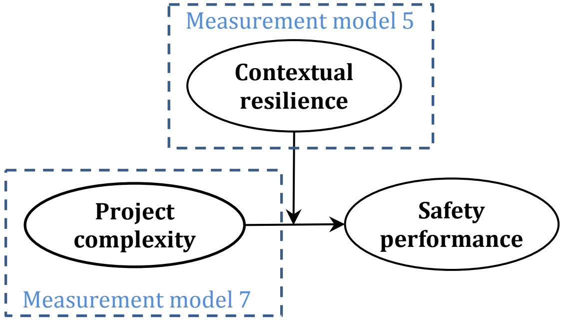
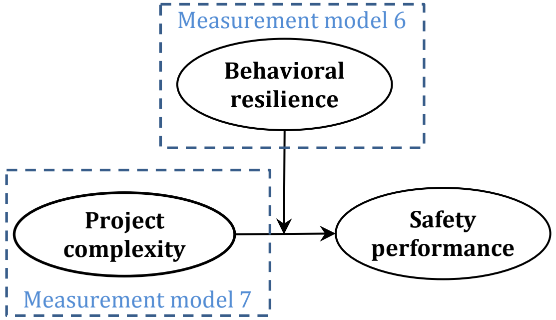
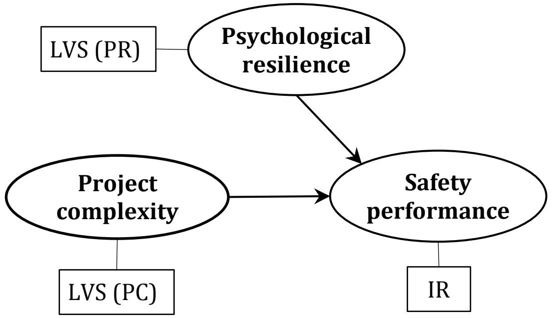
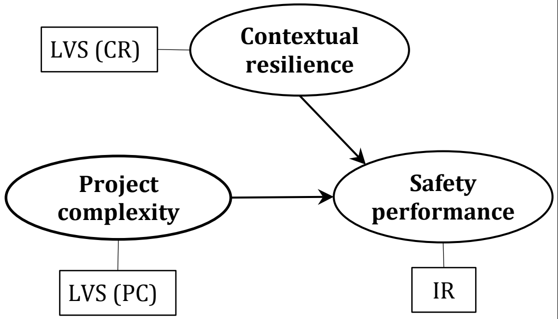
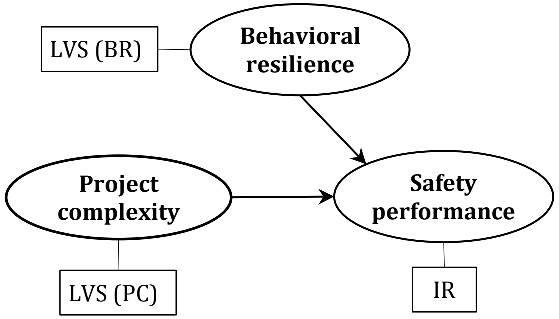
<table>
<tr><td>Hypotheses</td><td>H17</td><td>H18</td><td>H19</td></tr>
<tr><td>PLS models</td><td>PLS-M8</td><td>PLS-M9</td><td>PLS-M10</td></tr>
<tr><td>Conceptual model</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Stage 1</td><td>
</td><td>
</td><td>
</td></tr>
</table>

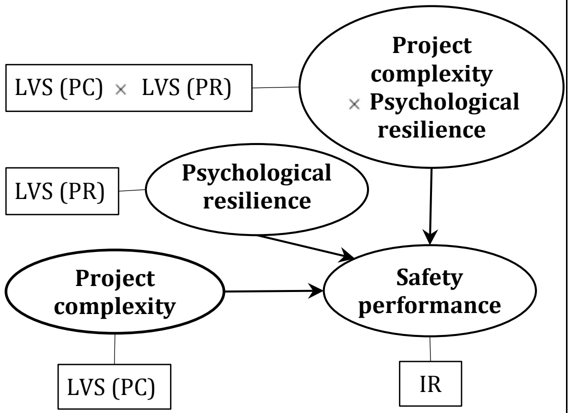
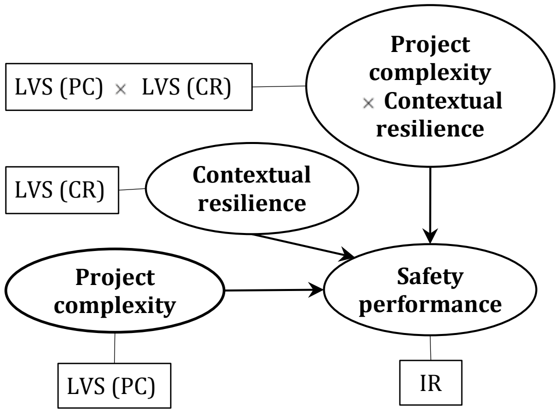
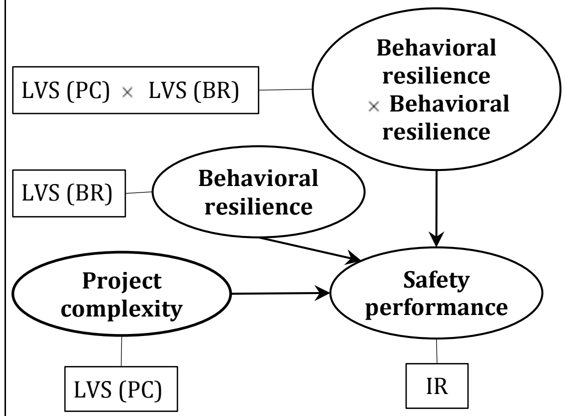
Hypotheses	**H17**	**H18**	**H19**
PLS models	**PLS-M8**	**PLS-M9**	**PLS-M10**
Stage 2			

(4) Modelling the moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance

The objectives 3 and hypotheses 20, 21 and 22 of this study indicate that this study sought to determine whether or not: (1) the relationship between project complexity and safety performance is affected by psychological resilience, (2) the relationship between project complexity and safety performance is affected by contextual resilience, and (3) the relationship between project complexity and safety performance is affected by behavioural resilience (See Section 3.4). The justification for the use of PLS two-stage approach of moderating effects was discussed earlier (See subsection (3) in Section 4.4.3.1). Accordingly, PLS-M11, PLS-M12 and PLS-M13 were developed and shown in Table 4.9. For example, in responding to hypothesis 20, PLS-M11 was developed. In this model, psychological resilience (a moderator) was hypothesised to change the strength and/or the direct relationship between project complexity (independent variable) and safety performance (dependent variable) (See the conceptual model of PLS-M11). In the first stage of this model, the scores of project complexity and psychological resilience, which are LVS (PC) and LVS (PR) respectively, were obtained. In the second stage, an interaction term (Project complexity x Psychological resilience) was developed by multiplying the latent variable scores of project complexity and psychological resilience.

Table 4.9: PLS-M11, PLS-M12 and PLS-M13 formulated to examine the moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance

Hypotheses	**H20**	**H21**	**H22**
PLS models	**PLS-M11**	**PLS-M12**	**PLS-M13**
Conceptual model			
Stage 1			

<table>
<tr><td>Hypotheses</td><td>H20</td><td>H21</td><td>H22</td></tr>
<tr><td>PLS models</td><td>PLS-M11</td><td>PLS-M12</td><td>PLS-M13</td></tr>
<tr><td>Stage 2</td><td>
</td><td>
</td><td>
</td></tr>
</table>

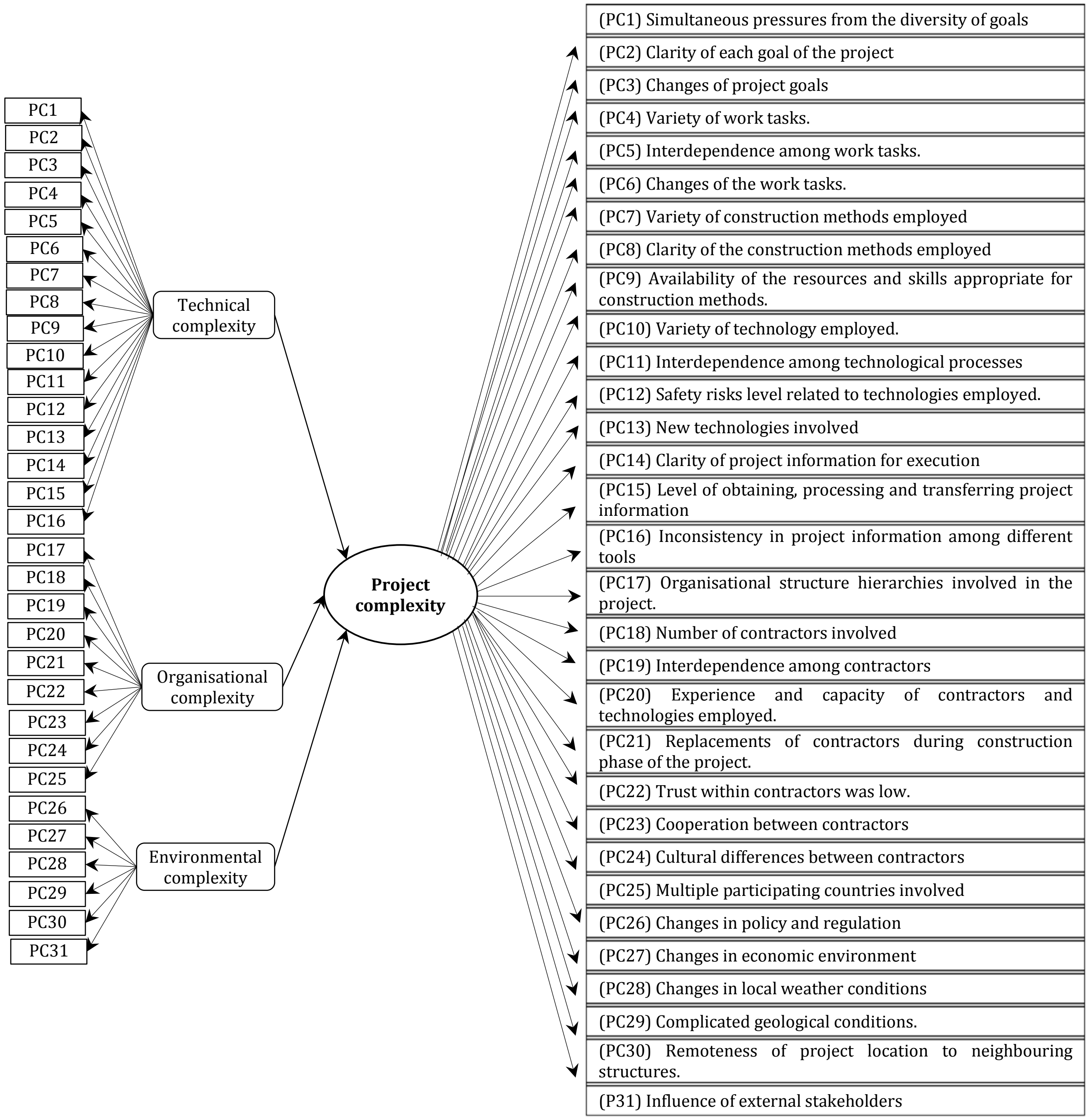


Figure 4.15: Measurement model 7 (Project complexity and indicators)

4.4.3.2 Sample data preparation

Before conducting data analysis with PLS-SEM approach, two potential inherent data problems (i.e. distributions and multicollinearity) in this study were identified and addressed.

(1) Data distribution

As PLS-SEM is a nonparametric statistical method, it does not require the data to be normally distributed (Hair et al. 2016). Nonetheless, it is crucial to verify that the data are not too far from normal as extremely non-normal data produce problems in assessing the significance of coefficients (Henseler et al. 2009). Skewness and kurtosis are two common measures used to examine the distribution of data. Skewness assesses the extent to which a variables' distribution is symmetrical. In addition, kurtosis assesses the extent to which the distribution is peaked. Accordingly, when both skewness and kurtosis are close to zero, the data distribution is considered to be normal. This study adopted a cutoff +/- 3 as indicative of 'extreme' skewness and +/- 10 as indicative of 'problematic' kurtosis (Bowen & Guo 2011). The inspection of skewness and kurtosis were conducted by Statistical Package for Social Sciences (SPSS) software before transferring data to SmartPLS for further analyses. The data distribution will be reported in Section 5.2.

(2) Multicollinearity

Multicollinearity occurs when there is a linear dependence among the predictor variables (Hoyle 2012). The correlation between predictor variables can cause computational errors in standard computer programs (Cronbach 1987). There are two sources of multicollinearity need to be addressed in this study, which include: (1) the multicollinearity between indicators measuring a latent variable, and (2) the multicollinearity among different independent variables in structural equation models. For the former, as the indicators of each latent variable are under reflective model (See Section 4.4.3.1 for measurement models), thereby being not affected by multicollinearity (Fornell & Bookstein 1982; Hair et al. 2016). For the latter, the presence of multicollinearity among independent variables was assessed based on the variance inflation factors (VIF) values, as suggested by Neter et al. (1996). In this study, the results of this test show that all VIF values are less than 10, indicating no critical levels of multicollinearity among independent variables in this study.

4.4.3.3 Models estimation

(1) Confirmatory factor analysis

Confirmatory factor analysis (CFA) is *"a type of structural equation modelling that deals specifically with measurement models, that is, the relationships between latent variables and indicators"* (Hoyle 2012, p. 361). CFA is commonly used for a variety of purposes such as: (1) to confirm the factor structure and quality of a new scale, (2) to determine if a modified scale performs adequately, (3) to establish that the use of observed composite variables in research and practice is justified, (4) to determine if an existing scale performs adequately for a new population, (5) to determine if an existing scale performs the same across two or more population, (6) to confirm that the factor structure and quality of an existing scale that is being used in practice but has not undergone rigorous testing, and (7) to determine that a measurement model is adequate for the available sample before performing a substantive latent variable analysis (Bowen & Guo 2011).

In this research, CFA was adopted to confirm the factor structure of the main latent variables found in this study (i.e. resilient safety culture dimensions, hazard prevention practice, error management practice, mindful organising practice and project complexity dimensions) before performing path analyses (See Section 4.4.3.1 for specification of measurement models). Relevant evaluation criteria of a specific measurement model will be discussed in the assessment of PLS-SEM results of measurement models (See Section 4.4.3.4).

(2) Path analysis

The path analysis in PLS-SEM concerns the relationships between constructs in the specified models. The PLS-SEM algorithm estimates the path coefficients in a way that maximise the explained variance of the predicted constructs (i.e. minimises the unexplained variance) (Bentler & Huang 2014; Hair et al. 2016; Lohmöller 2013). Path analysis is used to determine whether the data are consistent with the relationships between the constructs in the specified models. Thus, the inclusion of any paths between constructs in a model should have theoretical justification (Streiner 2005).

In this research, the path analysis was adopted to examine the relationships between (1) hazard prevention practice, error management practice, mindful organising practice and resilient safety culture dimensions, (2) project complexity dimensions and safety performance, (3) each dimension of resilient safety culture and safety performance, (4) interaction terms of resilient safety culture dimensions and safety performance, and (5) interaction terms of resilient safety culture dimensions and project complexity, and safety performance (See Section 4.4.3.1). The paths between constructs in the PLS-SEM models were developed based on an extensive review of pertinent literature. More specifically, the proposed models were grounded in the safety culture theory, resilience engineering theory, Latent failure model, human error theory, high-reliability theory and normal accident theory (See Section 3.5 for a theoretical framework and hypotheses developed in this study). Relevant evaluation criteria for evaluating the relationships between constructs will be discussed in the assessment of PLS-SEM results of structural models (See Section 4.4.3.4).

(3) Bootstrapping technique

In order to determine whether coefficients (i.e. factor loadings, path coefficients) are significant, data used for parametric significance tests are required to be normally distributed. As PLS-SEM is a nonparametric statistical method, normal distribution of data is not required. Instead, in PLS-SEM, the significance of coefficients are tested by a bootstrapping technique (Davison & Hinkley 1997; Efron & Tibshirani 1986).

Hair et al. (2016, p. 149) summarised the bootstrapping procedure as: *"In bootstrapping, a large number of samples (i.e. bootstrap samples) are developed from the original samples with replacement. Replacement means that each time an observation is drawn at random from the sampling population, it is returned to the sampling population before the next observation is drawn (i.e. the population from which the observations are drawn always contains all the same elements)."*. Accordingly, the bootstrap distribution can be seen as a reasonable approximation of an estimated coefficient's distribution in the population, and its standard deviation can be used as the population standard error (Tinsley & Brown 2000). Thus, the bootstrap distribution can be used: (1) to estimate confidence intervals, and (2) to test null hypotheses that a certain parameter in a population is rejected at a given level of confidence (Hair et al. 2016).

In this research, the bootstrapping technique was adopted to test the significance of coefficients (i.e. factor loadings and path coefficients) found in the PLS-SEM models using SmartPLS (v. 3.2.7) because: (1) the sample size is not too large, and (2) the sampling is not normally distributed. The number of bootstrap samples was set to 5000, as recommended by Hair et al. (2016).

4.4.3.4 Models assessment

(1) Assessing PLS-SEM results of measurement models

The assessment of measurement models concerns the adequacy of individual sets of indicators in capturing their related constructs by evaluating the internal consistency reliability, convergent validity and discriminant validity of constructs specified (Anderson & Gerbing 1988).

- **Internal consistency reliability**

Internal consistency reliability is defined as the extent to which independent indicators, created to measure the same trait of a construct, correlate among one another (Churchill 1979). Internal consistency can be evaluated by Cronbach's alpha reliability (Cronbach 1951) and composite reliability (Werts et al. 1974).

Cronbach's alpha reliability: $\alpha = \frac{k}{k-1}(1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_y^2})$ (Cronbach 1951)

Where k is the number of items measuring a construct,

σ_i^2 is the variance of item i, and

σ_y^2 is the variance of the total composite of test items

Composite reliability: $\Omega = \frac{(\sum_{i=1}^{k}\lambda_i)^2}{(\sum_{i=1}^{k}\lambda_i)^2 + \sum_{i=1}^{k}\text{var}(e_i)}$ (Werts et al. 1974)

Where λ_i symbolises the standardised outer loading of the indicator variable i of a specific construct measured with k indicators,

e_i is the measurement error of indicator variable i, and

var (e_i) denotes the variance of the measurement error, which is defined as 1 - λ_i^2.

The Cronbach's alpha reliability and composite reliability values vary between 0 and 1. The higher values indicate higher reliability levels. In this study, the threshold values of 0.7 were applied as an acceptable value for both Cronbach's alpha reliability and composite reliability (Hair et al. 2016; Nunnally & Bernstein 1967).

- **Convergent validity**

Convergent validity is the extent to which an indicator correlates positively with alternative indicators of the same construct. Convergent validity of measured constructs is evaluated using average variance extracted (AVE) (Hair et al. 2016). According to Fornell and Larcker (1981), AVE indicates the overall amount of variance in the indicators accounted for individual constructs and is a more conservative measure than the composite reliability index. The AVE is calculated using the following formula:

$$AVE = \frac{\sum_{i=1}^{k} \lambda_i^2}{k}$$ (Fornell & Larcker 1981)

Where λ_i symbolises the standardised outer loading of the indicator variable i of a specific construct measured with k indicators.

In this study, AVE value of individual constructs of at least 0.50 was considered acceptable, as suggested by Hair et al. (2016).

- **Discriminant validity**

Discriminant validity refers to the extent to which a latent variable is truly different from other latent variables by empirical standards (Hulland 1999). That means an individual latent variable is unique and captures phenomena not symbolised by other latent variables in the model (Chin 1998). There are two measures of discriminant validity: (1) cross-loadings, and (2) Fornell-Larker criterion (Hair et al. 2016). In terms of cross-loadings, an indicator's outer loading on the associated latent variable should be higher than any of its correlations on other latent variables. In terms of Fornell-Larker criterion, the square root of each latent variable's AVE should be greater than its highest correlation with any other latent variables (Hair et al. 2016).

In this research, the Cronbach's alpha reliability, composite reliability, AVE, cross-loadings and square root of AVE were evaluated using SmartPLS (v. 3.2.7) software. In addition, to establish internal consistency reliability, convergent validity and discriminant validity, any inconsistent or insignificant indicators were considered to be removed according to a set of rules, which given below:

- ✓ Individual construct and their measurement items with Cronbach's alpha and composite reliability index less than 0.7 are considered lack of internal consistency (Hair et al. 2016).

- ✓ Measurement items with factor loadings less than 0.4 are considered inconsistent, indicating a low level of convergent validity (Bagozzi et al. 1991).

- ✓ Individual construct with AVE value that less than 0.5 are considered unacceptable, indicating a low level of convergent validity (Fornell & Larcker 1981).

- ✓ A measurement item's outer loading on the associated construct should be higher than any of its correlations on other constructs; whereas the square root of the AVE value of a construct should be greater than the correlations between the construct and other constructs in the model in order to establish adequate discriminant validity (Hair et al. 2016).

(2) Assessing PLS-SEM results of structural models

Once the latent variables were confirmed to be reliable and valid, structural models were assessed to examine the relationship between latent variables in the models (e.g. structural model path coefficients) and the predictive capabilities of the model (i.e. coefficient of determination).

- **Structural model path coefficients**

The path coefficients indicate the hypothesised relationships between constructs. The path coefficient has standardised values varying approximately between -1 and +1 (e.g. estimated path coefficients close to +1 indicate strong positive relationships, whereas estimated path coefficients close to -1 indicate strong negative relationships) (Hair et al. 2016). In addition, to determine whether or not a coefficient is significant, its standard error needs to be estimated by means of bootstrapping. In the bootstrapping technique, the empirical t-values and p-values for all structural path coefficients are estimated. Accordingly, when a t-value is greater than the critical value, the coefficient is considered to be statistically significant at a certain error probability. In this study, the critical values for a two-tailed test of 1.96 (significant level = 5%) and 2.57 (significant level = 1%) were applied to assess the significance of the structural path coefficients.

- **Coefficient of Determination (R^2)**

Coefficient of determination is a measure of the predictive power of the structural model and is evaluated by examining the amount of variance in the dependent latent variables explained by all independent latent variables linked to it (Hair et al. 2016). The R^2 varies from 0 to 1, with the higher levels representing higher predictive accuracy levels. In this study, R^2 values were applied to evaluate: (1) the amount of variance in the resilient safety culture dimensions explained by hazard prevention practice, error management practice and mindful organising practice and (2) the amount of variance in the safety performance explained by resilient safety culture dimensions and project complexity).

- **Effect Size (f^2)**

In addition to evaluating the R^2 values of all dependent latent variables, the change in R^2 when a specified independent latent variable is omitted from the model can be used to evaluate whether the omitted variable has a substantive impact on the dependent latent variables. The measure is referred to as the f^2 effect size. In this study, the effect size values of less than 0.02 indicate that there is no effect as suggested by Hair et al. (2016).

4.5 Summary

This chapter presented the information relevant to the research design, data collection method and data analysis methods in this study. It provided the justification for the selection of a quantitative research approach and a survey research design. It also clarified the data collection procedure and its pertaining issues. Lastly, it provided the justification for the selection of structural equation modelling technique with partial least-squares estimation approach, and then presented the PLS-SEM modelling process adopted for analysing data in this study.

CHAPTER 5 RESULTS

5.1 Introduction

This chapter reports the research results which help to address the research aim and objectives. Section 5.2 reports the characteristics of collected data. Section 5.3 presents the results pertaining examinations of the internal reliability, the convergent and discriminant validities of measurement models; and addressing objective 1 (i.e. to identify the dimensions of resilient safety culture of construction projects). Section 5.4 reports the results addressing objective 2 (i.e. to identify the drivers of resilient safety culture) and objective 3 (i.e. to examine the interactive effects of resilient safety culture and project complexity on safety performance of construction projects).

5.2 Characteristics of data

Before conducting data analysis with PLS-SEM approach, the characteristics of collected data were illustrated to check its reliability using Statistical Package for Social Sciences software before the subsequent modelling process.

5.2.1 Recordable Incident Rate

The descriptive statistics for the data about Incident Rate are reported in Table 5.1. The incident rate of sample projects ranges from 0 to 89.89 with a mean value of 10.76 and a standard deviation of 17.13. The histogram indicates a positive skewness of 2.32 and a positive kurtosis of 5.99 for these data (See Figure 5.1). The data about IR satisfied the criteria set to check the data distribution (See Section 4.4.3.2), and thus be reliable for SEM modelling process.

Table 5.1: Descriptive statistics of IR

N	Valid	78
	Missing	0
Mean		10.76
Median		2.91
Std. Deviation		17.13
Variance		293.51
Skewness		2.32
Std. Error of Skewness		0.27
Kurtosis		5.99
Std. Error of Kurtosis		0.54
Range		89.89
Minimum		0.00
Maximum		89.89

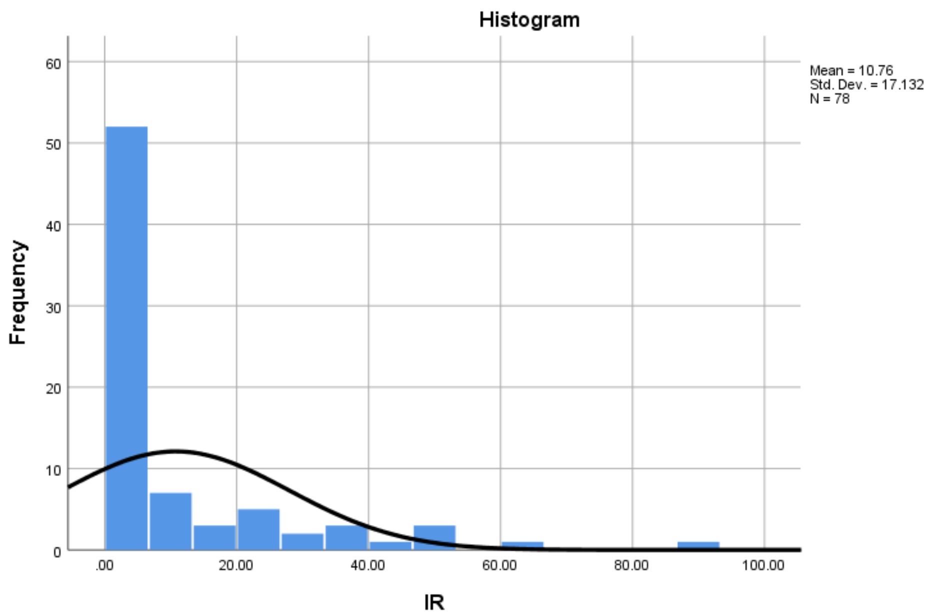


Figure 5.1: Histogram (IR)

5.2.2 Measurement items

Table 5.2 reports the descriptive statistics for the data about measurable scale items pertaining to the main research variables of this study. Accordingly, as the skewness and kurtosis indices of all measurable scale items satisfied the criteria set to check the data distribution (See Section 4.4.3.2 for skewness and kurtosis criteria), and thus being reliable for SEM modelling process.

Table 5.2: Descriptive statistics of measurement items

Items	Mean	Median	Standard Deviation	Excess Kurtosis	Skewness
PC1	4.449	5	0.762	5.004	-1.862
PC2	2.731	3	1.129	-1.023	0.062
PC3	3.09	3	1.134	-0.96	-0.234
PC4	4.385	5	0.772	4.143	-1.651
PC5	4.256	4	0.883	4.028	-1.785
PC6	3.244	3	1.04	-0.942	-0.09
PC7	3.603	4	1.017	0.041	-0.62
PC8	2.474	2	1.059	-0.102	0.729
PC9	2.41	2	1.055	-0.551	0.442
PC10	3.269	3	1.046	-0.614	-0.359
PC11	3.167	3	1.055	-0.747	-0.343
PC12	3.013	3	1.127	-1.056	-0.026
PC13	2.5	3	0.984	-0.304	0.247
PC14	2.41	2	1.079	-0.341	0.673
PC15	2.615	2	1.179	-1.005	0.316
PC16	2.641	2	1.086	-0.798	0.272
PC17	3.91	4	0.85	0.184	-0.718
PC18	4.141	4	0.984	1.674	-1.362
PC19	3.513	4	0.93	-0.815	-0.428
PC20	2.731	3	1.021	-0.666	0.273
PC21	2.705	3	1.178	-1.085	0.166
PC22	2.692	3	0.91	0.009	0.033
PC23	2.731	3	0.996	-0.742	0.172
PC24	3.346	4	0.998	-0.523	-0.591
PC25	2.231	2	1.208	-0.577	0.654
PC26	2.744	2	1.031	-0.66	0.466
PC27	3.295	4	1.027	-0.914	-0.263
PC28	3.333	4	1.046	-0.662	-0.3
PC29	2.846	3	1.178	-0.855	0.258
PC30	3.115	3	1.166	-1.159	-0.18

Items	Mean	Median	Standard Deviation	Excess Kurtosis	Skewness
PC31	3.423	4	0.954	-0.283	-0.407
Psy1	3.192	3	0.975	-0.56	-0.23
Psy2	3.385	4	0.964	-0.483	-0.497
Psy3	3.372	4	1.014	-0.723	-0.357
Psy4	3.026	3	1.062	-0.867	-0.183
Psy5	3.449	4	1.021	-0.892	-0.338
Psy6	2.949	3	0.999	-0.904	0.026
Psy7	3.269	3	0.956	-0.436	-0.48
Psy8	3.051	3	0.959	-0.402	-0.104
Psy9	2.962	3	1.031	-1.105	0.007
Psy10	3.038	3	1.006	-0.776	-0.078
Psy11	2.91	3	1.04	-0.87	0.114
Psy12	3.397	4	0.978	0.129	-0.627
Psy13	3.59	4	0.898	0.036	-0.709
Psy14	3.641	4	0.862	-0.302	-0.571
Man1	3.474	4	1.059	-0.497	-0.592
Man2	3.423	4	0.954	-0.618	-0.227
Man3	3.474	4	1.059	-0.738	-0.394
Man4	3.474	4	0.984	-0.692	-0.339
Man5	3.269	4	1.021	-1.107	-0.42
Man6	3.615	4	0.909	-0.608	-0.403
Man7	3.59	4	0.898	-0.56	-0.492
Man8	3.449	4	0.915	-0.031	-0.716
Man9	3.538	4	0.929	-0.332	-0.408
Man10	3.821	4	0.729	2.686	-1.119
Man11	3.654	4	0.814	-0.199	-0.44
Man12	3.449	4	0.872	0.283	-0.786
Man13	3.538	4	0.97	-0.529	-0.411
Man14	3.949	4	0.749	0.653	-0.66
Beh1	3.859	4	0.996	-0.093	-0.74
Beh2	3.782	4	0.943	-0.47	-0.576
Beh3	3.718	4	0.861	-0.247	-0.52
Beh4	3.436	4	0.969	-0.706	-0.376
Beh5	2.692	3	1.004	-0.313	0.502
Beh6	3.769	4	0.89	-0.195	-0.634
Beh7	3.885	4	0.862	0.184	-0.751
Beh8	2.795	3	1.042	-0.443	0.287
Beh9	3.449	4	0.915	-0.403	-0.306
Beh10	3.923	4	0.764	0.755	-0.746
Beh11	3.064	3	1.03	-0.842	0.085
Beh12	3.987	4	0.776	0.415	-0.648
Beh13	3.923	4	0.944	0.606	-0.962
HPP1	3.769	4	0.905	1.186	-1.003
HPP2	3.859	4	0.746	1.102	-0.893
HPP3	3.782	4	0.872	0.604	-0.738

Items	Mean	Median	Standard Deviation	Excess Kurtosis	Skewness
HPP4	3.885	4	0.8	0.115	-0.55
HPP5	3.603	4	1.066	-0.234	-0.694
HPP6	3.308	4	1.029	-0.862	-0.222
HPP7	3.346	4	1.06	-0.555	-0.475
HPP8	3.654	4	0.945	0.411	-0.828
HPP9	3.577	4	0.87	0.173	-0.718
HPP10	3.756	4	0.85	-0.171	-0.525
HPP11	3.885	4	0.832	0.832	-1.004
HPP12	3.641	4	0.862	-0.469	-0.326
HPP13	3.526	4	0.873	0.542	-0.552
HPP14	3.846	4	0.802	0.245	-0.623
HPP15	3.718	4	0.904	1.748	-1.207
HPP16	3.833	4	0.868	1.072	-0.982
HPP17	3.846	4	0.907	0.586	-0.843
HPP18	3.872	4	0.882	-0.088	-0.656
HPP19	3.756	4	0.976	0.405	-0.836
HPP20	4.051	4	0.799	0.778	-0.863
HPP21	3.615	4	0.95	-0.333	-0.43
HPP22	3.769	4	1.037	-0.081	-0.715
HPP23	3.974	4	0.933	0.592	-0.913
HPP24	3.615	4	0.977	-0.511	-0.331
HPP25	3.872	4	0.925	0.297	-0.73
HPP26	4.128	4	0.853	0.735	-1.012
HPP27	4.09	4	0.835	0.424	-0.847
HPP28	3.949	4	0.986	1.022	-1.124
HPP29	3.744	4	0.98	-0.655	-0.543
HPP30	3.577	4	1.08	-0.958	-0.327
HPP31	3.577	4	0.981	-0.209	-0.303
HPP32	3.872	4	0.868	-0.146	-0.585
HPP33	4.09	4	0.804	0.872	-0.922
HPP34	3.923	4	0.944	0.606	-0.962
HPP35	3.808	4	0.921	0.861	-0.809
HPP36	3.949	4	0.876	1.345	-1.067
HPP37	3.782	4	0.901	0.395	-0.73
MOP1	3.269	3	1.07	-0.735	-0.05
MOP2	2.923	3	1.035	-0.674	0.157
MOP3	2.962	3	0.993	-0.499	0.159
MOP4	3.346	4	0.985	-0.38	-0.504
MOP5	3.718	4	0.904	0.936	-0.888
MOP6	3.449	4	0.915	-0.451	-0.511
MOP7	3.5	4	0.888	-0.702	-0.28
MOP8	3.077	3	1.01	-0.658	-0.081
MOP9	3.718	4	0.89	1.89	-1.186
MOP10	3.615	4	0.964	-0.849	-0.291
MOP11	3.5	4	1.01	-0.449	-0.534

Items	Mean	Median	Standard Deviation	Excess Kurtosis	Skewness
MOP12	3.564	4	0.942	0.118	-0.612
MOP13	3.487	4	1.083	-0.825	-0.399
MOP14	3.705	4	0.879	-0.426	-0.419
MOP15	3.564	4	0.914	0.33	-0.656
MOP16	3.859	4	0.888	0.724	-0.837
MOP17	3.833	4	0.823	1.153	-0.803
MOP18	3.795	4	0.853	-0.061	-0.599
MOP19	3.449	4	0.995	-0.478	-0.452
EMP1	3.385	4	1.003	-0.606	-0.298
EMP2	3.756	4	0.88	1.515	-1.109
EMP3	3.282	3	0.986	-0.792	0.056
EMP4	3.59	4	0.883	0.012	-0.449
EMP5	3.41	3	0.926	-0.868	-0.028
EMP6	3.128	3	1.078	-0.819	-0.011
EMP7	3.667	4	0.887	-0.485	-0.408
EMP8	3.692	4	0.965	0.284	-0.738
EMP9	3.41	4	1.031	-0.921	-0.112
EMP10	3.372	4	0.949	-0.404	-0.449
EMP11	3.385	4	0.851	0.772	-0.84
EMP12	3.308	3	0.924	-0.204	-0.162
EMP13	3.128	3	1.078	-0.819	-0.011

5.3 Measurement models

As discussed in Section 4.4.3.3, confirmatory factor analysis is applied to establish the strength of measurement models via examining the internal reliability and the convergent and discriminant validities of measurement models, thereby confirming the factor structure of constructs and quality of measurable scale items used in this study. In the CFA, any removal of inconsistent indicators was subjected to the rules set in Section 4.4.3.4. The results of CFA indicate that measurement items and their corresponding dimensions are consistent among the PLS models specified in this study. These results can be explained by Hair et al. (2016), in which it is noted that the PLS-SEM algorithm maximises the explained variance of the dependent constructs (e.g. minimise the unexplained variance). In this section, the results of CFA are provided and discussed in order to assess measurement models specified in this study.

Table 5.3 presents the results of CFA, which include: (1) factor loadings and t-value of individual measurement items, (2) Cronbach's Alpha, (3) composite reliability, and (4) average variance extracted values for respective dimensions within their corresponding constructs. The description and coding for each measurement item can be found in Section 4.4.3.1.

Table 5.3: Results of confirmatory factor analysis for PLS models

Constructs	Dimension	Indicator	Loading	t-value	Cron-bach's Alpha	Composite Reliability	AVE
Resilient safety culture (3 dimensions, 24 measurement items)	Behavioural resilience (BR)	BEH10	0.815	16.604	0.89	0.914	0.605
		BEH12	0.807	16.386			
		BEH13	0.745	9.632			
		BEH3	0.821	22.237			
		BEH6	0.81	16.253			
		BEH7	0.743	10.897			
		BEH9	0.695	11.101			
	Contextual resilience (CR)	CON1	0.839	21.511	0.93	0.943	0.674
		CON11	0.759	12.422			
		CON13	0.81	17.43			
		CON2	0.863	27.579			
		CON4	0.856	27.362			
		CON6	0.873	34.69			
		CON7	0.811	17.485			
		CON9	0.746	13.859			
	Psychological resilience (PR)	PSY10	0.813	21.109	0.925	0.938	0.628
		PSY11	0.829	21.759			
		PSY2	0.753	13.52			
		PSY3	0.746	12.932			
		PSY4	0.805	20.771			
		PSY5	0.858	33.396			
		PSY6	0.775	14.193			
		PSY7	0.856	26.878			
		PSY9	0.68	8.68			
Hazard prevention practice (10 dimensions, 37	Safety Policy (H1)	HPP1	0.888	30.479	0.877	0.924	0.803
		HPP2	0.937	47.283			
		HPP3	0.862	17.496			
	Site Safety Organisation	HPP4	0.758	13.113	0.8	0.869	0.624
		HPP5	0.829	21.487			

Constructs	Dimension	Indicator	Loading	t-value	Cron-bach's Alpha	Composite Reliability	AVE
measurement items)	(H2)	HPP6	0.786	12.232			
		HPP7	0.786	17.368			
	Risk Assessment and Hazard Analysis (H3)	HPP8	0.92	40.286	0.919	0.949	0.861
		HPP9	0.946	62.819			
		HPP10	0.919	46.763			
	Safety Inspection (H4)	HPP11	0.836	18.479	0.877	0.916	0.733
		HPP12	0.855	27.146			
		HPP13	0.921	48.587			
		HPP14	0.808	18.547			
	Hazard Control Program (H5)	HPP15	0.842	17.007	0.891	0.925	0.754
		HPP16	0.886	31.149			
		HPP17	0.913	39.033			
		HPP18	0.831	17.677			
	Personal Protection Program (H6)	HPP19	0.788	14.736	0.862	0.906	0.707
		HPP20	0.857	21.516			
		HPP21	0.867	32.957			
		HPP22	0.85	24.707			
	Safety Meeting (H7)	HPP23	0.863	25.643	0.894	0.926	0.759
		HPP24	0.852	19.577			
		HPP25	0.911	42.936			
		HPP26	0.857	21.415			
	Safety Training (H8)	HPP27	0.784	12.796	0.893	0.927	0.76
		HPP28	0.914	40.023			
		HPP29	0.916	49.183			
		HPP30	0.867	30.571			
	Safety Promotion (H9)	HPP31	0.906	36.244	0.853	0.91	0.772
		HPP32	0.897	32.454			
		HPP33	0.832	16.078			
	Management Support (H10)	HPP34	0.892	34.961	0.882	0.918	0.738
		HPP35	0.841	16.451			
		HPP36	0.864	19.399			
		HPP37	0.839	19.452			
Error management practice (4 dimensions, 12 measurement items)	Learning from errors (E1)	EMP1	0.866	23.415	0.722	0.877	0.782
		EMP3	0.901	53.368			
	Error competence (E2)	EMP4	0.594	4.779	0.721	0.844	0.651
		EMP5	0.891	37.18			
		EMP6	0.897	46.197			
	Thinking about errors (E3)	EMP7	0.851	18.8	0.835	0.9	0.751
		EMP8	0.858	25.165			
		EMP9	0.89	38.71			
	Error communication (E4)	EMP10	0.839	18.878	0.803	0.872	0.63
		EMP11	0.823	22.303			
		EMP12	0.694	7.524			
		EMP13	0.812	19.757			
Mindful organising practice (5 dimensions, 18 measurement items)	Preoccupation with failure (M1)	MOP1	0.792	13.688	0.789	0.877	0.705
		MOP3	0.881	27.342			
		MOP4	0.842	25.559			
	Reluctance to simplify interpretations	MOP5	0.831	18.133	0.852	0.9	0.692
		MOP6	0.827	14.445			
		MOP7	0.837	24.546			

Constructs	Dimension	Indicator	Loading	t-value	Cron-bach's Alpha	Composite Reliability	AVE
	(M2)	MOP8	0.833	22.553			
	Sensitivity to operations (M3)	MOP9	0.793	10.027	0.866	0.909	0.714
		MOP10	0.871	30.784			
		MOP11	0.832	20.919			
		MOP12	0.881	27.754			
	Commitment to resilience (M4)	MOP13	0.845	25.06	0.873	0.913	0.724
		MOP14	0.892	38.671			
		MOP15	0.829	17.373			
		MOP16	0.836	14.911			
	Deference to expertise (M5)	MOP17	0.848	20.765	0.804	0.885	0.719
		MOP18	0.866	29.225			
		MOP19	0.828	14.198			
Project complexity (3 dimensions, 13 measurement items)	Technical complexity (TC)	PC14	0.708	7.492	0.818	0.87	0.531
		PC15	0.817	18.66			
		PC16	0.863	26.117			
		PC2	0.666	9.031			
		PC8	0.7	7.892			
		PC9	0.581	5.374			
	Organisational complexity (OC)	PC20	0.775	12.628	0.8	0.883	0.716
		PC22	0.887	34.842			
		PC23	0.873	28.292			
	Environmental complexity (EC)	PC26	0.766	11.501	0.737	0.835	0.559
		PC27	0.737	8.725			
		PC28	0.752	11.045			
		PC31	0.735	8.342			

Internal consistency reliability of measured constructs can be evaluated using Cronbach's alpha reliability and composite reliability (See Section 4.4.3.4). In Table 5.3, the results of the calculated Cronbach's alpha reliability and composite reliability are over 0.7, indicating that internal consistency reliability of the constructs involved was satisfactory (See the sixth and seventh columns of Table 5.3).

Convergent validity of measured constructs was evaluated in consideration of the loadings for all items of respective measurement models and average variance extracted (See Section 4.4.3.4). In Table 5.3, the loadings for all items of respective measurement models are above 0.4 (See the fourth column of Table

5.3). In addition, it also noted that t-values of all individual measurement items are above 2.57 (e.g. the two-tailed test of 2.57 required to achieve statistical significance level at $\rho < 0.01$) (See the fifth column of Table 5.3). Thus, all the measurement items are significantly associated with their corresponding constructs. It is also noted that AVE scores are higher than 0.5. These results indicate that each construct explained at least 50% of each measurement items' variance, suggesting that convergent validity of the measured constructs was satisfactory (See the eighth column of Table 5.3).

Discriminant validity of measured constructs was evaluated using: (1) cross-loading and (2) Fornell-Lacker criterion (See Section 4.4.3.4). The results of discriminant validity test are reported in Table 5.4 and Table 5.5 (cross-loading analysis), and Table 5.6 and Table 5.7 (Fornell-Lacker analysis). Table 5.4 and Table 5.5 show that all indicators loaded greater on the construct they are theoretically specified to measure when compared to other constructs in the models. These results demonstrate the discriminant validity of the constructs. In addition, the discriminant validity of constructs was further ascertained by comparing the square root of AVE scores and correlation coefficients between constructs (See Table 5.6 and Table 5.7). Therefore, discriminant validity was satisfactory, and the constructs were different from each other.

Table 5.4: Analysis of cross-loadings for hazard prevention practice, error management practice, error management practice and resilient safety culture

Items	BR	CR	E1	E2	E3	E4	H1	H10	H2	H3	H4	H5	H6	H7	H8	H9	M1	M2	M3	M4	M5	PR
BEH10	**0.815**	0.599	0.547	0.45	0.488	0.412	0.546	0.664	0.573	0.676	0.662	0.693	0.587	0.647	0.554	0.728	0.522	0.583	0.595	0.67	0.651	0.428
BEH12	**0.807**	0.566	0.486	0.451	0.493	0.381	0.58	0.663	0.459	0.469	0.482	0.445	0.446	0.52	0.626	0.619	0.543	0.657	0.577	0.63	0.513	0.467
BEH13	**0.745**	0.453	0.382	0.25	0.485	0.268	0.551	0.581	0.433	0.552	0.464	0.512	0.503	0.53	0.476	0.647	0.4	0.523	0.569	0.584	0.469	0.33
BEH3	**0.821**	0.63	0.434	0.417	0.543	0.36	0.63	0.639	0.48	0.642	0.517	0.67	0.561	0.553	0.561	0.618	0.535	0.516	0.537	0.612	0.643	0.534
BEH6	**0.81**	0.526	0.393	0.493	0.472	0.452	0.516	0.645	0.428	0.461	0.434	0.511	0.494	0.453	0.491	0.522	0.447	0.55	0.48	0.564	0.531	0.394
BEH7	**0.743**	0.559	0.478	0.468	0.471	0.338	0.573	0.623	0.422	0.514	0.408	0.454	0.455	0.483	0.656	0.534	0.484	0.56	0.478	0.536	0.508	0.425
BEH9	**0.695**	0.535	0.569	0.591	0.506	0.487	0.457	0.564	0.478	0.476	0.494	0.515	0.364	0.468	0.527	0.583	0.609	0.579	0.512	0.537	0.517	0.537
CON1	0.564	**0.839**	0.564	0.461	0.534	0.43	0.552	0.508	0.679	0.74	0.679	0.626	0.598	0.622	0.647	0.633	0.58	0.55	0.628	0.678	0.695	0.641
CON11	0.479	**0.759**	0.599	0.55	0.611	0.572	0.439	0.401	0.571	0.557	0.582	0.572	0.502	0.458	0.518	0.517	0.635	0.568	0.63	0.556	0.669	0.621
CON13	0.588	**0.81**	0.533	0.495	0.446	0.386	0.412	0.595	0.546	0.584	0.55	0.542	0.603	0.566	0.612	0.574	0.626	0.612	0.584	0.646	0.639	0.643
CON2	0.63	**0.863**	0.565	0.56	0.531	0.551	0.559	0.592	0.706	0.713	0.674	0.674	0.605	0.569	0.621	0.618	0.629	0.624	0.605	0.613	0.605	0.62
CON4	0.604	**0.856**	0.524	0.448	0.517	0.434	0.525	0.555	0.686	0.697	0.685	0.577	0.618	0.505	0.598	0.565	0.535	0.627	0.668	0.668	0.628	0.603
CON6	0.606	**0.873**	0.488	0.491	0.517	0.444	0.558	0.509	0.618	0.654	0.551	0.534	0.586	0.492	0.576	0.514	0.602	0.567	0.62	0.621	0.607	0.681
CON7	0.617	**0.811**	0.568	0.507	0.499	0.535	0.484	0.556	0.755	0.721	0.598	0.654	0.581	0.576	0.566	0.521	0.671	0.558	0.602	0.607	0.613	0.708
CON9	0.597	**0.746**	0.553	0.507	0.515	0.47	0.431	0.43	0.497	0.523	0.481	0.552	0.521	0.388	0.566	0.511	0.568	0.594	0.534	0.525	0.63	0.617
EMP1	0.558	0.606	**0.866**	0.566	0.593	0.533	0.399	0.488	0.605	0.622	0.596	0.64	0.518	0.615	0.603	0.586	0.677	0.603	0.622	0.69	0.707	0.603
EMP3	0.52	0.581	**0.901**	0.785	0.62	0.639	0.409	0.542	0.566	0.496	0.598	0.476	0.467	0.445	0.541	0.463	0.739	0.751	0.671	0.609	0.593	0.613
EMP4	0.379	0.338	0.425	**0.594**	0.316	0.43	0.174	0.375	0.408	0.346	0.345	0.322	0.291	0.315	0.306	0.262	0.452	0.384	0.258	0.436	0.272	0.358
EMP5	0.558	0.564	0.696	**0.891**	0.555	0.643	0.366	0.533	0.493	0.49	0.488	0.45	0.439	0.376	0.463	0.473	0.685	0.668	0.568	0.552	0.559	0.545
EMP6	0.454	0.548	0.704	**0.897**	0.663	0.777	0.373	0.459	0.529	0.42	0.547	0.458	0.419	0.357	0.411	0.421	0.688	0.685	0.624	0.516	0.534	0.637
EMP7	0.539	0.521	0.535	0.55	**0.851**	0.605	0.475	0.454	0.417	0.396	0.435	0.421	0.32	0.313	0.406	0.508	0.557	0.549	0.594	0.563	0.512	0.504
EMP8	0.652	0.593	0.533	0.438	**0.858**	0.513	0.67	0.549	0.498	0.562	0.497	0.539	0.495	0.545	0.629	0.654	0.562	0.595	0.652	0.704	0.647	0.512
EMP9	0.484	0.545	0.696	0.694	**0.89**	0.726	0.496	0.512	0.545	0.47	0.526	0.484	0.503	0.376	0.467	0.51	0.729	0.728	0.743	0.615	0.627	0.683
EMP10	0.396	0.551	0.592	0.698	0.579	**0.839**	0.302	0.435	0.54	0.396	0.548	0.403	0.352	0.272	0.32	0.361	0.675	0.646	0.635	0.59	0.53	0.636
EMP11	0.397	0.476	0.557	0.576	0.568	**0.823**	0.348	0.396	0.481	0.375	0.461	0.497	0.347	0.304	0.457	0.399	0.574	0.561	0.547	0.535	0.429	0.51

Items	BR	CR	E1	E2	E3	E4	H1	H10	H2	H3	H4	H5	H6	H7	H8	H9	M1	M2	M3	M4	M5	PR
EMP12	0.254	0.244	0.383	0.604	0.434	**0.694**	0.218	0.156	0.222	0.199	0.225	0.19	0.079	0.072	0.172	0.179	0.391	0.329	0.296	0.299	0.206	0.373
EMP13	0.51	0.542	0.563	0.617	0.68	**0.812**	0.47	0.485	0.529	0.487	0.426	0.4	0.445	0.358	0.417	0.465	0.633	0.621	0.624	0.553	0.503	0.628
HPP1	0.586	0.494	0.363	0.272	0.497	0.322	**0.888**	0.55	0.441	0.645	0.482	0.507	0.482	0.512	0.492	0.599	0.465	0.437	0.536	0.531	0.46	0.339
HPP2	0.692	0.559	0.44	0.335	0.606	0.395	**0.937**	0.583	0.495	0.664	0.55	0.583	0.493	0.543	0.54	0.67	0.527	0.534	0.603	0.646	0.574	0.384
HPP3	0.621	0.572	0.423	0.451	0.571	0.432	**0.862**	0.516	0.463	0.583	0.523	0.502	0.479	0.522	0.578	0.568	0.584	0.558	0.578	0.612	0.562	0.451
HPP34	0.659	0.494	0.449	0.457	0.412	0.353	0.508	**0.892**	0.613	0.593	0.637	0.627	0.673	0.618	0.586	0.542	0.454	0.583	0.496	0.528	0.567	0.394
HPP35	0.658	0.575	0.529	0.508	0.521	0.457	0.447	**0.841**	0.648	0.563	0.648	0.577	0.624	0.602	0.63	0.609	0.625	0.721	0.598	0.585	0.621	0.495
HPP36	0.74	0.514	0.391	0.395	0.439	0.345	0.582	**0.864**	0.493	0.521	0.502	0.555	0.548	0.563	0.607	0.627	0.504	0.6	0.552	0.572	0.596	0.415
HPP37	0.715	0.592	0.631	0.578	0.622	0.479	0.576	**0.839**	0.618	0.629	0.604	0.546	0.597	0.608	0.557	0.702	0.701	0.701	0.668	0.625	0.694	0.586
HPP4	0.548	0.55	0.469	0.407	0.475	0.367	0.447	0.564	**0.758**	0.579	0.579	0.567	0.618	0.538	0.488	0.486	0.486	0.562	0.529	0.486	0.506	0.465
HPP5	0.45	0.621	0.435	0.361	0.327	0.3	0.439	0.578	**0.829**	0.703	0.64	0.671	0.696	0.617	0.514	0.549	0.52	0.491	0.481	0.455	0.478	0.504
HPP6	0.397	0.621	0.594	0.621	0.509	0.58	0.358	0.455	**0.786**	0.571	0.649	0.526	0.496	0.438	0.379	0.464	0.587	0.591	0.565	0.495	0.572	0.638
HPP7	0.509	0.651	0.597	0.503	0.489	0.575	0.398	0.579	**0.786**	0.614	0.747	0.683	0.637	0.556	0.638	0.552	0.629	0.645	0.588	0.554	0.614	0.621
HPP8	0.625	0.741	0.572	0.443	0.514	0.41	0.659	0.628	0.698	**0.92**	0.676	0.721	0.704	0.712	0.549	0.747	0.616	0.543	0.677	0.707	0.744	0.561
HPP9	0.682	0.753	0.58	0.481	0.481	0.424	0.661	0.628	0.712	**0.946**	0.712	0.709	0.661	0.692	0.607	0.604	0.626	0.532	0.624	0.68	0.694	0.591
HPP10	0.641	0.715	0.593	0.522	0.524	0.471	0.64	0.616	0.772	**0.919**	0.71	0.771	0.705	0.678	0.643	0.615	0.619	0.571	0.59	0.622	0.63	0.617
HPP11	0.506	0.594	0.547	0.496	0.431	0.396	0.467	0.592	0.667	0.561	**0.836**	0.601	0.645	0.516	0.539	0.567	0.523	0.616	0.528	0.54	0.574	0.428
HPP12	0.5	0.62	0.618	0.551	0.467	0.444	0.381	0.58	0.736	0.587	**0.855**	0.671	0.764	0.635	0.562	0.561	0.571	0.68	0.562	0.516	0.61	0.534
HPP13	0.586	0.668	0.631	0.567	0.556	0.539	0.546	0.644	0.758	0.711	**0.921**	0.679	0.651	0.649	0.632	0.604	0.68	0.704	0.707	0.633	0.659	0.596
HPP14	0.598	0.627	0.511	0.371	0.465	0.441	0.582	0.57	0.674	0.712	**0.808**	0.663	0.602	0.672	0.627	0.612	0.541	0.582	0.579	0.638	0.589	0.517
HPP15	0.606	0.664	0.57	0.503	0.552	0.556	0.548	0.558	0.69	0.691	0.66	**0.842**	0.74	0.706	0.592	0.692	0.593	0.556	0.554	0.596	0.634	0.606
HPP16	0.605	0.554	0.451	0.328	0.397	0.311	0.547	0.562	0.631	0.667	0.593	**0.886**	0.714	0.692	0.55	0.684	0.466	0.477	0.458	0.484	0.559	0.423
HPP17	0.623	0.639	0.548	0.459	0.455	0.403	0.491	0.635	0.684	0.691	0.671	**0.913**	0.749	0.766	0.706	0.663	0.597	0.523	0.489	0.575	0.646	0.518
HPP18	0.606	0.65	0.594	0.49	0.514	0.387	0.476	0.574	0.703	0.697	0.73	**0.831**	0.712	0.647	0.693	0.551	0.548	0.555	0.545	0.576	0.603	0.519
HPP19	0.424	0.59	0.328	0.388	0.357	0.317	0.316	0.519	0.601	0.53	0.537	0.586	**0.788**	0.555	0.534	0.523	0.355	0.517	0.44	0.437	0.467	0.513
HPP20	0.598	0.537	0.407	0.31	0.374	0.22	0.537	0.616	0.618	0.617	0.691	0.732	**0.857**	0.725	0.576	0.651	0.409	0.511	0.44	0.512	0.585	0.373
HPP21	0.518	0.635	0.54	0.483	0.426	0.392	0.407	0.594	0.747	0.642	0.703	0.772	**0.867**	0.685	0.676	0.602	0.567	0.63	0.517	0.496	0.6	0.555

Items	BR	CR	E1	E2	E3	E4	H1	H10	H2	H3	H4	H5	H6	H7	H8	H9	M1	M2	M3	M4	M5	PR
HPP22	0.561	0.609	0.571	0.438	0.546	0.411	0.54	0.658	0.654	0.703	0.669	0.719	**0.85**	0.661	0.581	0.612	0.549	0.651	0.62	0.521	0.674	0.525
HPP23	0.582	0.497	0.487	0.315	0.403	0.243	0.535	0.5	0.497	0.598	0.537	0.696	0.668	**0.863**	0.663	0.677	0.433	0.419	0.393	0.586	0.552	0.359
HPP24	0.554	0.512	0.573	0.375	0.415	0.322	0.418	0.629	0.612	0.671	0.64	0.701	0.635	**0.852**	0.656	0.586	0.578	0.533	0.495	0.587	0.612	0.527
HPP25	0.603	0.65	0.623	0.501	0.429	0.352	0.541	0.664	0.684	0.722	0.706	0.725	0.72	**0.911**	0.723	0.673	0.623	0.584	0.522	0.612	0.639	0.538
HPP26	0.612	0.557	0.372	0.293	0.381	0.218	0.549	0.626	0.586	0.61	0.633	0.702	0.708	**0.857**	0.615	0.679	0.516	0.474	0.474	0.532	0.611	0.378
HPP27	0.504	0.518	0.516	0.358	0.404	0.272	0.355	0.528	0.553	0.445	0.579	0.523	0.567	0.576	**0.784**	0.469	0.445	0.555	0.404	0.497	0.484	0.447
HPP28	0.687	0.615	0.497	0.412	0.473	0.318	0.535	0.63	0.543	0.543	0.571	0.687	0.674	0.722	**0.914**	0.658	0.479	0.605	0.469	0.618	0.57	0.459
HPP29	0.631	0.667	0.618	0.476	0.551	0.438	0.55	0.625	0.541	0.588	0.632	0.654	0.606	0.681	**0.916**	0.621	0.624	0.636	0.551	0.67	0.647	0.585
HPP30	0.657	0.688	0.611	0.46	0.55	0.484	0.623	0.624	0.619	0.661	0.629	0.679	0.611	0.674	**0.867**	0.665	0.656	0.663	0.595	0.666	0.634	0.609
HPP31	0.721	0.703	0.6	0.523	0.647	0.498	0.627	0.658	0.658	0.724	0.676	0.756	0.691	0.733	0.68	**0.906**	0.669	0.646	0.693	0.755	0.783	0.556
HPP32	0.704	0.58	0.527	0.379	0.551	0.329	0.641	0.622	0.547	0.587	0.594	0.682	0.6	0.64	0.639	**0.897**	0.523	0.586	0.555	0.59	0.669	0.364
HPP33	0.639	0.489	0.405	0.372	0.464	0.35	0.531	0.621	0.502	0.534	0.524	0.506	0.58	0.595	0.506	**0.832**	0.418	0.562	0.529	0.566	0.531	0.405
MOP1	0.555	0.56	0.661	0.502	0.613	0.515	0.545	0.574	0.602	0.609	0.551	0.563	0.51	0.571	0.533	0.625	**0.792**	0.598	0.583	0.565	0.63	0.542
MOP3	0.528	0.602	0.704	0.754	0.623	0.702	0.442	0.515	0.579	0.496	0.557	0.504	0.504	0.467	0.475	0.451	**0.881**	0.731	0.619	0.61	0.58	0.742
MOP4	0.564	0.694	0.657	0.663	0.576	0.604	0.493	0.59	0.592	0.583	0.601	0.538	0.41	0.528	0.596	0.494	**0.842**	0.691	0.636	0.639	0.616	0.68
MOP5	0.678	0.58	0.56	0.551	0.619	0.485	0.495	0.685	0.552	0.459	0.577	0.477	0.586	0.505	0.657	0.569	0.572	**0.831**	0.676	0.681	0.604	0.544
MOP6	0.513	0.526	0.655	0.657	0.537	0.56	0.359	0.587	0.611	0.382	0.583	0.487	0.637	0.48	0.518	0.541	0.625	**0.827**	0.585	0.512	0.524	0.556
MOP7	0.66	0.704	0.649	0.546	0.579	0.538	0.575	0.647	0.647	0.609	0.733	0.553	0.586	0.537	0.667	0.68	0.726	**0.837**	0.725	0.689	0.642	0.631
MOP8	0.567	0.559	0.702	0.712	0.679	0.718	0.448	0.603	0.593	0.5	0.61	0.502	0.488	0.403	0.499	0.471	0.745	**0.833**	0.693	0.542	0.634	0.688
MOP9	0.64	0.578	0.502	0.334	0.624	0.523	0.641	0.586	0.574	0.62	0.578	0.568	0.5	0.44	0.452	0.634	0.534	0.566	**0.793**	0.674	0.613	0.451
MOP10	0.584	0.616	0.637	0.62	0.683	0.643	0.597	0.592	0.613	0.594	0.627	0.469	0.511	0.408	0.491	0.599	0.658	0.758	**0.871**	0.652	0.667	0.542
MOP11	0.578	0.67	0.66	0.524	0.634	0.452	0.49	0.528	0.535	0.592	0.535	0.495	0.484	0.555	0.546	0.554	0.601	0.626	**0.832**	0.723	0.681	0.599
MOP12	0.541	0.646	0.666	0.625	0.659	0.655	0.448	0.574	0.586	0.501	0.616	0.471	0.54	0.436	0.483	0.521	0.668	0.767	**0.881**	0.714	0.691	0.652
MOP13	0.607	0.651	0.714	0.621	0.639	0.623	0.461	0.506	0.543	0.575	0.593	0.562	0.469	0.607	0.642	0.641	0.669	0.673	0.702	**0.845**	0.643	0.656
MOP14	0.673	0.672	0.654	0.513	0.64	0.502	0.581	0.559	0.502	0.652	0.548	0.577	0.484	0.598	0.663	0.627	0.639	0.586	0.706	**0.892**	0.734	0.553
MOP15	0.611	0.647	0.572	0.553	0.546	0.519	0.54	0.64	0.542	0.547	0.606	0.486	0.545	0.503	0.552	0.554	0.612	0.667	0.686	**0.829**	0.647	0.534
MOP16	0.705	0.577	0.538	0.412	0.624	0.509	0.694	0.587	0.557	0.688	0.573	0.565	0.5	0.554	0.545	0.668	0.528	0.563	0.683	**0.836**	0.617	0.479

Items	BR	CR	E1	E2	E3	E4	H1	H10	H2	H3	H4	H5	H6	H7	H8	H9	M1	M2	M3	M4	M5	PR
MOP17	0.616	0.553	0.55	0.431	0.639	0.403	0.537	0.608	0.451	0.538	0.547	0.517	0.503	0.585	0.564	0.654	0.535	0.563	0.664	0.649	**0.848**	0.443
MOP18	0.625	0.726	0.575	0.5	0.551	0.451	0.46	0.593	0.549	0.592	0.61	0.619	0.615	0.586	0.593	0.693	0.597	0.664	0.688	0.705	**0.866**	0.543
MOP19	0.56	0.685	0.731	0.553	0.561	0.513	0.519	0.635	0.739	0.758	0.65	0.652	0.647	0.594	0.554	0.586	0.706	0.614	0.645	0.621	**0.828**	0.629
PSY10	0.487	0.639	0.639	0.576	0.603	0.68	0.362	0.379	0.538	0.53	0.494	0.462	0.435	0.375	0.452	0.439	0.681	0.668	0.585	0.596	0.567	**0.813**
PSY11	0.363	0.566	0.544	0.597	0.582	0.624	0.213	0.385	0.52	0.4	0.458	0.398	0.444	0.292	0.411	0.352	0.648	0.661	0.517	0.492	0.485	**0.829**
PSY2	0.458	0.628	0.454	0.334	0.498	0.485	0.408	0.422	0.597	0.519	0.448	0.511	0.546	0.518	0.494	0.426	0.557	0.481	0.538	0.525	0.477	**0.753**
PSY3	0.433	0.607	0.465	0.348	0.448	0.448	0.367	0.379	0.525	0.439	0.425	0.459	0.427	0.415	0.528	0.354	0.524	0.475	0.472	0.473	0.418	**0.746**
PSY4	0.513	0.678	0.545	0.533	0.474	0.517	0.39	0.475	0.599	0.583	0.554	0.591	0.498	0.492	0.541	0.47	0.639	0.492	0.451	0.507	0.483	**0.805**
PSY5	0.561	0.72	0.656	0.623	0.564	0.496	0.419	0.55	0.635	0.597	0.564	0.481	0.52	0.544	0.59	0.5	0.709	0.682	0.62	0.646	0.593	**0.858**
PSY6	0.417	0.586	0.43	0.49	0.416	0.496	0.308	0.431	0.513	0.449	0.441	0.415	0.379	0.309	0.477	0.314	0.593	0.559	0.468	0.401	0.419	**0.775**
PSY7	0.442	0.673	0.55	0.622	0.536	0.648	0.355	0.491	0.648	0.572	0.545	0.517	0.504	0.384	0.404	0.371	0.618	0.544	0.566	0.517	0.541	**0.856**
PSY9	0.428	0.442	0.574	0.48	0.57	0.472	0.282	0.401	0.415	0.417	0.387	0.41	0.386	0.362	0.424	0.37	0.587	0.605	0.516	0.475	0.522	**0.68**

Table 5.5: Analysis of cross-loadings for resilient safety culture and project complexity

Items	BR	CR	TC	OC	EC	PR
BEH10	**0.815**	0.599	-0.169	-0.273	-0.1	0.428
BEH12	**0.807**	0.566	-0.124	-0.221	0.048	0.467
BEH13	**0.745**	0.453	-0.045	-0.215	0.031	0.33
BEH3	**0.821**	0.63	-0.232	-0.289	-0.109	0.534
BEH6	**0.81**	0.526	-0.238	-0.215	0.165	0.394
BEH7	**0.743**	0.559	-0.237	-0.191	0.126	0.425
BEH9	**0.695**	0.535	-0.186	-0.272	0.161	0.537
CON1	0.564	**0.839**	-0.236	-0.269	-0.03	0.641
CON11	0.479	**0.759**	-0.267	-0.251	-0.047	0.621
CON13	0.588	**0.81**	-0.265	-0.412	-0.058	0.643
CON2	0.63	**0.863**	-0.291	-0.416	-0.035	0.62
CON4	0.604	**0.856**	-0.219	-0.304	-0.084	0.603
CON6	0.606	**0.873**	-0.264	-0.367	0.054	0.681
CON7	0.617	**0.811**	-0.202	-0.201	0.036	0.708
CON9	0.597	**0.746**	-0.334	-0.457	-0.095	0.617
PC14	-0.086	-0.082	**0.708**	0.441	0.399	-0.059
PC15	-0.154	-0.353	**0.817**	0.573	0.45	-0.333
PC16	-0.19	-0.262	**0.863**	0.544	0.44	-0.222
PC2	-0.302	-0.252	**0.666**	0.645	0.229	-0.215
PC8	-0.135	-0.13	**0.7**	0.41	0.136	-0.109
PC9	-0.134	-0.278	**0.581**	0.469	0.208	-0.279
PC20	-0.2	-0.279	0.552	**0.775**	0.23	-0.213
PC22	-0.333	-0.34	0.584	**0.887**	0.323	-0.329
PC23	-0.248	-0.408	0.659	**0.873**	0.25	-0.316
PC26	0.029	-0.012	0.339	0.296	**0.766**	0.06
PC27	0.137	0.023	0.251	0.219	**0.737**	0.029
PC28	0.013	-0.025	0.386	0.214	**0.752**	0.004
PC31	-0.006	-0.095	0.339	0.215	**0.735**	-0.059
PSY10	0.487	0.639	-0.215	-0.369	-0.048	**0.813**
PSY11	0.363	0.566	-0.283	-0.301	-0.008	**0.829**
PSY2	0.458	0.628	-0.15	-0.162	0.103	**0.753**
PSY3	0.433	0.607	-0.189	-0.191	-0.026	**0.746**
PSY4	0.513	0.678	-0.185	-0.245	-0.002	**0.805**
PSY5	0.561	0.72	-0.274	-0.323	0.003	**0.858**
PSY6	0.417	0.586	-0.229	-0.285	0.124	**0.775**
PSY7	0.442	0.673	-0.226	-0.246	0.02	**0.856**
PSY9	0.428	0.442	-0.274	-0.315	-0.09	**0.68**

Table 5.6: Comparison of Square-Rooted AVEs and Correlation Coefficient analysis for hazard prevention practice, error management practice, error management practice and resilient safety culture

Factors	**BR**	**CR**	**E1**	**E2**	**E3**	**E4**	**H1**	**H10**	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**	**M1**	**M2**	**M3**	**M4**	**M5**	**PR**
BR	**0.778**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CR	0.712	**0.821**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E1	0.608	0.67	**0.884**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E2	0.576	0.612	0.772	**0.807**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E3	0.636	0.636	0.686	0.658	**0.866**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
E4	0.498	0.583	0.666	0.785	0.718	**0.794**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H1	0.708	0.605	0.457	0.393	0.624	0.428	**0.896**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H10	0.806	0.633	0.584	0.566	0.581	0.477	0.614	**0.859**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H2	0.605	0.774	0.66	0.591	0.564	0.571	0.521	0.693	**0.79**	-	-	-	-	-	-	-	-	-	-	-	-	-
H3	0.7	0.794	0.627	0.52	0.546	0.469	0.704	0.672	0.784	**0.928**	-	-	-	-	-	-	-	-	-	-	-	-
H4	0.641	0.734	0.675	0.58	0.563	0.534	0.579	0.698	0.829	0.754	**0.856**		-	-	-	-	-	-	-	-	-	-
H5	0.703	0.723	0.624	0.514	0.553	0.478	0.593	0.671	0.78	0.791	0.765	**0.868**	-	-	-	-	-	-	-	-	-	-
H6	0.629	0.704	0.555	0.481	0.509	0.399	0.54	0.712	0.78	0.744	0.777	0.84	**0.841**	-	-	-	-	-	-	-	-	-
H7	0.675	0.639	0.592	0.429	0.468	0.327	0.587	0.697	0.685	0.748	0.725	0.81	0.784	**0.871**	-	-	-	-	-	-	-	-
H8	0.715	0.717	0.644	0.492	0.571	0.438	0.599	0.692	0.646	0.646	0.691	0.733	0.706	0.763	**0.872**	-	-	-	-	-	-	-
H9	0.784	0.68	0.588	0.489	0.637	0.452	0.684	0.721	0.652	0.706	0.685	0.746	0.713	0.75	0.698	**0.879**	-	-	-	-	-	-
M1	0.653	0.739	0.803	0.766	0.719	0.725	0.586	0.666	0.703	0.669	0.679	0.636	0.564	0.62	0.636	0.62	**0.84**	-	-	-	-	-
M2	0.73	0.716	0.771	0.739	0.727	0.691	0.569	0.759	0.723	0.591	0.755	0.608	0.688	0.579	0.707	0.682	0.804	**0.832**	-	-	-	-
M3	0.69	0.743	0.732	0.629	0.769	0.675	0.639	0.674	0.683	0.679	0.697	0.589	0.602	0.543	0.583	0.68	0.73	0.808	**0.845**	-	-	-
M4	0.762	0.75	0.73	0.62	0.72	0.633	0.666	0.672	0.629	0.722	0.682	0.643	0.586	0.665	0.707	0.731	0.721	0.732	0.816	**0.851**	-	-
M5	0.708	0.774	0.73	0.585	0.687	0.538	0.595	0.722	0.685	0.743	0.711	0.704	0.696	0.694	0.673	0.761	0.723	0.725	0.786	0.777	**0.848**	-
PR	0.575	0.779	0.687	0.653	0.662	0.686	0.436	0.551	0.702	0.636	0.609	0.595	0.582	0.52	0.605	0.508	0.783	0.729	0.667	0.655	0.636	**0.792**

Table 5.7: Comparison of Square-Rooted AVEs and Correlation Coefficient analysis for resilient safety culture and project complexity

Factors	BR	EC	CR	OC	PR	TC
BR	**0.778**	-	-	-	-	-
EC	0.054	**0.747**	-	-	-	-
CR	0.715	-0.038	**0.821**	-	-	-
OC	-0.31	0.317	-0.407	**0.846**	-	-
PR	0.578	0.012	0.783	-0.341	**0.792**	-
TC	-0.23	0.444	-0.315	0.708	-0.282	**0.728**

Based on the results obtained from CFA, the main research variables in this study (i.e. resilient safety culture, hazard prevention practice, error management practice, mindful organising practice and project complexity) satisfied all criteria set to determine the reliability and validity of each construct. Therefore, the measurement models specified in this study was reliable and valid for the structural models' evaluation. The confirmed research variables and its corresponding indicators are presented in Table 5.8.

Table 5.8: Confirmed constructs and corresponding measurement items

Constructs	Dimensions	Indicators	Interpretation
Resilient safety culture	Behavioural resilience (BR)	BEH10	Listen to feedback from workers
		BEH12	Draw conclusions when any hazardous events happened
		BEH13	In incident investigations, the aim directs to prevent the future similar accidents rather than blame workers on such events
		BEH3	Conduct the site inspections to check the changes of working conditions (i.e. safety hazards and its preventive safety measures).
		BEH6	Pay attention to not sending people to work sites in which the safety risks are not clear
		BEH7	Act decisively when encountering any regular and irregular safety issues
		BEH9	React quickly to the cases of emergency situations
	Contextual resilience (CR)	CON1	Analysis of potential safety risks of accident
		CON11	Provision of preventive safety measures following any changes to the working conditions
		CON13	Collection and distribution of feedback or revisions on safety issues
		CON2	Assessment of needed safety resources
		CON4	Assessment of potential changes of working conditions that might present a risk of an accident.
		CON6	Provision of up-to-date information about safety risks
		CON7	Surveillance and monitoring of working conditions
		CON9	Provision of safety resources related to observed

Constructs	Dimensions	Indicators	Interpretation
			hazards
	Psychological resilience (PR)	PSY10	Tendency to refuse to work when appropriate preventive and protective measures are not provided
		PSY11	Tendency to refuse to work when it is not clear on how to execute the work task
		PSY2	Awareness of the negative consequences resulting from non-compliance with health and safety rules
		PSY3	Acknowledgement of the occurrence of unexpected hazardous events
		PSY4	Mindfulness of the project hazards even when they are recognised and controlled with preventive measures
		PSY5	Knowledge and procedure level for identifying potential hazards regarding work tasks
		PSY6	Heedfulness of co-workers' activities
		PSY7	Awareness of major safety worries and concerns on sites
		PSY9	Tendency to refuse to work when hazards and safety risks related to work task are not clear
Hazard prevention practice	Safety Policy (H1)	HPP1	Setting objectives for health and safety performance within the workplace
		HPP2	Stating the importance of health and safety requirements as equally important as any other objectives
		HPP3	Availability of safety policy to all workers
	Site Safety Organisation (H2)	HPP4	Assigning roles and responsibilities in order to eliminate or reduce the risks of hazards
		HPP5	Competent safety officers and safety supervisors for the project
		HPP6	Subcontractors submit detailed site-specific safety plans prior to execution of work tasks
		HPP7	Arrangements to collect and review feedback on health and safety issues
	Risk Assessment and Hazard Analysis (H3)	HPP8	Identifying workplace and task hazards prior to execution
		HPP9	Evaluating the risks of harm from project hazards prior to execution
		HPP10	Designing preventive measures prior to execution.
	Safety Inspection (H4)	HPP11	Examining hazardous conditions related to work tasks.
		HPP12	Supervising safety activities and safety performance of workers
		HPP13	Analysing the findings of safety inspections
		HPP14	Taking actions after safety inspections
	Hazard Control Program (H5)	HPP15	Implementing preventive measures for identified hazards
		HPP16	Providing plant, machine & equipment for each work task
		HPP17	Inspecting and maintaining plant, machine & equipment
		HPP18	Monitoring the proper use of plant, machine & equipment
	Personal Protection Program (H6)	HPP19	Providing personal protective equipment (PPE) complied with a safety plan
		HPP20	Implementing procedures for supplying PPE to everyone on site
		HPP21	Inspecting, maintaining and replacing PPE
		HPP22	Monitoring the proper use of PPE
	Safety Meeting (H7)	HPP23	Planning toolbox talks
		HPP24	Organising safety discussions in workgroups
		HPP25	Organising safety awareness activities
		HPP26	Organising safety committee meetings

Constructs	Dimensions	Indicators	Interpretation
	Safety Training (H8)	HPP27	Conducting training courses following the safety legislation
		HPP28	Organising basic general safety training
		HPP29	Organising site-specific safety training
		HPP30	Organising toolbox training related to the specific work tasks
	Safety Promotion (H9)	HPP31	Positive impact on safety was recognised and rewarded
		HPP32	Recognising and punishing negative impact on safety
		HPP33	Providing safety warning signs, posters and bulletin boards
	Management Support (H10)	HPP34	Site management and supervisors act as safety role models for all workers
		HPP35	Site management and supervisors praise workers for working safely
		HPP36	Site management and supervisors challenge unsafe behaviours/attitude
		HPP37	Site management and supervisors make site visits and speak directly to workers about safety
Error management practice	Learning from errors (E1)	EMP1	Delivering training on how to deal with errors to workers
		EMP3	Accepting feedback about how to avoid and/or correct errors
	Error competence (E2)	EMP4	Not letting go of the final goal of their work tasks when errors are made
		EMP5	Correcting errors right away when they are made
		EMP6	Recognising the way to correct an error when it occurs
	Thinking about errors (E3)	EMP7	Thinking through how to correct error when it occurs
		EMP8	Analysing errors thoroughly after errors occur
		EMP9	Being mindful of how an error can be avoided
	Error communication (E4)	EMP10	Asking others for advice on how to continue the work tasks after an error
		EMP11	Turning to others being unable to correct an error
		EMP12	Relying on others when being unable to continue their work after an error
		EMP13	Sharing errors with others
Mindful organising practice	Preoccupation with failure (M1)	MOP1	Giving equal attention to all types of project hazards
		MOP3	Identifying safety activities required for each work task prior to execution in order not to misconduct
		MOP4	Having a discussion on what to look out for when a specific work task or worksite was taken over by new workers
	Reluctance to simplify interpretations (M2)	MOP5	Seeking various viewpoints on how to improve health and safety on site
		MOP6	Bringing up their health and safety issues
		MOP7	Having alternative safety plans for each work task
		MOP8	Having a discussion when confronted with unfamiliar safety instructions/procedures/rules and working conditions
	Sensitivity to operations (M3)	MOP9	Paying attention to and recording what was happening on site
		MOP10	Monitoring the workloads and take actions to reduce them when they became excessive
		MOP11	Delivering project and work task inductions to workers before commencing their jobs
		MOP12	Interacting to build a clear picture of what was happening on site
	Commitment to resilience (M4)	MOP13	Delivering training on how to act in emergency situations to workers
		MOP14	Providing facilities and procedures for responses to emergency situations

Constructs	Dimensions	Indicators	Interpretation
		MOP15	Building employees' competence in emergency situations on site
		MOP16	Seeking for the weaknesses of their safety activities at work, and what could be learned from emergency situations
	Deference to expertise (M5)	MOP17	Delegating an authority to make final decisions to the safety manager
		MOP18	Acknowledging person who has the expertise to responding to a health and safety issue out of the ordinary
		MOP19	Obtaining expert assistance when a health and safety issue come up that no one on site knows how to handle
Project complexity	Technical complexity (TC)	PC14	Clarity of project information for execution
		PC15	Level of obtaining, processing and transferring project information
		PC16	Inconsistency in project information among different tools
		PC2	Clarity of each goal of the project
		PC8	Clarity of the construction methods employed
		PC9	Availability of the resources and skills appropriate for construction methods
	Organisational complexity (OC)	PC20	Experience and capacity of contractors and technologies employed
		PC22	Trust within contractors
		PC23	Cooperation between contractors
	Environmental complexity (EC)	PC26	Changes in policy and regulation
		PC27	Changes in economic environment
		PC28	Changes in local weather conditions
		PC31	Influence of external stakeholders

In light of these results, an important finding pertaining to the first research objective is also derived (i.e. to identify the dimensions of resilient safety culture of construction projects). The results empirically confirm three dimensions (i.e. psychological resilience, behavioural resilience and contextual resilience) with 24 measurable scale items to assess the resilient safety culture (See Table 5.8). Therefore, hypothesis 1 is supported. The dimensions of resilient safety culture will be further discussed in Section 6.2.

5.4 Structural models

As discussed in Section 4.4.3.3, the use of path analysis concerns the relationships between constructs in the structural models (e.g. structural model path coefficients, β) and the model's predictive capabilities (i.e. coefficient of determination, R^2). This section presents the results of PLS models (See Section 4.4.3.1 for PLS-SEM models specification) to address the research objectives: (1) to identify the drivers of resilient safety culture, and (2) to examine the interactive effects of resilient safety culture and project complexity on safety performance of construction projects (See Section 1.4 for research aim and objectives). The results of path analysis are reported in the subsequent sections 5.4.1 and 5.4.2.

5.4.1 Impacts of hazard prevention practice, error management practice and error management practice on resilient safety culture

In evaluating the PLS-M1 structural model, the path coefficients between hazard prevention practice, error management practice, mindful organising practice and three dimensions of resilient safety culture were examined. The test results of the structural model are shown in Figure 5.2 and Table 5.9. Figure 5.2 depicts: (1) the paths between hazard prevention practice, error management practice, mindful organising practice and their respective dimensions, and (2) the impacting paths of hazard prevention practice, error management practice, mindful organising practice on the three dimensions of resilient safety culture. The solid lines with estimated standardised effect coefficients (β) represent significant paths which supported the hypotheses, while dotted lines represent insignificant paths which failed to support the hypotheses. Accordingly, all of the relationships between hazard prevention practice, error management practice, mindful organising practice and their associated dimensions were significant (ρ <0.01). The results confirmed that hazard prevention practice was determined by its ten dimensions (i.e. safety policy, site safety organisation, safety meeting, safety inspection, safety training, safety promotion, risk assessment and hazard analysis, personal protection program, hazard control program and management support) (ρ <0.01). Error management practice was determined by its four dimensions (i.e. learning from errors, thinking about errors, error competence and error communication) (ρ <0.01). Mindful organising practice was determined by its five dimensions (i.e. preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience and deference to expertise) (ρ <0.01) (See Figure 5.2).

It is also shown in Figure 5.2 that there are significant positive correlations between (1) hazard prevention practice and contextual resilience ($\beta = 0.419, \rho<0.01$), (2) hazard prevention practice and behavioural resilience ($\beta = 0.485, \rho<0.05$), (3) error management practice and psychological resilience ($\beta = 0.403, \rho<0.05$), and (4) mindful organising practice and contextual resilience ($\beta = 0.445, \rho<0.01$). In addition, as discussed in Section 4.4.3.4, the squared multiple correlations (R^2) is a measure of the model's predictive power and is estimated as the squared correlation between a specific endogenous construct's actual and predicted values (Hair et al. 2016). Relatively high R-square values of resilient safety culture's dimensions were obtained in the model. The model explains 62.7% of psychological resilience's variance, 72.6% of contextual resilience's variance and 69.1% of behavioural resilience's variance. Table 5.9 summarised the hypotheses, path coefficients obtained from the PLS analysis, t-values, the associated levels of significance for each path and the squared multiple correlations (R^2). Therefore, hypotheses 3, 4, 5 and 9 are supported. The results of the impacts of hazard prevention practice, error management practice and error management practice on resilient safety culture will be further discussed in Section 6.2.2.

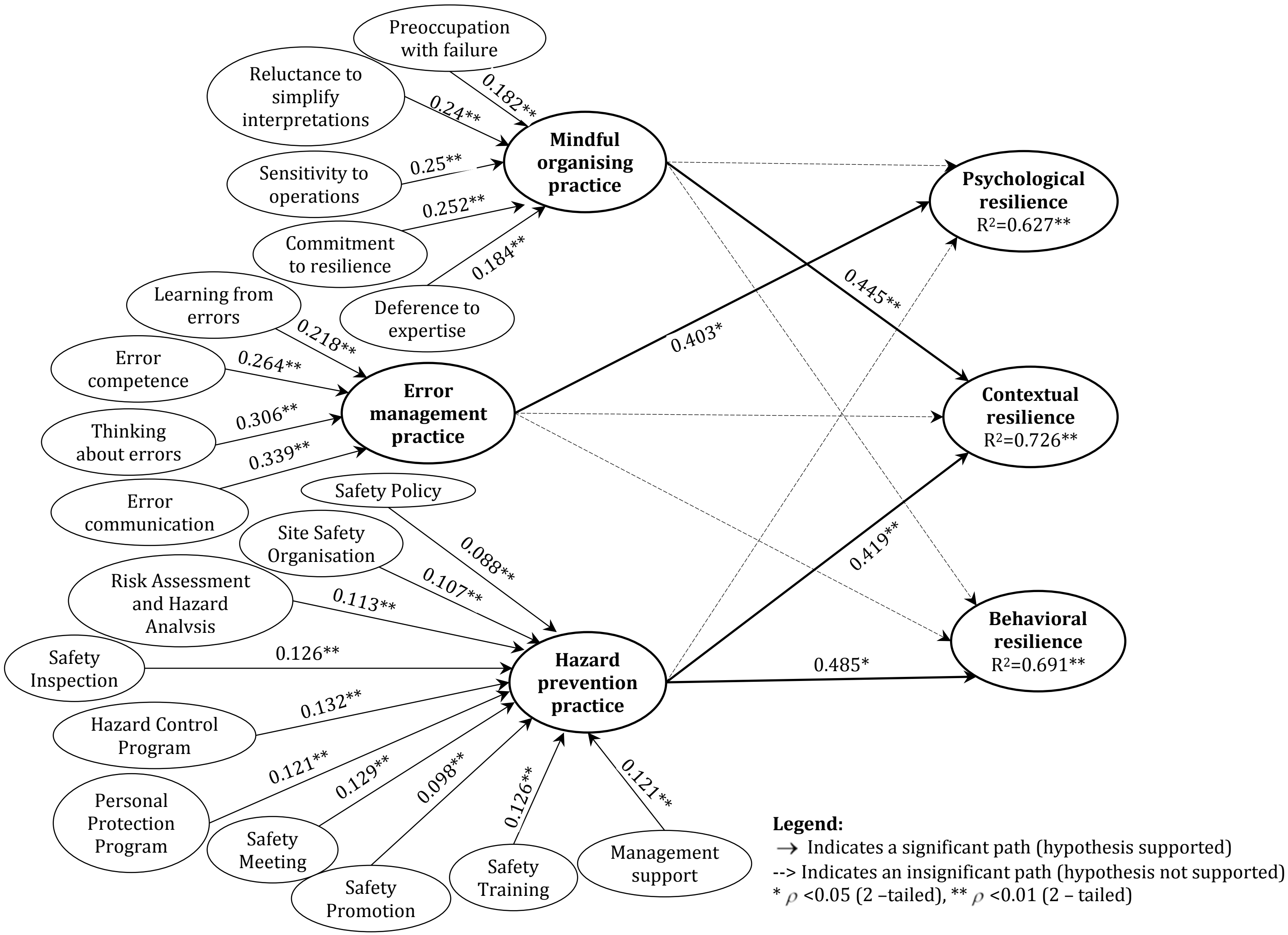


Figure 5.2: Relationships between hazard prevention practice, error management practice, mindful organising practice and three dimensions of resilient safety culture

Table 5.9: Results of relationships between hazard prevention practice, error management practice, mindful organising practice and resilient safety culture dimensions.

Predicted constructs	**Hypothesis and corresponding path**	β	***t*-value**	**f^2**	**R^2**	**t-value for R^2**	**Interpretation**
Psychological resilience	**H2** - Hazard prevention practice → Psychological resilience	0.144	0.949	0.015	0.627**	6.809	Not Supported
	H5 - Error management practice → Psychological resilience	0.403*	2.634	0.102			**Supported**
	H8 - Mindful organising practice → Psychological resilience	0.293	1.514	0.028			Not Supported
Contextual resilience	**H3** - Hazard prevention practice → Contextual resilience	0.419**	4.174	0.168	0.726**	16.301	**Supported**
	H6 - Error management practice → Contextual resilience	0.026	0.23	0.001			Not Supported
	H9 - Mindful organising practice → Contextual resilience	0.445**	2.957	0.088			**Supported**
Behavioural resilience	**H4** - Hazard prevention practice → Behavioural resilience	0.485*	2.206	0.200	0.691**	9.543	**Supported**
	H7 - Error management practice → Behavioural resilience	-0.049	0.346	0.002			Not Supported
	H10 - Mindful organising practice → Behavioural resilience	0.418	1.369	0.069			Not Supported

Notes: * ρ <0.05 (2 –tailed), ** ρ <0.01 (2 – tailed)

5.4.2 Interactive effects of resilient safety culture and project complexity on safety performance

5.4.2.1 Impacts of project complexity dimensions on safety performance

The relationship between project complexity dimensions and safety performance was investigated using models PLS-M2, PLS-M3 and PLS-M4 (See Section 4.4.3.1 for PLS-SEM models specification). The results of the structural models testing the relationship between project complexity dimensions (i.e. technical complexity, organisational complexity and environmental complexity) and safety performance are reported in Table 5.10. The results show that there are significant positive correlations between (1) technical complexity and Incident Rate (IR) (β = 0.293, t-value = 2.414, $\rho<0.05$) (Model PLS-M2 in Table 5.10), and (2) environmental complexity and IR (β = 0.228, t-value = 3.286, $\rho<0.01$) (Model PLS-M4 in Table 5.10). No significant relationship was found between organisational complexity and IR (β = -0.085, t-value = 0.556, $\rho>0.1$) (Model PLS-M3 in Table 5.10). Therefore, hypotheses 11 and 13 are supported. The results of the relationship between project complexity and safety performance will be further discussed in Section 6.4.1.

Table 5.10: Results of the relationship between project complexity dimensions and safety performance

Results	Hypotheses		
	H11	**H12**	**H13**
	Technical complexity → Safety performance	Organisational complexity → Safety performance	Environmental complexity → Safety performance
	PLS-M2	PLS-M3	PLS-M4
Dependent variable	Incident Rate	Incident Rate	Incident Rate
Independent variable	Technical complexity	Organisational complexity	Environmental complexity
Coefficient	0.293*	-0.085	0.228**
t-value	2.414	0.556	3.286
R^2	0.086	0.007	0.052
R^2 adjusted	0.074	-0.006	0.040
f^2	0.094	0.007	0.055
Interpretation	**Supported**	Not supported	**Supported**

Notes: * ρ <0.05 (2 –tailed), ** ρ <0.01 (2 – tailed)

5.4.2.2 Impacts of resilient safety culture dimensions on safety performance

The relationship between resilient safety culture dimensions and safety performance was investigated using models PLS-M5, PLS-M6 and PLS-M7 (See Section 4.4.3.1 for PLS-SEM models specification). The results of the structural models testing the relationship between resilient safety culture dimensions (i.e. psychological resilience, contextual resilience and behavioural resilience) and safety performance are reported in Table 5.11. The results show that there are significant negative correlations between (1) psychological resilience and IR (β = -0.351, t-value = 4.183, p<0.01) (Model PLS-M5 in Table 5.11), (2) contextual resilience and IR (β = -0.351, t-value = 4.105, p<0.01) (Model PLS-M5 in Table 5.11), and (3) behavioural resilience and IR (β = -0.296, t-value = 2.857, p<0.01) (Model PLS-M5 in Table 5.11). The results provide evidence to support hypotheses 14, 15 and 16. A detailed discussion about the impacts of resilient safety culture dimensions on safety performance can be found in Section 6.2.2.

Table 5.11: Results of relationships between resilient safety culture dimensions and safety performance

Results	**Hypotheses**					
	H14	**H15**	**H16**	**H17**	**H18**	**H19**
	Psychological resilience → Safety performance	Contextual resilience → Safety performance	Behavioural resilience → Safety performance	(Psychological resilience * Contextual resilience) → Safety performance	(Behavioural resilience * Contextual resilience) → Safety performance	(Psychological resilience * Behavioural resilience) → Safety performance
	PLS-M5	PLS-M6	PLS-M7	PLS-M8: Moderating effect 1	PLS-M9: Moderating effect 2	PLS-M10: Moderating effect 3
Dependent variable	Incident Rate	Incident Rate	Incident Rate	Incident Rate	Incident Rate	Incident Rate
Independent variable	Psychological resilience	Contextual resilience	Behavioural resilience	Psychological resilience	Behavioural resilience	Psychological resilience
Moderator variable	-	-	-	Contextual resilience	Contextual resilience	Behavioural resilience
Calculation method	-	-	-	Two-stage	Two-stage	Two -stage
Product term generation	-	-	-	Standardised	Standardised	Standardised
Coefficient	-0.351**	-0.351**	-0.296**	0.282**	0.180	0.268*
t-value	4.183	4.105	2.857	2.900	1.312	2.118
R^2	0.124	0.123	0.087	0.244	0.174	0.240
R^2 adjusted	0.112	0.112	0.075	0.213	0.141	0.209
f^2	0.141	0.141	0.096	0.138	0.056	0.136
Interpretation	**Supported**	**Supported**	**Supported**	**Supported**	Not supported	**Supported**

Notes: * ρ <0.05 (2 –tailed), ** ρ <0.01 (2 – tailed)

The moderated effects between dimensions of resilient safety culture on safety performance were investigated using models PLS-M8, PLS-M9 and PLS-M10 (See Section 4.4.3.1 for PLS-SEM models specification). The results show that there are significant positive correlations between (1) moderating effect 1 and IR (hypothesis 17) ($\beta = 0.282$, t-value = 2.900, $p<0.01$) (Model PLS-M8 in Table 5.11), and (2) moderating effect 3 and IR (Hypothesis 19) ($\beta = 0.268$, t-value = 2.118, $p<0.05$) (Model PLS-M10 in Table 5.11). However, no significant relationship was found between moderating effect 2 and IR (hypothesis 18) ($\beta = 0.180$, t-value = 1.312, $p>0.05$) (Model PLS-M9 in Table 5.11).

The results indicate that the relationship between psychological resilience and IR does not hold constant under different contextual resilience levels and behavioural resilience levels (Model PLS-M8 and Model PLS-M10 in Table 5.11). Figure 5.3 shows the variance of the simple slope for IR on psychological resilience at different contextual resilience levels. The three lines show the relationship between psychological resilience and IR. The red line indicates the relationship for an average level of the moderator variable 'Contextual resilience'. The other two lines (blue and green) indicate the relationship between psychological resilience and IR for smaller (i.e. mean value of contextual resilience minus one standard deviation unit) and greater (i.e. mean value of contextual resilience plus one standard deviation unit) levels of the contextual resilience (e.g. moderator variable). The blue line, which represents a low level of contextual resilience, has steeper slope while the red line, which represents an average level of contextual resilience, has a flatter slope. Thus, higher contextual resilience levels entail a weaker correlation between psychological resilience and IR. This finding provides empirical evidence to support the hypothesis 17. The moderating effect of contextual resilience on the relationship between psychological resilience and safety performance is further discussed in Section 6.2.3.

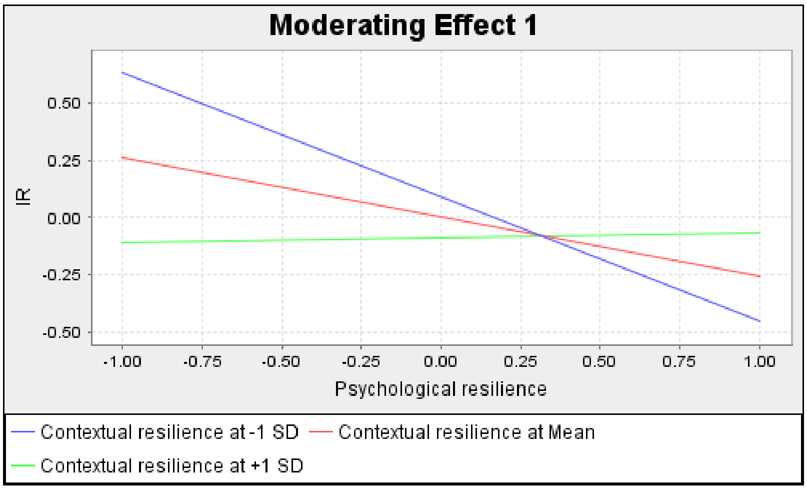


Figure 5.3: Simple slope line in SmartPLS for IR on centred psychological resilience at three typical values of centred contextual resilience

Figure 5.4 shows the variance of the simple slope for IR on psychological resilience at different behavioural resilience levels. The relationship between psychological resilience and IR is negative for all three lines as indicated by their negative slope. Nevertheless, the blue line, which indicates a low level of the moderator 'Behavioural resilience', has a steeper slope while the red and green lines, which represent high levels of the moderator, has flatter slopes. Hence, this finding indicates that higher behavioural resilience levels entail a weaker relationship between psychological resilience and IR. This provides empirical evidence to support hypothesis 19. The moderating effect of behavioural resilience on the relationship between psychological resilience and safety performance is further discussed in Section 6.2.3.

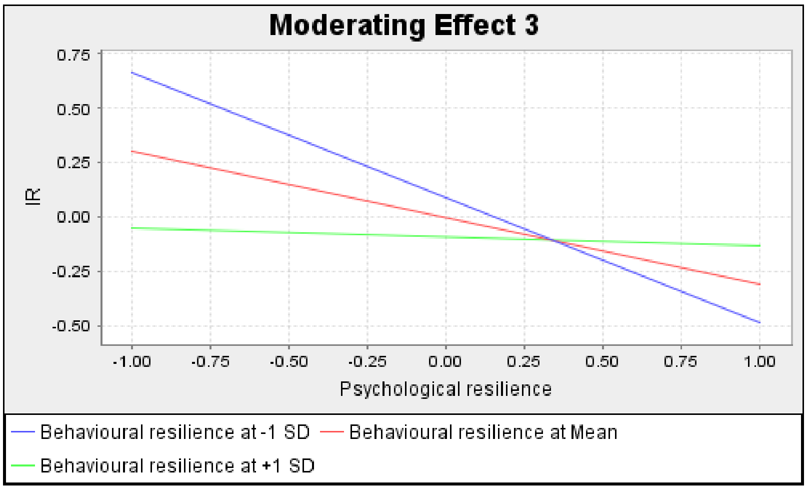


Figure 5.4: Simple slope line in SmartPLS for IR on centred psychological resilience at three typical values of centred behavioural resilience

5.4.2.3 Moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance

In this study, the moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance were investigated using models PLS-M11, PLS-M12 and PLS-M13 (See Section 4.4.3.1 for PLS-SEM models specification). The results of the models are reported in Table 5.12. The results show that the correlations between all moderating effects and IR are significantly negative: (1) moderating effect 4 and IR (β = - 0.327, t-value = 3.030, $p<0.01$) (Model PLS-M11 in Table 5.12), (2) moderating effect 5 and IR (β = - 0.282, t-value = 2.528, $p<0.05$) (Model PLS-M12 in Table 5.12), and (3) moderating effect 6 and IR (β = - 0.345, t-value = 2.586, $p<0.01$) (Model PLS-M13 in Table 5.12).

Table 5.12: Results of moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance

Results	Hypotheses		
	H20	**H21**	**H22**
	(Psychological resilience*Project complexity) → Safety performance	(Contextual resilience*Project complexity) → Safety performance	(Behavioural resilience*Project complexity) → Safety performance
	PLS-M11: Moderating effect 4	PLS-M12: Moderating effect 5	PLS-M13: Moderating effect 6
Dependent variable	Incident Rate	Incident Rate	Incident Rate
Independent variable	Project complexity	Project complexity	Project complexity
Moderator variable	Psychological resilience	Contextual resilience	Behavioural resilience
Calculation method	Two-stage	Two-stage	Two-stage
Product term generation	Standardised	Standardised	Standardised
Coefficient	-0.327**	-0.282*	-0.345**
t-value	3.030	2.528	2.586
R^2	0.316	0.289	0.32
R^2 adjusted	0.288	0.260	0.293
f^2	0.196	0.159	0.231
Interpretation	**Supported**	**Supported**	**Supported**

Notes: * ρ <0.05 (2 –tailed), ** ρ <0.01 (2 – tailed)

The results in Table 5.12 indicate that the relationships between project complexity and IR do not hold constant under different levels of psychological, contextual and behavioural resilience. Figure 5.5 shows the variance of the simple slope for IR on project complexity at different psychological resilience levels. The three lines represent the relationship between project complexity (x-axis) and IR (y-axis). The blue line representing the relationship for a low level of psychological resilience has steeper slope whereas the red line representing the relationship for an average level of psychological resilience has a flatter slope. Thus, higher psychological resilience levels entail a weaker correlation between project complexity and IR. In addition, the Figure 5.5 depicts that the correlation between project complexity and IR is positive when psychological is at low (-1 Std. Dev.) and at mean, whereas this value is even negative when is at high (+1Std. Dev.). This result indicates that the impact of project complexity on safety performance might be not significant if psychological resilience was high. This provides empirical evidence to support hypothesis 20. The moderating effects of psychological resilience on the relationship between project complexity and safety performance will be further discussed in Section 6.4.2.

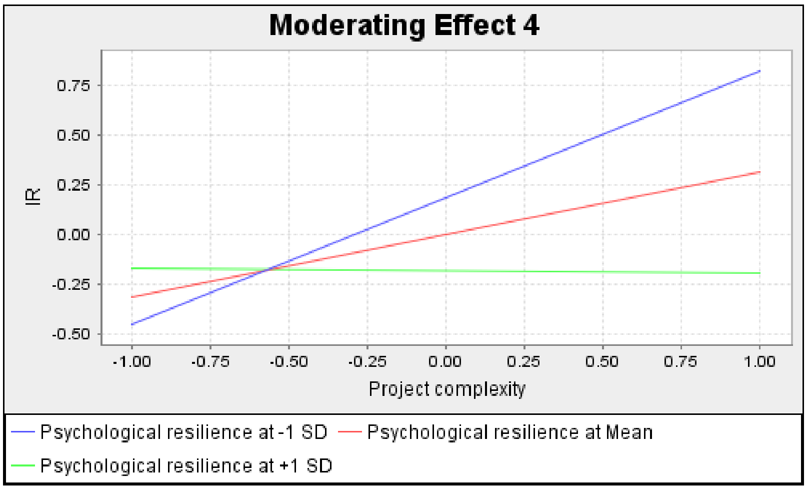


Figure 5.5: Simple slope line in SmartPLS for IR on centred project complexity at three typical values of centred psychological resilience

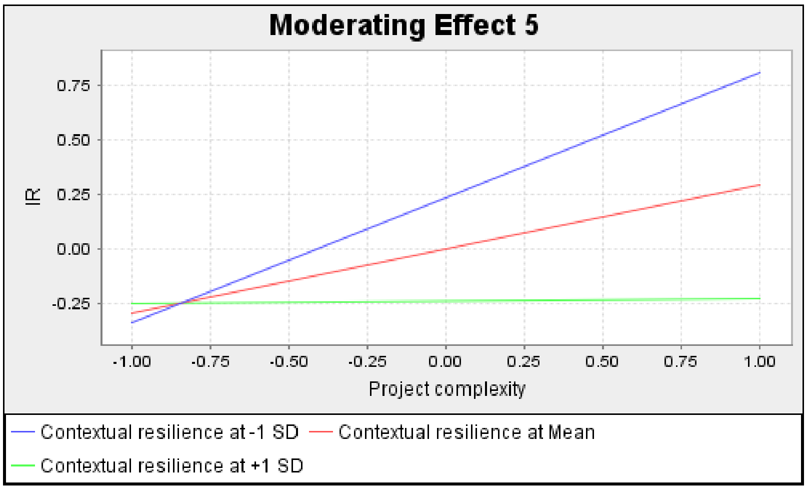


Figure 5.6: Simple slope line in SmartPLS for IR on centred project complexity at three typical values of centred contextual resilience

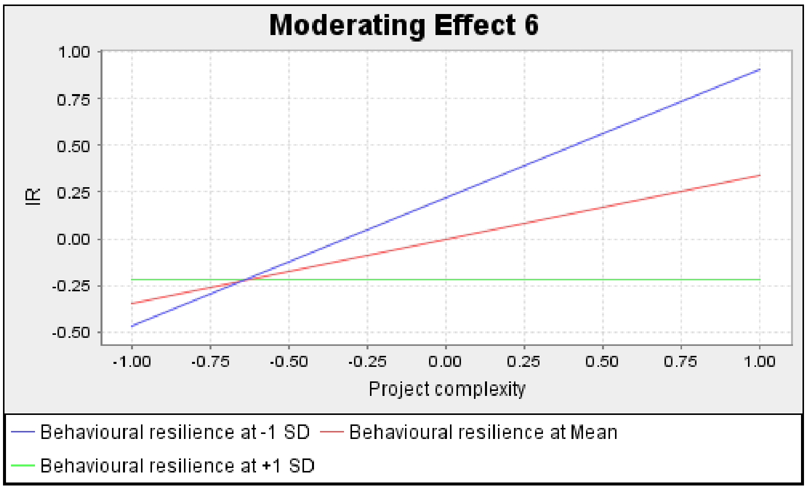


Figure 5.7: Simple slope line in SmartPLS for IR on centred project complexity at three typical values of centred behavioural resilience

Figure 5.6 and Figure 5.7 show the variance of the simple slope for IR on project complexity at different levels of contextual resilience and behavioural resilience, respectively. In both figures, the relationship between project complexity and IR is positive for all three lines as indicated by their positive slope. Nonetheless, the blue line, which represents a low level of the moderators (i.e. 'Contextual resilience' and 'Behavioural resilience') have a steeper slope while the red and green lines, which represent a high level of the moderator, has a flatter slope. Hence, this finding indicates that higher contextual and behavioural resilience levels entail a weaker relationship between project complexity and IR. Figure 5.6 and Figure 5.7 also depict that the correlation coefficient value between project complexity and IR is even roughly zero when contextual and behavioural resilience is at high (+1Std. Dev.). These results indicate that the impacts of project complexity on safety performance might be not significant if contextual and behavioural resilience were high. This provides empirical evidence to support hypotheses 21 and 22. The moderating effects of contextual and behavioural resilience on the relationship between project complexity and safety performance will be further discussed in Section 6.4.2.

5.5 Summary

This chapter analysed the collected data. Section 5.3 examined the confidence of internal reliability, the convergent and discriminant validities of constructs needed for the subsequent structural models' analyses; and examined the dimensions of resilient safety culture of construction projects (Objective 1 of this study). The results confirm 24 measurable scale items comprising three dimensions (i.e. psychological resilience, contextual resilience and behavioural resilience) to define and assess resilient safety culture. Thus, hypothesis 1 is supported.

Section 5.4.1 examined the relationship between hazard prevention practice, error management practice, mindful organising practice and resilient safety culture dimensions (Objective 2 of this study). The results provide evidence to support hypotheses 3 and 4 (i.e. hazard prevention practice has a significant positive impact on contextual and behavioural resilience), hypothesis 5 (i.e. error management practice has a significant positive impact on psychological resilience) and hypothesis 9 (i.e. mindful organising practice has a significant positive impact on contextual resilience).

Section 5.4.2 examined the interactive effects of resilient safety culture and project complexity on safety performance of construction projects (Objective 3 of this study). The results (See Section 5.4.2.1) show that technical and environmental project complexities have significant negative impacts on safety performance, thereby supporting hypotheses 11 and 13. It is also shown in Section 5.4.2.2 that resilient safety culture dimensions have positive impacts on safety performance of construction projects, thus supporting hypotheses 14, 15 and 16. Psychological resilience has a weaker impact on accident prevention under higher contextual resilience and behavioural resilience levels. These above results provide empirical evidence to support hypotheses 17 and 19. Lastly, the results (See Section 5.4.2.3) show that the negative impact of project complexity on safety performance becomes less significant when there is a higher level of psychological, contextual and behavioural resilience; while this impact might be not significant if psychological, contextual and behavioural resilience were high. These results, therefore, provide empirical evidence to support hypotheses 20, 21 and 22.

Based on the aforementioned results, a total of 14 out of 21 proposed paths are found to be statistically significant, supporting the hypothesised relationships among the constructs in this research. The paths are statistically significant at $\rho < 0.05$ level or less. Figure 5.8 depicts the standardised path coefficients and the statistical significance for 14 statistically significant paths integrated into a model of resilient safety culture.

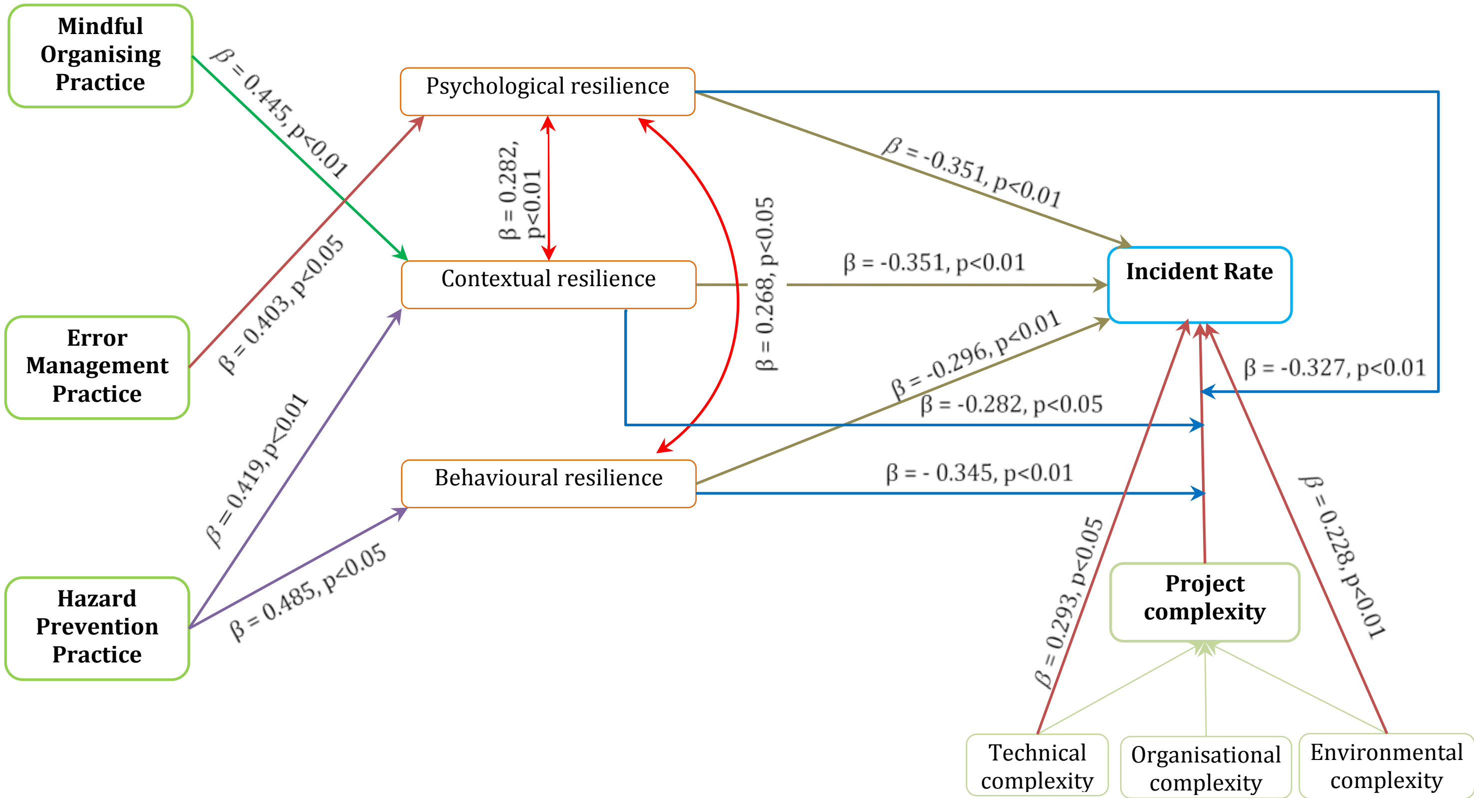


Figure 5.8: Model of resilient safety culture with significant standardised path coefficients

CHAPTER 6 DISCUSSION

6.1 Introduction

This chapter presents the interpretation and discussion of the empirical results derived from SEM analyses in Chapter 5. It begins with discussing the dimensions of resilient safety culture and their impacts on safety performance (Section 6.2). It is followed by explaining the mechanisms by which resilient safety culture can be created in construction organisations (Section 6.3). This chapter ends with the discussion of the moderated effects of project complexity and resilient safety culture on safety performance (Section 6.4).

6.2 Resilient safety culture dimensions and their impacts on safety performance

6.2.1 Dimensions of resilient safety culture

The results of confirmatory factor analysis of measurement models validate 24 measurable scale items comprising three dimensions (i.e. psychological resilience, contextual resilience and behavioural resilience) to define and assess resilient safety culture (See Section 5.3 and Table 5.8).

6.2.1.1 Psychological resilience

The results (See Table 5.8) show that psychological resilience was characterised by nine measurable scales: awareness of the negative consequences resulting from non-compliance with health and safety rules (Psy2), acknowledgement of the occurrence of unexpected hazardous events (Psy3), mindfulness of the project hazards even when they are recognised and controlled with preventive measures (Psy4), knowledge for identifying potential hazards regarding to work tasks (Psy5), heedfulness of co-workers' activities (Psy6), awareness of major safety worries and concerns on sites (Psy7), tendency to refuse to work when hazards and safety risks related to work task are not clear (Psy9), tendency to refuse to work when appropriate preventive and protective measures are not provided (Psy10) and tendency to refuse to work when it is not clear on how to execute the work task (Psy11). Accordingly, these measurable scales characterised employees' psychological abilities on sites, which involve: risk recognition (i.e. Psy5, Psy6 and Psy7), risk perception (i.e. Psy2, Psy3 and Psy4) and unwillingness to take risks (i.e. Psy9, Psy10 and Psy11). This result indicates that these psychological abilities enhanced the organisation's capabilities to manage safety risks.

The finding of this study is supported by many studies (Carter & Smith 2006; Choudhry & Fang 2008; Guo et al. 2012; Khorsandi & Aven 2014; Rundmo 1996), where the findings revealed the important role of risk recognition, risk perception and risk-taking behaviours of employees to safety management in construction organisations. The finding of Khorsandi and Aven's (2014) study indicates that the employees' capability of decisions on whether or not to take action is dependent on their level of risk recognition. Choudhry and Fang (2008) also found that if workers are more knowledgeable about safety risks, they may be at lower risk. In terms of risk perception, the study of Rundmo (1996) indicated that more precise perception of risk could cause more accurate judgements of potentially hazardous situations, and thus produce more appropriate action towards the safety risks and decisions towards safety measures. In terms of risk-taking behaviours, Guo et al.'s (2012) study found that safety attitude of construction workers towards risk-taking could influence the crane/heavy plant/equipment related fatalities. Carter and Smith (2006) further pointed out that risk-taking behaviour of construction workers emerges due to an inability to adequately recognise and perceive risks, and is not deliberate.

In this study, as psychological resilience characterised the abilities of project's employees to interpret, analyse and formulate responses to regular and irregular safety risks on sites, psychological resilience enhanced an organisation's capabilities to manage safety risks. Thus, measuring psychological resilience helps to estimate the level of resilient safety culture.

6.2.1.2 Contextual resilience

The results (See Table 5.8) show that contextual resilience was characterised by eight measurable scales: analysis of potential safety risks of accident (Con1), assessment of needed safety resources (Con2), assessment of potential changes of working conditions that might present a risk of accident (Con4), provision of up-to-date information about safety risks (Con6), surveillance and monitoring of working conditions (Con7), provision of safety resources related to observed hazards (Con9), provision of preventive safety measures following any changes to the working conditions (Con11) and collection and distribution of feedback or revisions on safety issues (Con13). Accordingly, these measurable scales characterised the capabilities of contractors to provide the backdrop for responses to safety risks on sites. They include: process of identifying and assessing the current and potential safety risks (i.e. Con1, Con2 and Con4), process of checking the changes of safety risks (i.e. Con6 and Con7), process of preparedness to respond to safety risks (i.e. Con9 and Con11) and process of taking lessons from safety issues (Con13). This result indicates that these contextual capabilities improved the organisation's capabilities to manage safety risks on sites.

The finding of this study is supported by a number of studies (Aksorn & Hadikusumo 2008; Hinze 2002; Mitropoulos et al. 2005; Tam et al. 2004). Hinze's (2002) study revealed that safety pre-project/pre-task planning is one of nine specific areas that are vital for safety and risk management. The findings of studies (Aksorn & Hadikusumo 2008; Tam et al. 2004) indicated that sufficient resource allocation to safety has a critical effect on safety performance improvement. In addition, the studies (Mitropoulos et al. 2005; Radujković & Burcar 2005; Zou et al. 2009) indicates that the changing shapes of safety risks are inevitable in the construction environment. Mitropoulos et al. (2005) through a model of construction accident causation, pointed out that there are many circumstances in which the actual conditions differ from expected, or resources (information, tool, material, etc.) may be missing. Zou et al. (2009) further asserted that those changing shapes of safety risks could emanate from changes in legislation, uncertain working conditions, adoption of nonstandard building contracts and effects of related authorities. As a result, the nature of safety risks and their impacts alter during the construction stage of a project (Radujković & Burcar 2005).

In this study, as contextual resilience characterised the contractor's capabilities to provide the backdrop for responses to identified and changing shapes of safety risks, contextual resilience enhanced an organisation's capabilities to manage safety risks on sites. Thus, measuring contextual resilience helps to estimate the level of resilient safety culture.

6.2.1.3 Behavioural resilience

The results (See Table 5.8) show that behavioural resilience was characterised by seven measurable scales: conduct the site inspections to check the changes of working conditions (i.e. safety hazards and its preventive safety measures) (Beh3), pay attention to not sending people to work sites in which the safety risks are not clear (Beh6), act decisively when encountering any regular and irregular safety issues (Beh7), react quickly to the cases of emergency situation (Beh9), listen to feedback from others (Beh10), draw conclusions when any hazardous events happened (Beh12) and in incident investigations, the aim directs to prevent the future similar accidents rather than blame workers on such events (Beh13). Accordingly, these measurable scales characterised the competencies and patterns of behaviours on sites, which include building up situation risk awareness (i.e. Beh3 and Beh10), understanding the risky situations (i.e. Beh12 and Beh13) and implementing actions in responding to safety risks (i.e. Beh6, Beh7 and Beh9). This result indicates that these behavioural characteristics enhanced the organisation's capabilities to manage safety risks.

The finding of this study could be explained by Situation Awareness Theory developed by Endsley (1995). Endsley (1995) found that the perception of situation elements in relation to the proper operation just in time is crucial for safety and risk management. Employees should be able to recognise the surroundings in which they are involved, in order to predict what will happen next, and thus producing appropriate action (Endsley 1995). Situation Awareness Theory postulates that situation awareness is developed on three phases: (1) recognising the elements of a situation, (2) understanding the current circumstance, and (3) predicting future states to produce actions (Endsley 1995). In this study, as behavioural resilience characterised the competencies and patterns of behaviours of projects' employee to recognise, understand, predict and react towards hazardous situations, behavioural resilience enhanced an organisation's capabilities to manage safety risks. Thus, measuring behavioural resilience helps to estimate the level of resilient safety culture.

In light of the above, psychological resilience, contextual resilience and behavioural resilience constituted a framework for defining and measuring resilient safety culture. This finding also suggests that the measurable scales items of resilient safety culture can be served as useful indicators to assess the capabilities of construction organisations to manage safety risks on sites.

6.2.2 Impacts of resilient safety culture dimensions on safety performance

The results show that there are significant negative correlations between (1) psychological resilience and IR $(\beta = -0.351, \rho<0.01)$, (2) behavioural resilience and IR $(\beta = -0.296, \rho<0.01)$, and (3) contextual resilience and IR $(\beta = -0.351, p<0.01)$ (See Section 5.4.2.2). These results indicate that an improvement in all of the psychological, contextual and behavioural resilience could produce safety performance improvement of construction projects as measured through a decreased IR value. This finding could be explained by Wachter and Yorio's (2014) study, where it was indicated that the employees on sites, who daily interact with safety hazards and are at the sharp boundary of accidents, play an equally important role as does the safety management system (i.e. plans, processes and procedures) implemented on sites to reduce and prevent accidents. This is because employees interact necessarily with the safety system through their cognition, perception and behaviours; and keep the system effective (Wachter & Yorio 2014). Therefore, the higher levels of psychological, contextual and behavioural resilience produce the higher level of safety performance, which was indicated by the lower value of IR. Based on these findings, it is implied that the assessment of resilient safety culture dimensions could provide a reliable prediction of safety performance of construction projects.

6.2.3 Moderated effects of psychological resilience on safety performance

As presented in Section 5.4.2.2, the results show that the effect of psychological resilience on Recordable Incident Rate does not hold constant under different contextual resilience levels and behavioural resilience levels (See Figure 5.3 and Figure 5.4). The results indicate that psychological resilience has a weaker impact on accident prevention under a higher level of contextual resilience and a higher level of behavioural resilience.

The above results could be explained by Peltzman's (1975) Risk Compensation Theory. Peltzman (1975) found that, in a safer situation, drivers have a tendency to increase speed instead of enjoying the increased safety related to driving at the same speed. Risk Compensation Theory postulates that individuals tend to modify their actions in response to perceived changes in risk. They are more likely to act less cautiously in settings where they feel more protected or 'safer'. It is implied that when individuals' perception of risk increase, they tend to act more cautiously (Peltzman 1975). This theory is also supported by several researchers (Huang et al. 2013; Vernero & Montanari 2007; Weyman & Kelly 1999). Huang et al.'s (2013) study found that individuals with a perceived higher knowledge of ecological hazards tend to have a higher risk tolerance than those who have less knowledge of hazards. Vernero and Montanari (2007) found that, in a chemical plant, when workers believed they had an appropriate perception of risk, they workers were unwilling to use PPE. The sense of being protected in a specific situation could reduce anxiety, thereby causing a worker to become more relaxed towards involving in unsafe behaviours (Weyman & Kelly 1999). In this study, contextual resilience and behavioural resilience involve the capabilities which provide construction workers with the awareness about work tasks and its safety risks, and appropriate safety resources and measures to conduct their jobs safely. Therefore, for those building project with better contextual and behavioural resilience, employees tend to believe that they are more fully informed of work tasks and its related safety risks, and more protected. Consequently, workers are more likely to have higher levels of risk tolerance.

6.3 Developing resilient safety culture

The results of path analysis of structural models supported the hypothesised relationships between hazard prevention practice, error management practice and resilient safety culture dimensions (See Figure 5.8 and Table 5.9). Direct impacts on resilient safety culture dimensions are interpreted and discussed in the subsequent sections 6.3.1, 6.3.2 and 6.3.3.

6.3.1 Developing psychological resilience

The results show that there is a significant positive correlation between error management practice and psychological resilience ($\beta = 0.403, \rho<0.05$) (See Figure 5.2 and Table 5.9). It is also indicated that error management practice explained 62.7% of psychological resilience's variance (See Figure 5.2). This result provides empirical evidence to support that error management practice can enhance psychological resilience, and that psychological resilience is not likely to be impacted by hazard prevention practice and mindful organising practice.

This finding can be explained by Cognitive Failure Theory (Malaterre 1990; Wagenaar et al. 1990), which concerns how individuals involve in unsafe behaviours, provides the implication for enhancing individuals' capabilities extrapolate accident scenarios and avoiding accidents. For example, in an examination of the causes of road accidents, Malaterre (1990) categorised the driving process into four sequential phases, which include data acquisition, data processing, decision-making and action, and postulated that failures in any of the above stages could produce unsafe behaviours. Malaterre's (1990) study found that unsafe behaviours largely occur in the first two stages (e.g. data acquisition and data processing), whereas a small portion is due to conscious decision-making and risk-taking. Similarly, when analysing 57 road accidents, Wagenaar et al. (1990) found that only one unsafe act was associated with the conscious awareness of a known risk, whereas most actors did not recognise that they were involved in an accident scenario and could not be assisted by warnings. Rather, they believed that they were in a routine situation, to which their normal repertoire of habits would apply. Wagenaar et al. (1990) further explained that the inability to extrapolate accident scenarios occurs because individuals tend to use 'backward reasoning' instead of 'forward reasoning'. Individuals with 'backward reasoning' begin with known accidents, listing their causes to see whether the present actions are among them, whereas individuals with 'forward reasoning' tend to extrapolate from known actions to an unknown accident. Based on Cognitive Failure Theory, it is self-evident that individuals will better extrapolate accident scenarios and thus better avoiding accidents when they are more engaged in 'forward reasoning'. In this study, error management practice involves 'forward reasoning' strategies towards behaviours of project's employees (See Section 4.3.1.3 for the conceptualisation of error management practice), and thus enhancing their capabilities to extrapolate accident scenarios.

The finding of this study is also consistent with many studies (Casey & Krauss 2013; Cigularov et al. 2010), where the findings provided the empirical evidence of the impact of error management practice on safety behaviours and injuries. This finding also suggests that, when error management practice was fostered on sites, project's employees could better extrapolate accident scenarios, and thus being less engaged in unsafe behaviours and accidents.

6.3.2 Developing contextual resilience

The results show that there are significant positive correlations between (1) hazard prevention practice and contextual resilience (β = 0.419, ρ<0.01), and (2) mindful organising practice and contextual resilience ($\beta = 0.445, \rho<0.01$) (See Figure 5.2 and Table 5.9). It is also indicated that the inclusion of hazard prevention practice and mindful organising practice explained 72.6% of contextual resilience's variance (See Figure 5.2). Thus, the results indicate that the combination of hazard prevention practice and mindful organising practice can improve contextual resilience.

The positive impact of hazard prevention practice on contextual resilience is supported by many studies (Carter & Smith 2006; Heinrich et al. 1980; Hinze et al. 1998; Spellman 1998; Wilson & Koehn 2000), where the findings revealed the prevalence of project hazards and their impacts on safety performance, and the need for improving an organisation's capability to address the inherent hazards and prevent accidents in construction site environments. Carter and Smith (2006) found that the majority of construction accidents occur due to the inability of predicting, identifying and responding to the project hazards. These unrecognised hazards limit the capability of site management to establish safety controls and of construction workers to behave safely (Carter & Smith 2006). Mohamed and Bostock (1999) also found that site management could better establish safety controls and construction workers could act more safely when there were more project hazards detected beforehand. Thus, contractors are required to provide: (1) a workplace free from recognised hazards, and (2) construction workers with the skills, knowledge and motivation to identify hazards, thus enforcing them to make safety-conscious decisions and behave safely (Spellman 1998; Wilson & Koehn 2000). In this study, hazard prevention practice involves those safety strategies, which identify project hazards, estimate risks related to the hazards, and place engineering and administrative controls for workers to conduct their jobs safely (See Section 4.3.1.2 for the conceptualisation of hazard prevention practice). Therefore, with the better hazard prevention practice, contractors could better provide the backdrop for responses to safety risks.

The positive impact of mindful organising practice on contextual resilience can be supported by many studies (Enya et al. 2018; Harvey et al. 2016; Mitropoulos et al. 2005; Mitropoulos & Cupido 2009; olde Scholtenhuis & Dorée 2014), where the findings indicated the prevalence of the unexpected and their impacts on safety performance, and the need for improving an organisation's capability to address the unexpected and prevent accidents in construction site environments. The prevalence of the unexpected on construction sites can be explained by Mitropoulos et al.'s (2005) accident causation model, which indicated that, there are many circumstances in which the actual conditions are different than expected, or resources (information, tool, material, etc.) may be missing, thereby generating the unpredictable hazardous situations and the possibility of accidents. These types of accidents should be described as the result of a combination of a number of the unexpected (Harvey et al. 2016; olde Scholtenhuis & Dorée 2014). Therefore, identifying and preventing potential unwanted situations (e.g. anticipation) and reacting to and recovering from such situations (e.g. containment) are essential for avoiding the unexpected hazardous situations and accidents (olde Scholtenhuis & Dorée 2014). In this study, mindful organising practice involves those safety strategies, which induce a rich awareness of the emerging unexpected, thereby reacting to such events on construction workplaces (See Section 4.3.1.4 for the conceptualisation of mindful organising practice). Therefore, with the better mindful organising practice, contractors could better provide the backdrop for responses to safety risks. The finding of this study is in line with Mitropoulos and Cupido's (2009) study, where it looked into the mindful organising practices in residential framing crews and found that mindful organising practices helped teams to finish their work quicker, which also resulted in fewer errors and accidents.

The results of this study also show that there is no significant correlation between error management practice and contextual resilience (See Figure 5.2 and Table 5.9). A possible explanation is that error management practice emphasises on detecting and managing unintentional unsafe behaviours of construction workers, and thus not be helpful in providing the backdrop or contextual conditions for responses to safety risks (See Section 3.3.2 and Table 5.8 for further details of error management practice). In other words, contractors cannot provide the better backdrop for responses to safety risks by implementing error management practice in the context of Vietnamese construction industry.

Taken together, the results of this study indicate that contextual resilience could be improved by the combination of hazard prevention practice and mindful organising practice. Based on this finding, it is also suggested that when contractors fostered the synergies of hazard prevention practice and mindful organising practice, they could better provide the backdrop, which facilitates effective responses to safety risks on sites.

6.3.3 Developing behavioural resilience

The results show that there is a significant positive correlation between hazard prevention practice and behavioural resilience ($\beta = 0.485, \rho < 0.05$) (See Figure 5.2 and Table 5.9). It is also indicated that hazard prevention practice explained 69.1% of behavioural resilience's variance (See Figure 5.2). This result provides empirical evidence to support that hazard prevention practice can promote behavioural resilience.

This finding can be explained by human performance theory (Reason 1990, 1997). Human performance theory postulates that there are inevitable inherent weaknesses within organisations in terms of its mission, goals, policies, processes and programs, which could give rise unfavourable conditions and increase the probability of misjudgement or inappropriate operation while performing specific actions (Reason 1990, 1997). Human performance theory has implication for safety management by suggesting that, in order to prevent workplace accidents, levels of employees' involvement in safety activities should be promoted by making them more involved with, and aware of their tasks/surroundings and related risks that could be presented (Reason 1990, 1997). Human performance theory was supported by the findings of Wachter and Yorio's (2014) study, which suggest that the best safety strategies for human performance improvement and accident prevention could be those, which allow employees to continually learn and adapt to their work surroundings in order to be more aware of and safely cope with the inadequacies within or changes rising in the workplaces. Hollnagel (2016) also stressed that, in order to behave safely in responses to safety risks, individuals should be able to: (1) detect that safety risks have occurred, (2) identify, recognise and rate the associated hazardous situations so that a response is required, and (3) command the appropriate resources for the response to have an effect. In this study, a possible reason for the positive impact of hazard prevention practice on behavioural resilience could be that, hazard prevention practice involves employees to be more conscious of the tasks to be performed, the hazards and associated risks in a specific project, and thus promote better competencies and patterns of behaviours in responses to safety risks. This finding also suggests that, when hazard prevention practice was fostered on sites, project's employees could take safer decision making and behaviours.

The results of this study also show that there are no significant correlations between (1) error management practice and behavioural resilience, and (2) mindful organising practice and behavioural resilience (See Figure 5.2 and Table 5.9). These results indicate that behavioural resilience is not likely to be impacted by error management practice and mindful organising practice in the context of Vietnamese construction industry.

6.4 Moderated effects of project complexity and resilient safety culture on safety performance

The results of path analysis of structural models supported the hypothesised relationships between project complexity and safety performance, and the moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance (See Figure 5.8). The empirical results of these relationships are interpreted and discussed in subsequent sections 6.4.1 and 6.4.2.

6.4.1 Impacts of project complexity dimensions on safety performance

The results show that there are significant positive correlations between (1) technical complexity and IR ($\beta = 0.293$, $\rho < 0.05$), and (2) environmental complexity and IR ($\beta = 0.228$, $\rho < 0.01$) (See Table 5.10 and Figure 5.8). These results indicate that technical and environmental project complexities could increase the occurrence of accidents.

This finding can be explained by the construction accident causation models (Haslam et al. 2005; Suraji et al. 2001). These models show that there are two major hierarchies of accident causal factors, namely distal factors and proximal factors (Haslam et al. 2005; Suraji et al. 2001). Proximal factors are actions (or inactions) by contractors' employees during the project construction stage that lead directly to accidents. Proximal factors include inappropriate operative action, inappropriate construction operation, inappropriate site conditions, and inappropriate construction control and planning. Distal factors are actions (or inactions) by pre-construction project participants (i.e. project managers/planners, designers and clients), produce the introduction of the proximal factors in the construction process and of the increased risk of accidents. Distal factors can include modify design, reduce program timescales, change project objectives, reduce project budget, etc. (Haslam et al. 2005; Suraji et al. 2001). Based on those studies, a possible explanation of the negative impacts of technical and environmental project complexities on safety performance could be that, technical and environmental project complexities (See Section 5.3 for details on technical and environmental project complexities) emerge from the changed and undetailed planning of the project participants in the pre-construction stage of project procurement. As a result, technical and environmental project complexities fall into the category of distal factors of accident causation, produce the changing and unforeseen safety risks on sites, and thus make the construction organisations more vulnerable to accidents.

The results of this study also indicate that the occurrence of accidents is not likely to be impacted by organisational project complexity in the context of Vietnamese construction industry. This finding is consistent with Luo et al.'s (2016) study, which indicates that organisational project complexity has no significant effect on project success (i.e. time, cost, quality, health and safety, environmental performance, participants' satisfaction, user satisfaction, and commercial value).

The finding of this study is also supported by many studies, where the findings indicated the influences of various aspects of the construction process on safety performance. These studies revealed that variations of project objectives (i.e. schedule, cost and quality) (Han et al. 2014; Suraji et al. 2001), construction method change and unclear method statement (Suraji et al. 2001), firm's resources unavailability (Cheng, CW et al. 2010; Holte et al. 2015), missing project information (i.e. tasks and conditions unpredictability, safety measures and updated specifications) (Cheng, EWL et al. 2012; Mitropoulos et al. 2005), lack or inappropriateness of regulations and legislation (Kartam et al. 2000; Toole 2005), weather conditions (Ayyub & Haldar 1985; Liao & Perng 2008; Mitropoulos et al. 2009), economic pressures (Choudhry & Fang 2008; Ng et al. 2005), external stakeholders (i.e. competitive tendering and government) (Kartam et al. 2000) are among important factors affecting safety performance of construction projects. In light of the above, this finding implies that changing and undetailed planning on the technical and environmental aspects of the construction process could increase the occurrence of accidents.

6.4.2 Moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance

The results of this study indicate that the impact of project complexity on Recordable Incident Rate does not hold constant under different levels of psychological, contextual and behavioural resilience (See Table 5.12). The negative impact of project complexity on safety performance becomes less significant when there is a higher level of psychological resilience (See Figure 5.5), contextual resilience (See Figure 5.6) and behavioural resilience (See Figure 5.7); while this impact might be not significant if there were high psychological, contextual and behavioural resilience levels. These results indicate that stronger resilient safety culture in all three dimensions could reduce or eliminate the adverse effect of project complexity on safety performance.

These findings can also be explained by construction accident causation models (Haslam et al. 2005; Suraji et al. 2001), which were discussed earlier in Section 6.4.1. Accordingly, the project technical and environmental complexities fall into the category of distal factors of accident causation, and thus produce the changing and unforeseen safety risks that confront contractors during the construction stage. Having discussed the level of safety risks in the construction industry based on Normal Accident Theory framework, Harvey et al. (2016) affirmed that although construction projects become increasingly tightly coupled and complex, changing and unforeseen safety risks in the construction process are not highly unpredictable and frequent. This is because construction materials are more assembled rather than fabricated, and the work tasks are more structured and routine. Construction processes are therefore visible and can be understood, and thus provide construction organisations more opportunities to detect potential safety issues, make appropriate decisions and act decisively (Harvey et al. 2016). Consequently, although the complex nature of construction projects has a tendency to increase, its associated emerging safety risks seem to be recognised and withstood by contractors and employees during the project construction stage.

In this study, resilient safety culture is characterised by continuous improvements of safety performance and the capability of creating foresight, recognising and anticipating the changing shape of safety risks in the complex sociotechnical systems. Specifically, psychological resilience characterised the psychological capabilities of project's employees to interpret, analyse and formulate responses to regular and irregular safety risks on sites; contextual resilience characterised the contractor's capabilities to provide the backdrop for responses to both identified and changing shapes of safety risks; behavioural resilience characterised the behavioural capabilities of projects' employee to recognise, understand, predict and react towards hazardous situations (See Section 6.2.1 for a detailed discussion). These capabilities, therefore, enable organisations to recognise and respond effectively to the unforeseen and changing shapes of safety risks (Beck & Lengnick-Hall 2016). Thus, in those construction projects with higher resilient safety culture levels, the adverse effects of project complexity on safety performance were more likely to be reduced or eliminated.

These findings imply that increasing project complexity levels did not automatically result in negative safety performance as measured by Incident Rate. The extent to which safety performance of a construction project adversely affected by project complexity, was directly related to the capabilities of its contractors and employees to manage safety risks on sites. Further, an improvement of construction safety performance was more likely to be sustained in those projects with high capabilities to manage safety risks as measured by resilient safety culture levels.

6.5 Summary

In this chapter, the empirical results from the data analysis were discussed in the context of theories and previous studies. The discussions mainly concerned the three dimensions of resilient safety culture, the management strategies for developing resilient safety culture dimensions, and the interactive effects of resilient safety culture and project complexity on safety performance. These findings contribute to knowledge in construction safety management and have implications for practices. Next chapter will conclude this study by presenting a summary of key findings, the contribution of the findings to theory and practice, research limitations and recommendations for future research.

CHAPTER 7 CONCLUSIONS

7.1 Summary

Although traditional safety culture approach has significantly contributed to accident reduction, it may be inadequate for organisations to effectively respond to the changing and unforeseen safety risks associated with the increasingly complex nature of construction projects. In order to achieve a sustained improvement of safety performance in the construction environment, there is a need for developing an organisational safety culture based on a new perspective of safety management, which allows organisations to address not only known risks but also potential new risks. This need was addressed in this study by investigating the development of resilient safety culture of construction projects.

7.2 Key findings

As stated in Chapter 1, this research aims to investigate the development of resilient safety culture in the construction environment with three specific research objectives. This section summarises the key findings addressing the research aim and objectives.

7.2.1 Dimensions of resilient safety culture of construction projects

The first objective of this research is to identify the dimensions of resilient safety culture of construction projects (See Section 1.4). To achieve this objective, model PLS-M1 was formulated, and hypothesis 1 was tested (See Section 4.4.3.1). It is found that psychological resilience, behavioural resilience and contextual resilience constitute a framework for defining and measuring resilient safety culture, and thus support hypothesis 1 (See Section 6.2.1).

7.2.2 Drivers of resilient safety culture

The second objective of this research is to identify the drivers of resilient safety culture (See Section 1.4). To achieve this objective, path analysis was used to examine nine hypothesised relationships specified in model PLS-M1 (See Section 4.4.3.1). Four out of nine hypotheses were supported. Hazard prevention practice has a significant positive impact on contextual and behavioural resilience (hypotheses 3 and 4). Error management practice has a significant positive impact on psychological resilience (hypothesis 5). Mindful organising practice has a significant positive impact on contextual resilience (hypothesis 9).

7.2.3 Interactive effects of resilient safety culture and project complexity on safety performance

The third objective of this research is to examine the interactive effects of resilient safety culture and project complexity on safety performance of construction projects (See Section 1.4). To achieve this objective, PLS-SEM models were formulated (See Section 4.4.3.1), which include: (1) examining the relationship between project complexity dimensions and safety performance (PLS-M2, PLS-M3 and PLS-M4), (2) examining the relationship between resilient safety culture dimensions and safety performance (PLS-M5, PLS-M6, PLS-M7, PLS-M8, PLS-M9 and PLS-M10), and (3) examining the moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance (PLS-M11, PLS-M12 and PLS-M13).

Ten out of twelve hypotheses were supported. Technical and environmental project complexities have negative impacts on safety performance (hypotheses 11 and 13). Resilient safety culture dimensions have positive impacts on safety performance (hypotheses 14, 15 and 16). Psychological resilience has a weaker impact on accident prevention under higher contextual and behavioural resilience levels (hypotheses 17 and 19). The negative impact of project complexity on safety performance becomes less significant when there is a higher level of psychological, contextual and behavioural resilience; while this impact might be not significant if psychological, contextual and behavioural resilience were high (hypotheses 20, 21 and 22).

7.3 Contribution to knowledge

Although numerous studies have been conducted to examine the concept and theoretical models of safety culture, these models failed to address the organisation's capabilities to 'adapt, learn and anticipate' in dealing with safety risks which emerge as the result of the increasingly inherent complexity in technology, work tasks and organisational structures (Bergström et al. 2015; Dekker 2016). This research contributes to knowledge in construction safety management by investigating the development of resilient safety culture in the construction environment. By addressing the three specific research objectives, this study provides the theoretical development and empirical evidence to clarify the concept of resilient safety culture in terms of definition, purpose, value, and assessment and improvement mechanisms in the context of construction projects.

First, this research contributes to the conceptualisation of resilient safety culture. It proposes a measurement method for resilient safety culture of construction projects based on safety culture theory and resilience engineering theory (See Sections 2.3 and 2.4). The possible innovations of this measurement method lie in the following aspects:

- It reflects the definition of resilient safety culture by integrating the resilience engineering processes of safety management into existing safety culture models (See Section 3.2). In addition, it provides empirical evidence to confirm that resilient safety culture is a multidimensional concept comprising: (1) psychological resilience, (2) contextual resilience, and (3) behavioural resilience (See Section 5.3 for details).

- It develops and validates measurable scale items of resilient safety culture. The measurable scale items of resilient safety culture identified in this study offer an understanding of construction safety practices by which resilient safety culture is operationalised in order to manage safety risks in the construction environment (See Section 6.2.1 for a detailed discussion).

Second, this study identifies the drivers of resilient safety culture. It explains how resilient safety culture can be created in a construction organisation by examining the impacts of hazard prevention practice, error management practice and mindful organising practice on resilient safety culture dimensions. It is recognised that psychological resilience could be enhanced by error management practice, contextual resilience could be improved by synergies of hazard prevention practice and mindful organising practice, and behavioural resilience could be promoted by hazard prevention practice (See Section 6.3 for a detailed discussion).

Third, this study clarifies the value of resilient safety culture concept in construction safety management. It is recognised that: (1) the assessment of resilient safety culture could provide a reliable prediction of the frequency of accidents in the construction workplaces (See Section 6.2.2 for a detailed discussion), (2) a stronger resilient safety culture could reduce or eliminate the adverse effect of project complexity on safety performance, and (3) an improvement of construction safety performance was more likely to be sustained in those projects with high resilient safety culture levels (See Section 6.4.2 for a detailed discussion).

7.4 Contribution to practice

This study develops and validates an instrument for measuring resilient safety culture. The findings suggest that measurable scale items of psychological resilience can be used to assess internal psychological abilities of project's employees to interpret, analyse and formulate responses to regular and irregular safety risks on sites. Measurable scale items of contextual resilience can be used to assess the contractor's capabilities to provide the backdrop for responses to identified and changing shapes of safety risks. Measurable scale items of behavioural resilience can be used to assess the behavioural capabilities of projects' employee to recognise, understand, predict and react towards hazardous situations (See Section 6.2 for a detailed discussion). Thus, the measurable scale items of resilient safety culture identified in this study can be used to assess the organisation's capabilities to manage safety risks in a specific construction project. The proposed measurement instrument of resilient safety culture may enable construction organisations to understand their strengths and weaknesses pertaining to safety and risk management in place. As a result, safety management strategies can be allocated appropriately in their portfolio.

The drivers of resilient safety culture identified in this study can be used for improving and maintaining the state of workplace safety on construction sites. Firstly, the findings of this study suggest that error management practice can enhance the project's employees to extrapolate accident scenarios (See Section 6.3.1 for a detailed discussion). It is recommended for project's employees to be more involved in error management practice, thereby being less engaged in unsafe behaviours and accidents (See Table 5.8 for detailed safety strategies of error management practice). Secondly, the findings of this study suggest that hazard prevention practice and mindful organising practice can improve the capabilities of construction organisations to provide the backdrop, which facilitates effective responses to safety risks (See Section 6.3.2 for a detailed discussion). Accordingly, contractors may implement the synergies of hazard prevention practice and mindful organising practice for improving their contextual conditions of construction projects (See Table 5.8 for detailed safety strategies of hazard prevention practice and mindful organising practice). Lastly, the findings of this study suggest that hazard prevention practice can promote the competencies and patterns of behaviours for responses to safety risks (See Section 6.3.3 for a detailed discussion). It is recommended that hazard prevention practice should be fostered for promoting behavioural safety of project's employees in place (See Table 5.8 for detailed safety strategies of hazard prevention practice).

The findings of interactive effects between resilient safety culture dimensions on safety performance recognise the settings from which risk tolerance of construction workers can emanate in the construction environment (See Section 6.2.2 for a detailed discussion). As recommended by Harvey et al. (2016), developing 'chronic unease' (e.g. contextualising others' accidents) or safety imagination (e.g. imagining ways things could fail) in those settings may help reduce risk tolerance.

The findings of the relationship between project complexity dimensions on safety performance imply that changing and undetailed planning on the technical and environmental aspects of the construction process can increase the occurrence of accidents (See Section 6.4.1 for a detailed discussion). It is recommended for construction organisations to better anticipate the potential changes and uncertainties on the aforementioned aspects (See Table 5.8 for details on technical and environmental project complexities) and provide more stabilised and detailed planning in the pre-construction stage of project procurement.

In an examination of the moderating effects of resilient safety culture dimensions on the relationship between project complexity and safety performance, the findings imply that increasing project complexity levels do not automatically result in negative safety performance as measured by Recordable Incident Rate. The extent to which safety performance of a construction project adversely affected by project complexity, is directly related to the capabilities of its contractors and employees to manage safety risks on sites. Further, an improvement of construction safety performance is more likely to be sustained in those projects with high capabilities to manage safety risks as measured by resilient safety culture levels (See Section 6.4.2 for a detailed discussion). It is suggested that construction organisations may develop better capabilities to manage safety risks based on safety strategies identified in this study. Such capabilities would enable construction organisations to achieve a sustained improvement of safety performance regardless of the changing complexity levels of construction projects.

7.5 Limitations of the study

The limitations of this research are now discussed.

The first limitation concerns the triangulation of observers. The findings of this study were reached using self-reported response data by project managers. It is acknowledged that it is not likely to completely rule out the limitations of a single source data (e.g., subjectivity, a biased view on an issue, unintentional errors). In this study, the impact of this limitation was minimised by (1) a careful selection of appropriate respondents (See Section 4.3.3), (2) respondents were encouraged to consult other project management positions when completing the questionnaire, (3) data collection procedure ensures the voluntary nature of participation in the questionnaire, anonymity of respondents and confidentiality of respondents' responses in order to prevent lies and deceptions (See Section 4.3.8), (4) assuring the comprehensiveness and clarity of the research instrument in terms of instruction, statements and questions in order to avoid unintended error made by respondents when answering the questionnaire (See Section 4.3.4), (5) respondents were encouraged to review and revise their recorded responses (See Section 4.3.5), and (6) a careful check on the completed questionnaire and data problems carried out by the researcher (See Section 4.4.3.2). As a result, the extensive working experience, high education level of the respondents, their position as a project manager and a high consultation rate (See Section 4.3.10) could enhance the quality and reliability of collected data. In addition, the validity of the research findings can be assured by (1) confirming reliability and validity of constructs specified in this study before performing any substantive analyses (See Section 5.3), and (2) interpreting the statistical results within an extensive review of the pertinent literature (See Chapter 6).

The second limitation concerns the selection of research methodological approach. The findings of this research were achieved based upon the adoption of a quantitative approach and a survey research design (See Sections 4.2.2 and 4.2.3). As a result, the quantitative data were collected to establish relationships between variables. Nonetheless, quantitative data are not efficient to explain the relationships among variables. It is acknowledged that the relationship among variables could be explained clearly with qualitative data (e.g. interviews and observation). This limitation leads to the future research possibilities discussed in Section 7.6.

The third limitation is that the response rate and the sample size were not as large. The data were collected from 78 building construction projects, representing a response rate of 26.2%. The relatively low response rate may impact on the representativeness of the project samples and the validity of the results (See Section 4.3.5.2). In this study, this impact was minimised by: (1) taking into account the expected response rate (15%) when determining a minimum sample for data collection and (2) applying the principles of random sampling as the sampling strategy (See Section 4.3.7). In addition, as the PLS-SEM approach and bootstrapping technique were applied, analyses show that a small sample size did not affect the validity of the results (See Section 4.4.2).

The last limitation concerns the generalisability of the findings. The findings were reached based on the data collected from building projects located in the five largest cities in Vietnam. Thus, the findings of this research should be interpreted in the context of Vietnamese construction industry. The profile of the projects suggests that whereas the data were obtained from various locations and across the whole range of building projects, the focus of attention is given to projects, which are civil buildings (71.8%) and located in Ho Chi Minh City (80.8%) (See Section 4.3.10). The findings are based upon this set of data and thus cannot be automatically used in other countries and for other types of projects without additional data collection.

7.6 Recommendations for future research

As highlighted in Section 7.5, there are several areas of interest which can be further explored in future research.

As discussed in the first limitation, there may be problems with a single source of data such as subjectivity, a biased view on an issue and unintentional errors due to the use of self-reported response by project managers in this study. Future research could overcome this limitation by the use of multiple respondents for each construction project. For example, three respondents (i.e. project manager, site manager and safety manager) may be requested to provide information pertaining to a construction project. Multiple observers may offer a chance to cross-verify the accuracy of the data obtained from the respondents, thereby boosting the validity of the research.

As mentioned in the second limitation, collected quantitative data were effectively employed to examine the associations between variables in this study. Nonetheless, the use of quantitative data alone failed to explain the causal mechanism among variables. Future research may be carried out using both quantitative and qualitative data. For example, interviews or discussions can be used to capture the psychological aspect of resilient safety culture, observations can be employed to examine the behavioural aspect of resilient safety culture, and surveys can be adopted to assess the contextual aspect of resilient safety culture. Accordingly, the combination of quantitative and qualitative data could discover the meanings behind the relationship between the variables, which may include: (1) to explain how three dimensions of resilient safety culture can be improved with the better hazard prevention practice, error management practice and mindful organising practice, (2) to explain why risk tolerance of construction workers occur in those building project with better contextual and behavioural resilience, and (3) to explain the cases in which the negative impact of project complexity on safety performance becomes not significant when the resilient safety culture level is very high. Thus, collecting diverse types of data can boost the validity of the relationship between the variables, thereby offering a better understanding of a research problem than either qualitative or quantitative data alone.

The last limitation mentioned that the data were collected mainly from Ho Chi Minh City (80.8%) and on the civil sector (71.8%). Future studies may be conducted to investigate the development of resilient safety culture in other types of projects and/or in other regions. This may help to explore the differences and similarities among various types and locations of construction projects on: (1) the measurable scale items to assess resilient safety culture, (2) the impacts of hazard prevention practices, error management practice on resilient safety culture dimensions, and (3) interactive effects of resilient safety culture and project complexity on safety performance of construction projects. In such studies, additional sets of data should also be collected.

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APPENDIX A LETTER OF HUMAN RESEARCH ETHICS APPROVAL

Locked Bag 1797

Penrith NSW 2751 Australia

Research Engagement, Development and Innovation (REDI)

REDI Reference: H12023

Risk Rating: Low 2 – HREC

HUMAN RESEARCH ETHICS COMMITTEE

16 March 2017

Doctor Yingbin Feng

School of Computing, Engineering and Mathematics

Dear Yingbin,

I wish to formally advise you that the Human Research Ethics Committee has approved your research proposal H12023 "Developing Resilient Safety Culture for Construction Projects in Vietnam", until 9 July 2018 with the provision of a progress report annually if over 12 months and a final report on completion.

In providing this approval the HREC determined that the proposal meets the requirements of the National Statement on Ethical Conduct in Human Research.

This protocol covers the following researchers:

Yingbin Feng, Sean Jin, Tri Trinh

Conditions of Approval

1. A progress report will be due annually on the anniversary of the approval date.
2. A final report will be due at the expiration of the approval period.
3. Any amendments to the project must be approved by the Human Research Ethics Committee prior to being implemented. Amendments must be requested using the HREC Amendment Request Form: https://www.westernsydney.edu.au/__data/assets/word_doc/0012/1096995/FORM_Amendment_Request.docx
4. Any serious or unexpected adverse events on participants must be reported to the Human Research Ethics Committee via the Human Ethics Officer as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the Committee as a matter of priority
6. Consent forms are to be retained within the archives of the School or Research Institute and made available to the Committee upon request.
7. Project specific conditions:

There are no specific conditions applicable.

Please quote the registration number and title as indicated above in the subject line on all future correspondence related to this project. All correspondence should be sent to the e-mail address humanethics@westernsydney.edu.au as this e-mail address is closely monitored.

Yours sincerely

Professor Elizabeth Deane

Presiding Member,

Western Sydney University Human Research Ethics Committee

APPENDIX B INVITATION LETTER

Dear Sir/Madam,

Nowadays, the Vietnamese construction industry has been confronted with the fact that building projects are increasingly complex. The increasing complexity of building projects could influence negatively on safety performance (e.g. number of injuries and accidents increases) in construction workplaces. In addition, as the level of project complexity changes among various building projects, the safety performance (number of injuries and accidents) has fluctuated accordingly. Therefore, we are conducting a study to develop resilient safety culture, which can adapt to the various complexity levels of building projects in Vietnam. We expect that, even though a construction company participates in various projects with different levels of complexity, once they adopt resilient safety culture we proposed, their safety performance will be improved and kept in stable.

In this regard, you are invited participate in this research study being conducted by Mr Minh Tri Trinh, Doctor of Philosophy Candidate at Western Sydney University under the supervision of Dr Yingbin Feng and Dr Xiaohua Jin. The participation includes completing an online survey based on the safety practices, the complexity level and archival records related to your completed building project, namely…………………………………………………………………......

It takes approximately 30 minutes to complete the survey and your participation in the survey is highly appreciated. Please be informed that all the information provided in this questionnaire will be treated with strict confidentiality and used solely for the purpose of research. In addition, since the survey is completed online, your identity will remain anonymous throughout the research.

To complete the survey, please follow the steps given below:

Step 1: Click on the link below in order to access the survey website:

[this line is given to the link access to an online survey]

Step 2: Read and provide your agreement in the participant information sheet in order to access the participant consent form.

Step 3: Read and provide your consent by choosing 'I agree to participate in this study' in order to access the questionnaire.

Step 4: Answer all questions in the questionnaire.

Please contact Mr Minh Tri Trinh should you wish to discuss the research further before deciding whether or not to participate.

Yours faithfully,

PhD Candidate

Minh Tri TRINH

School of Computing, Engineering and Mathematics

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APPENDIX C PARTICIPANT INFORMATION SHEET

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WESTERN SYDNEY UNIVERSITY

Project Title: Developing Resilient Safety Culture for Construction Projects in Vietnam

Project Summary:

Nowadays, Vietnamese construction industry has been confronted with the fact that building projects are increasingly complex. The increasing complexity of building projects could influence negatively on safety performance (e.g. number of injuries and accidents increases) in construction workplaces. In addition, as the level of project complexity changes among various building projects, the safety performance (number of injuries and accidents) has fluctuated accordingly. Therefore, we are conducting a study to develop resilient safety culture, which can adapt to the various complexity levels of building projects in

Vietnam. We expect that, even though a construction company participates in various projects with different levels of complexity, once they adopt a resilience safety culture we proposed, their safety performance will be improved and kept in stable.

In this regard, you are invited to participate in this research study being conducted by Mr Minh Tri Trinh, Doctor of Philosophy Candidate at Western Sydney University under the supervision of Dr Yingbin Feng and Dr Xiaohua Jin.

How is the study being paid for?

The study is being sponsored by the Joint scholarship by Vietnamese Ministry of Education and Training, and Western Sydney University.

What will I be asked to do?

You are invited to complete an online survey based on the safety practices, the complexity level and archival records related to your completed building project that its name was indicated in the invitation email.

To complete the survey, please follow two steps below:

1. Provide your consent in order to be able to access the questionnaire.
2. Answer all questions in the questionnaire. You are encouraged to consult other construction project management staff of your building project (e.g. site manager, safety officers, safety manager) while answering the questions.

How much of my time will I need to give?

Approximately 30 minutes.

What benefits will I, and/or the broader community, receive for participating?

Safety is vital because of its impact on the wellbeing and lives of people. The reputation of a construction organisation is at stake when does not implement proper safety measures to protect the safety and well-being of its employees. This research will provide building projects with resilient safety culture, as an approach to improve safety performance in order to reduce injuries and accidents in construction workplaces. This research will also provide you with opportunities to reflect on your safety practices which were implemented on your building project to improve future safety performance.

Will the study involve any discomfort or risk for me? If so, what will you do to rectify it?

This study may involve some minor discomforts since the questions require recollection of unfavourable events (injuries, accidents) which may cause personal distress. Therefore, you are encouraged to contact Ucare Vietnam (Centre for Community Health Support) through hotline 1900 6180 or email tuvan@ucare.vn for any psychological support. You are also encouraged to contact the researcher for any further instructions.

How do you intend to publish the results?

The findings of the research will be published as Thesis and in academic journals.

Can I withdraw from the study?

You can withdraw from the study without giving a reason.

Data storage

There are a number of government initiatives in place to centrally store research data and to make it available for further research. For more information, see http://www.ands.org.au/

and http://www.rdsi.uq.edu.au/about. Regardless of whether the information you supply or about you is stored centrally or not, it will be stored securely and it will be de-identified before it is made available to any other researcher.

What if I require further information?

Please contact Mr Minh Tri Trinh should you wish to discuss the research further before deciding whether or not to participate.

Mr Minh Tri Trinh, PhD Candidate

Ph:(+84)1685749044

Email: trimitri0605@gmail.com or m.trinh@westernsydney.edu.au

What if I have a complaint?

This study has been approved by the Western Sydney University Human Research Ethics Committee. The Approval number is H12023.

If you have any complaints or reservations about the ethical conduct of this research, you may contact the Ethics Committee through the Research, Engagement, Development and Innovation office on Tel +61 24736 0229 Fax +61 2 4736 0905 or email humanethics@westernsydney.edu.au.

Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

If you agree to participate in this study, you may be asked to sign the Participant Consent Form.

APPENDIX D PARTICIPANT CONSENT FORM

Human Research Ethics Committee
Office of Deputy Vice Chancellor and
Vice President, Research and Development

WESTERN SYDNEY UNIVERSITY

This is a project-specific consent form. It restricts the use of the data collected to the named project by the named investigators.

Project Title: Developing Resilient Safety Culture for Construction Projects in Vietnam

I consent to participate in the research project titled Developing a Resilience Safety Culture for Building Projects in Vietnam.

I acknowledge that:

I have read the participant information sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

I consent to complete and return the questionnaire issued by the researcher.

I understand that my involvement is confidential and that the information gained during the study may be published, but no information about me will be used in any way that reveals my identity.

I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher now or in the future.

☐ I agree to participate in this study ☐ I do not agree to participate in this study

APPENDIX E QUESTIONNAIRE

Western Sydney University

School of Computing, Engineering and Mathematics

QUESTIONNAIRE ON RESILIENT SAFETY CULTURE OF BUILDING PROJECTS

Please answer the questions based on your completed building project that we mentioned in our invitation email.

A. General Information

I. Project Information

1. Location: ☐ Hanoi ☐ Haiphong ☐ Hochiminh ☐ Danang ☐ Cantho

2. Duration: ☐ < 12 months ☐ 12 - 24 months ☐ 25 - 36 months ☐ > 36 months

3. Year of completion:

4. Total man-days worked for this project:

5. Type of project: ☐ Civil building ☐ Industrial building

6. Project grade: ☐ IV ☐ III ☐ II ☐ I ☐ Extraordinary

7. Contract size: ☐ C ☐ B ☐ A ☐ National important project

II. Personal Information

1. Educational background: ☐ College degree and below ☐ Bachelor degree
☐ Master degree ☐ Doctor degree

2. Your work experience in the construction industry:

☐ up to 5 years ☐ 6 - 10 years ☐ 11 - 15 years ☐ 16 - 20 years ☐ > 20 years

B. Safety performance

Based on your completed building project, please answer the following questions.

1. Number of fatal deceased workers:

2. Number of injured workers (permanently disabled):

3. Number of injured workers (temporarily disabled with three or more days lost):

4. Number of injured workers (minor injuries with less than 3 days lost):

C. Project complexity

Based on your completed building project, please rate the level of your agreement on the actual conditions during the construction phase of the project by using the following scale:

1 – Strongly disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly agree

Statements	1	2	3	4	5
Technical aspect					
(1) The project was always under the simultaneous pressures from the diversity of goals (health and safety, quality, cost, time and cost, etc.).	☐	☐	☐	☐	☐
(2) Each goal of the project was not always clear amongst contractors.	☐	☐	☐	☐	☐
(3) The project goals were changed very often during the construction phase.	☐	☐	☐	☐	☐

Statements	1	2	3	4	5
(4) The project involved a variety of work tasks.	☐	☐	☐	☐	☐
(5) All work tasks of the project were highly interdependent.	☐	☐	☐	☐	☐
(6) The work tasks for the project were changed very often (type, requirement, volume).	☐	☐	☐	☐	☐
(7) The project involved a variety of construction methods (i.e. construction techniques and processes) employed.	☐	☐	☐	☐	☐
(8) The construction methods (i.e. construction techniques and processes) required for the project were not always clear amongst contractors.	☐	☐	☐	☐	☐
(9) The resources (materials, personnel) and skills appropriate for construction methods were not always available.	☐	☐	☐	☐	☐
(10) The project involved a variety of technology employed.	☐	☐	☐	☐	☐
(11) The technological processes were highly interdependent (i.e. the later technological process relied on the completion of the previous technological process).	☐	☐	☐	☐	☐
(12) There were high safety risks related to technologies employed.	☐	☐	☐	☐	☐
(13) The project involved new technologies (e.g. technology which was new in the world, not only new to the contractors).	☐	☐	☐	☐	☐
(14) Project information (construction methods, technologies employed, requirements, material…) for execution was not always clear among contractors.	☐	☐	☐	☐	☐
(15) There were insufficient obtaining, processing and transferring of project information between contractors.	☐	☐	☐	☐	☐
(16) Project information obtained, processed and transferred between contractors via different tools (email, meeting, telephone, mail) is always inconsistent.	☐	☐	☐	☐	☐
Organisational aspect					
(17) There were many organisational structure hierarchies involved in the project.	☐	☐	☐	☐	☐
(18) There were many contractors (main contractors and subcontractors) involved in the project.	☐	☐	☐	☐	☐
(19) Contractors for the project were highly interdependent.	☐	☐	☐	☐	☐
(20) The contractors had insufficient experience and capacity with the construction methods and technologies employed.	☐	☐	☐	☐	☐
(21) There were often replacements of contractors during the construction phase of the project.	☐	☐	☐	☐	☐
(22) The level of trust within contractors was low.	☐	☐	☐	☐	☐
(23) There was a low level of cooperation between contractors.	☐	☐	☐	☐	☐

Statements	1	2	3	4	5
(24) There were cultural differences between contractors.	☐	☐	☐	☐	☐
(25) The project involved multiple participating countries.	☐	☐	☐	☐	☐
Environmental aspect					
(26) There were often changes in policy and regulation during the construction phase.	☐	☐	☐	☐	☐
(27) The economic environment of the project was always unstable (e.g. exchange rates, raw material pricing) during the construction phase.	☐	☐	☐	☐	☐
(28) The local weather conditions of the project were always unstable.	☐	☐	☐	☐	☐
(29) The project was located in complicated geological conditions.	☐	☐	☐	☐	☐
(30) The location of the project was close to neighbouring structures.	☐	☐	☐	☐	☐
(31) The project was highly influenced by external stakeholders (i.e. governments, suppliers, communities).	☐	☐	☐	☐	☐

D. Resilient safety culture

Based on your completed building project, please rate the level of your agreement on the following statements by using the following scale:

1 – Strongly disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly agree

Statements	1	2	3	4	5
Psychological aspect					
(1) Workers were concerned with working conditions and appropriate preventive measures associated with their work tasks.	☐	☐	☐	☐	☐
(2) Everyone on site was aware of the negative consequences to their health and safety resulting from non-compliance with health and safety rules.	☐	☐	☐	☐	☐
(3) Everyone on site acknowledged that unexpected hazardous events (i.e. unobserved hazardous conditions, unintentional unsafe behaviours) could occur anytime and anywhere.	☐	☐	☐	☐	☐
(4) Everyone on site was mindful of the project hazards even when they had been recognised and controlled with preventive measures.	☐	☐	☐	☐	☐
(5) Everyone on site had sufficient knowledge to identify potential hazards regarding their work tasks by themselves.	☐	☐	☐	☐	☐
(6) In an effort to conduct a work task appropriately and safely, workers in a workgroup always knew exactly what	☐	☐	☐	☐	☐

Statements	1	2	3	4	5
their co-workers were doing.					
(7) Everyone on site was aware of major worries and concerns about health and safety issues.	☐	☐	☐	☐	☐
(8) Workers on site had sufficient knowledge to conduct the work tasks appropriately and safely.	☐	☐	☐	☐	☐
(9) Workers had a tendency to refuse to work when hazards and safety risks related to their work task were not clear.	☐	☐	☐	☐	☐
(10) Workers had a tendency to refuse to work when appropriate preventive measures (PPE, hazard control programs) had not been provided.	☐	☐	☐	☐	☐
(11) Workers had a tendency to refuse to work when it was not clear on how to execute the work task.	☐	☐	☐	☐	☐
(12) Everyone on site was aware of the importance of discussion and exchange of views about safety risks.	☐	☐	☐	☐	☐
(13) Safety management and supervisors knew how to encourage site employees to share their safety experiences.	☐	☐	☐	☐	☐
(14) Everyone on site considered past hazardous events as useful sources to improve safety performance on site.	☐	☐	☐	☐	☐
Contextual aspect					
(1) There was sufficient analysis of potential hazards and their risks of accidents on an ongoing basis.	☐	☐	☐	☐	☐
(2) The resources needed to achieve health and safety targets associated with potential project hazards were assessed.	☐	☐	☐	☐	☐
(3) Health and safety issues (i.e. qualifications, injury records) related to subcontractors and their employees were clearly identified before tendering.	☐	☐	☐	☐	☐
(4) Potential changes in working conditions that might present a risk of accidents were assessed.	☐	☐	☐	☐	☐
(5) Observed hazards were subject to maintain at an acceptable level of risk.	☐	☐	☐	☐	☐
(6) Workers had access to up-to-date information about safety risks to conduct work task safety if necessary every time before commencing the work tasks.	☐	☐	☐	☐	☐
(7) Any changes in working conditions were monitored on an ongoing basis.	☐	☐	☐	☐	☐
(8) Any risky behaviours of workers were noticed.	☐	☐	☐	☐	☐
(9) The project was provided with sufficient resources (financial, technical, human) appropriate to achieve health and safety targets related to observed hazards.	☐	☐	☐	☐	☐
(10) All safety instructions/procedures/rules on site were appropriate, practical, and easy to follow.	☐	☐	☐	☐	☐
(11) The appropriate preventive measures were immediately provided following any changes to the working conditions (i.e. new hazards identified,	☐	☐	☐	☐	☐

Statements	1	2	3	4	5
hazardous events occurred).					
(12) The resources (facilities, instructions, etc.) for dealing with emergency situations were accessible to everyone on site.	☐	☐	☐	☐	☐
(13) Feedback or revisions on health and safety issues were collected, collated and distributed effectively on site.	☐	☐	☐	☐	☐
(14) Past hazardous events (i.e. hazardous conditions, risky behaviours) were continually documented and considered in developing accident preventive measures in the future.	☐	☐	☐	☐	☐
Behavioural aspect					
(1) Site management and supervisors actively conducted safety meetings or discussions to expect potential health and safety issues.	☐	☐	☐	☐	☐
(2) Site management and supervisors appreciated when workers expressed their intuitive feelings about potential hazards on site.	☐	☐	☐	☐	☐
(3) Site management and supervisors conducted sufficient site inspections.	☐	☐	☐	☐	☐
(4) Everyone on site always reported hazardous events (i.e. observed hazardous conditions, risky behaviours) when encountered.	☐	☐	☐	☐	☐
(5) Workers on site actively sought for comprehensive and complete information of the hazards related to their work tasks.	☐	☐	☐	☐	☐
(6) Site management and supervisors paid attention to not sending people to work sites which involved physical and mental harm.	☐	☐	☐	☐	☐
(7) Site management and supervisors acted decisively when encountering health and safety issues.	☐	☐	☐	☐	☐
(8) Workers always worked safely even when they were not being supervised.	☐	☐	☐	☐	☐
(9) Everyone on site reacted quickly to the cases of emergency situations (i.e. injury, damage to properties, incident).	☐	☐	☐	☐	☐
(10) Site management and supervisors listened to feedback from workers.	☐	☐	☐	☐	☐
(11) Workers talked to site management and supervisors about hazardous events without any concern, even if they had contributed to the occurrence of such events.	☐	☐	☐	☐	☐
(12) After an incident/accident at work, an investigation was taken to draw conclusions for the future.	☐	☐	☐	☐	☐
(13) In incident/accident investigations, site management and supervisors aimed to prevent the future similar accidents rather than blame their workers on such events.	☐	☐	☐	☐	☐

E. Hazard prevention practice

Based on your completed building project, please rate the level of your agreement on the following statements by using the following scale:

1 – Strongly disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly agree

Statements	1	2	3	4	5
Safety Policy					
(1) Safety policy set objectives for health and safety performance within the workplace.	☐	☐	☐	☐	☐
(2) Safety policy clearly stated the importance of health and safety requirements as equally important as any other objectives.	☐	☐	☐	☐	☐
(3) Safety policy was available to all workers reflecting management's concern for safety, principles of action and objectives to achieve.	☐	☐	☐	☐	☐
Site Safety Organisation					
(4) Everyone on site was clearly assigned their roles and responsibilities in order to eliminate or reduce the risks of hazards.	☐	☐	☐	☐	☐
(5) Competent safety officers and safety supervisors were sufficient for the project.	☐	☐	☐	☐	☐
(6) Detailed site-specific safety plans were submitted by subcontractors prior to execution of work tasks.	☐	☐	☐	☐	☐
(7) There were arrangements to collect and review feedback on health and safety issues.	☐	☐	☐	☐	☐
Risk Assessment and Hazard Analysis					
(8) Workplace and task hazards in the project were clearly identified prior to execution.	☐	☐	☐	☐	☐
(9) The risks of harm from project hazards were evaluated prior to execution.	☐	☐	☐	☐	☐
(10) Appropriate preventive measures for identified risks were designed prior to execution of the project.	☐	☐	☐	☐	☐
Safety Inspection					
(11) Hazardous conditions related to work tasks were examined at regular intervals.	☐	☐	☐	☐	☐
(12) Safety activities and safety performance of workers were regularly supervised.	☐	☐	☐	☐	☐
(13) The findings of inspections were analysed.	☐	☐	☐	☐	☐
(14) Appropriate actions were taken after inspections.	☐	☐	☐	☐	☐
Hazard Control Program					
(15) Appropriate preventive measures for identified hazards were implemented.	☐	☐	☐	☐	☐
(16) Appropriate plant, machine & equipment for each work task were provided.	☐	☐	☐	☐	☐
(17) Plant, machine & equipment were inspected and maintained regularly.	☐	☐	☐	☐	☐

Statements	1	2	3	4	5
(18) Appropriate procedures were conducted to monitor the proper use of plant, machine & equipment.	☐	☐	☐	☐	☐
Personal Protection Program					
(19) The provision of personal protective equipment (PPE) complied with a safety plan.	☐	☐	☐	☐	☐
(20) Appropriate procedures were implemented for supplying PPE to everyone on site.	☐	☐	☐	☐	☐
(21) PPEs were inspected, maintained at regular intervals, and replaced (if necessary).	☐	☐	☐	☐	☐
(22) Appropriate procedures were conducted to monitor the proper use of PPE.	☐	☐	☐	☐	☐
Safety Meeting					
(23) Toolbox talks were planned and delivered to everyone on site.	☐	☐	☐	☐	☐
(24) Safety discussions in workgroups were organised at regular intervals.	☐	☐	☐	☐	☐
(25) Safety awareness activities were organised at regular intervals.	☐	☐	☐	☐	☐
(26) Safety committee meetings were organised at regular intervals.	☐	☐	☐	☐	☐
Safety Training					
(27) Training courses were regularly conducted and followed the safety legislation.	☐	☐	☐	☐	☐
(28) All workers had received basic general safety training.	☐	☐	☐	☐	☐
(29) All workers had received site-specific safety training.	☐	☐	☐	☐	☐
(30) All workers had received toolbox training related to their work tasks.	☐	☐	☐	☐	☐
Safety Promotion					
(31) Positive impact on safety was recognised and rewarded.	☐	☐	☐	☐	☐
(32) Negative impact on safety was recognised and punished.	☐	☐	☐	☐	☐
(33) Safety warning signs, posters and bulletin boards were provided sufficiently and clearly visible on site.	☐	☐	☐	☐	☐
Management Support					
(34) Site management and supervisors behaved as safety models for all workers.	☐	☐	☐	☐	☐
(35) Site management and supervisors praised workers for working safely.	☐	☐	☐	☐	☐
(36) Site management and supervisors challenged unsafe behaviours or attitudes at any level when encountered.	☐	☐	☐	☐	☐
(37) Site management and supervisors made site visits and spoke directly to workers about safety issues.	☐	☐	☐	☐	☐

F. Mindful organising practice

Based on your completed building project, please rate the level of your agreement on the following statements by using the following scale:

1 – Strongly disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly agree

Statements	1	2	3	4	5
Preoccupation with failure					
(1) Minor project hazards and their risks of harm were given as much attention as major project hazards.	☐	☐	☐	☐	☐
(2) There was a sense of complacency about hazard control program implemented on site.	☐	☐	☐	☐	☐
(3) Workers always spent time identifying safety activities required for each work task prior to execution in order not to misconduct.	☐	☐	☐	☐	☐
(4) When a specific work task or worksite was taken over by new workers, there was a discussion on what to look out for.	☐	☐	☐	☐	☐
Reluctance to simplify interpretations					
(5) The site management sought various viewpoints on how to improve health and safety on site.	☐	☐	☐	☐	☐
(6) Everyone on site felt free to bring up their health and safety issues.	☐	☐	☐	☐	☐
(7) There were always alternative safety plans for each work task.	☐	☐	☐	☐	☐
(8) When workers confronted with unfamiliar safety instructions/procedures/rules and working conditions, they discussed with others.	☐	☐	☐	☐	☐
Sensitivity to operations					
(9) There was always someone who was in charge of paying attention to and recording what was happening on site.	☐	☐	☐	☐	☐
(10) Site management and supervisors regularly monitored the workloads and took actions to reduce them when they became excessive.	☐	☐	☐	☐	☐
(11) Before commencing their jobs, workers had been delivered project and work task inductions in order to be familiar with the working conditions.	☐	☐	☐	☐	☐
(12) Everyone interacted often enough to build a clear picture of what was happening on site.	☐	☐	☐	☐	☐
Commitment to resilience					
(13) Workers had received training on how to act in emergency situations (i.e. injury, damage to properties, incident).	☐	☐	☐	☐	☐
(14) The project was provided with facilities and procedures response to emergency situations.	☐	☐	☐	☐	☐
(15) There was a concern with building employees' competence in emergency situations on site.	☐	☐	☐	☐	☐

Statements	1	2	3	4	5
(16) After an emergency situation, everyone on site sought for the weaknesses of their safety activities at work, and what could be learned from them.	☐	☐	☐	☐	☐
Deference to expertise					
(17) In regarding important health and safety issues, site management delegated an authority to make final decisions to the safety manager (or who was most qualified for health and safety).	☐	☐	☐	☐	☐
(18) When a health and safety issue out of the ordinary occurred, everyone site knew who had the expertise to respond.	☐	☐	☐	☐	☐
(19) It was easy to obtain expert assistance when a health and safety issue came up that no one on site knew how to handle.	☐	☐	☐	☐	☐

G. Error management practice

Errors are **unintentional unsafe behaviours of workers** in the workplace. Based on your completed building project, please rate the level of your agreement on the following statements by using the following scale:

1 – Strongly disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly agree

Statements	1	2	3	4	5
Learning from errors					
(1) Workers had received training on how to deal with errors on site.	☐	☐	☐	☐	☐
(2) Errors were used as useful information to improve safety performance on site.	☐	☐	☐	☐	☐
(3) Workers readily accepted feedback about how to avoid and/or correct errors.	☐	☐	☐	☐	☐
Error competence					
(4) When errors were made, workers on site did not let go of the final goal of their work tasks.	☐	☐	☐	☐	☐
(5) When an error was made, it was corrected right away.	☐	☐	☐	☐	☐
(6) When an error had occurred, workers on site knew how to correct it.	☐	☐	☐	☐	☐
Thinking about errors					
(7) After an error, everyone on site thought through how to correct it.	☐	☐	☐	☐	☐
(8) After an error had occurred, it was analysed thoroughly.	☐	☐	☐	☐	☐
(9) When working on site, people were mindful of how an error could have been avoided.	☐	☐	☐	☐	☐

Statements	1	2	3	4	5
Error communication					
(10) When workers on site made errors, they asked others for advice on how to continue.	☐	☐	☐	☐	☐
(11) When workers were unable to correct an error by themselves, they turned to their co-workers.	☐	☐	☐	☐	☐
(12) If workers were unable to continue their work after an error, they relied on others.	☐	☐	☐	☐	☐
(13) Everyone on site shared errors with their co-workers so that the same mistakes would not occur.	☐	☐	☐	☐	☐

H. Consultation for the completion of response

Please tick as many of the following 'types of project positions' whom you consulted with when completing this questionnaire. If none apply, please indicate this below:

☐ Site manager ☐ Site safety manager ☐ Site supervisor

☐ Other, please specify:.............................. ☐ Site safety officer

☐ None

Thank you for your kind assistance!