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Stakeholder Attributes and Approaches in Natural Disaster Risk Management in the Built Environment: the Case of Flood Risk Management in Transport Infrastructure

by

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Abstract

The increasing number of natural disasters has demonstrated the importance of natural disaster risk management. Flooding is the most common natural disaster of all natural disasters. There is little consensus regarding the role of stakeholder attributes in reducing flood damage and explaining stakeholder proactive and reactive approaches. Local Councils are important stakeholders in flood risk management in transport infrastructure across New South Wales, Australia. Hence, the characteristics of floods, Local Councils' stakeholder attributes, and the exposure and vulnerability of the socio-economic and transport infrastructure were contextualised to examine flood damage and Local Councils' proactive and reactive approaches. This study examines three dominant Local Councils' stakeholder attributes of power, legitimacy and urgency by focusing on flood damage and Local Councils' proactive and reactive approaches to improve flood risk management in transport infrastructure. Data was collected from historical archive databases and a structured questionnaire survey involving Local Councils in New South Wales, Australia that covered the time period from 1992 to 2012. This data was analysed using multi-attribute decision-making and structural equation modelling with partial least square estimation approaches.

The results show that the exposure and vulnerability of Australian states and territories to flood damage depend on both socio-economic and built environment conditions simultaneously. The structural equation model shows that the greater the flood characteristics such as frequency, severity and type, the greater the flood damage. The exposure and vulnerability of socio-economic and transport infrastructure of a Local Council have mediating effects on the direct relationship between their stakeholder attributes and flood damage. Proactive and reactive approaches by Local Councils are highly affected by stakeholder attributes in flood risk management.

The developed stakeholder disaster response index shows that Local Councils have practised more reactive approaches than proactive approaches to flood risk management in transport infrastructure. Policy makers might use the stakeholder disaster response index through continuous assessment of proactive and reactive approaches by Local Councils to achieve a high level of flood risk management.

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List of Abbreviations

ABS	Australian Bureau of Statistics
BoM	Bureau of Meteorology
FMA	Floodplain Management Association
FRM	Flood Risk Management
GDP	Gross Domestic Product
GRP	Gross Regional Product
IPMA	Importance Performance Matrix Analysis
MADM	Multi-Attribute Decision-Making
MDA	Multivariate Data Analysis
NDM	Natural Disaster Management
NDRM	Natural Disaster Risk Management
NDRR	Natural Disaster Risk Reduction
NSW	New South Wales
PLS	Partial Least Square
RMS	Roads and Maritime Services
SDRI	Stakeholder Disaster Response Index
SEM	Structural Equation Modelling
TOPSIS	Technique for the Order Preference by Similarity to Ideal Solution

CHAPTER

1

Introduction

1.1 Background

The built environment is subject to risks associated with both natural and technological disasters (Haigh and Amaratunga, 2010, Bosher, 2008, Alexander, 1993). Natural disasters refer to events that have natural causes and result in ten or more mortalities, affect 100 or more people, or result in a call for international assistance or the declaration of a state of emergency (Guha-sapir et al., 2010). Technological disasters, on the other hand, involve breakdown in human-made systems including industrial accidents, such as chemical spills, nuclear explosions and fire, and transport accidents by air, rail, road or water (Guha-sapir et al., 2010, Baum et al., 1983). Despite the detrimental impact of technological disasters (United Nations International Strategy for Disaster Reduction (UNISDR), 2004), natural disasters are becoming more frequent and expensive. They jeopardise society, the performance of the economy, the built environment, and other socio-economic and physical conditions (Intergovernmental Panel on Climate Change (IPCC), 2012, UNISDR 2011). Flooding is the most common natural disaster (Sohn, 2006) and it is regarded as the most lethal of all natural disasters (Alexander, 1997).

All types of built environments can be at risk of direct damage from natural disasters (Wilby, 2007). For example, transport infrastructure is vulnerable to extremes in temperature, river floods and storm surges, which can lead to damage to roads, rail, airports and ports (IPCC, 2012). Transport infrastructure is considered to be vulnerable to flooding, but the exposure and impact will vary by region, location, elevation and condition of the infrastructure (United Nations Conference on Trade and Development (UNCTAD), 2009, Humphrey, 2008). Roads, bridges and culverts are the most vulnerable elements in transport infrastructure in those areas with projected increases in flooding (Meyer, 2008).

Damage from natural disasters has risen dramatically over recent decades (Crompton and McAneney, 2008) and worldwide expenditure associated with natural disasters has increased dramatically since the 1950s (Masozera et al., 2007, Guha-Sapir and Panhuis, 2004). Both developing and developed countries have experienced calamitous natural disasters (Hacker and Holmes, 2007, Ibarrarán et al., 2007, Kahn et al., 2005, Pelling and Uitto, 2001). Australia is one of the countries most susceptible to natural disaster damage, particularly to flooding damage (Blong, 2004). Most Australian roads and bridges are located in coastal and riverine areas, where they are more vulnerable to rises in sea level and localised flooding. New South Wales (NSW) is one of the most susceptible states in Australia for flood damage, particularly to its transport infrastructure (Bureau of Transport Economics, 2001). This study focuses on flood risk management in transport infrastructure in NSW, Australia.

Research to date has focused on the impact of natural disasters on different subjects including society (Raschky, 2008, Pérez-Maqueo et al., 2007, Haque, 2003), national economies (Noy, 2009, Raschky, 2008, Toya and Skidmore, 2007), the built environment (Mojtahedi and Oo, 2014a, Wilby, 2007), the public health system (Barnett et al., 2005), the environment (Rocheleau et al., 1995), the automobile industry (Levy and Rothenberg, 2002, Rosenthal and Kouzmin, 1997), the insurance industry (Browne and Hoyt, 2000, Ganderton et al., 2000, Kunreuther, 1996), the tourism industry (Ritchie, 2004, Faulkner, 2001), sustainable development (Shrivastava, 1993) and critical infrastructure (Boin and McConnell, 2007, Boin and Smith, 2006).

While natural disasters cannot be eliminated, successful natural disaster risk management and a resilient built environment are those where natural disasters are effectively managed by stakeholders (Mojtahedi and Oo, 2014b, Bosher et al., 2009). There are many different stakeholders involved in managing natural disaster risks. Local Councils are selected as stakeholders for this study of flood risk management in transport infrastructure as they are responsible for investing, constructing, maintaining and restoring a high proportion of roads and bridges across NSW. However, there has been little discussion about stakeholder attributes and approaches to natural disaster risk management.

Although there are many factors involved in stakeholders' organisational capacity and performance in natural disaster risk management (Raschky, 2008), this research focuses on three stakeholder attributes: (i) power; (ii) legitimacy; and (iii) urgency (Phillips et al., 2003, Mitchell et al., 1997, Freeman, 1984). These attributes have not yet been evaluated in the context of natural disaster risk management. These three distinct stakeholder attributes play an essential role in an organisation's performance (Freeman 1984). Olander (2007) showed that these three stakeholder attributes are essential factors in defining stakeholders' overall performance. Stakeholder attributes play a pivotal role in organisational performance whether an organisation is taking proactive or reactive behaviours in managing internal and external predicaments (Olander, 2007, Phillips et al., 2003, Mitchell et al., 1997, Freeman, 1984).

Although stakeholders have distinct attributes, they use both proactive and reactive approaches to manage natural disasters in the society and built environment (Moe and Pathranarakul, 2006). A proactive approach includes mitigation and preparedness activities that have been planned and conducted by stakeholders before natural disasters, while a reactive approach includes response and recovery activities that are executed by stakeholders during and after natural disasters (IPCC, 2012, Moe and Pathranarakul, 2006, Pearce, 2003).

The research to date has tended to focus on the impact of natural disasters on socio-economic and built environment separately (Sections 2.5 and 2.6), and little attempt has been made to investigate the role of stakeholder attributes in natural disaster damage and stakeholder approaches to natural disaster risk management (Sections 4.7 to 4.12). The development of measurement tools to assess stakeholder approaches to natural disaster risk management has been absent from previous studies (Section 2.7). This study investigates the role of Local Councils' stakeholder attributes on both flood damage and on Local Councils' proactive and reactive approaches to flood risk management including mitigation, preparedness, response and recovery activities. The identified research problems are highlighted in the next section.

1.2 Research problem

Numerous studies have investigated the direct and indirect impact of natural disasters on socio-economic conditions (e.g., Kellenberg and Mobarak, 2008, Ibarrarán et al., 2007, Skidmore and Toya, 2002) and built environment conditions (e.g., Lertworawanich, 2012, Hunt and Watkiss, 2010, Kim et al., 2002) separately. However, there is no integrated framework that evaluates the impact of natural disasters on both the socio-economic and built environment conditions in the literature. Hence, the first main research question in this study is as follows:

1- Does the exposure and vulnerability of a region to natural disaster depend on both socio-economic and built environment conditions?

Although proactive and reactive approaches can be used to address natural disasters, most studies have claimed that stakeholders often resolve the predicaments that surface in natural disasters by reactive approaches (Bosher et al., 2009; Brilly and Polic, 2005; Loosemore and Hughes, 1998). Despite the detrimental impact of natural disasters, Bosher et al. (2009) noted there is still insufficient evidence to support that key stakeholders are playing a proactive role in mitigating natural disasters in the built environment, and that natural disaster stakeholder management is absent in natural disaster risk management. Stakeholder attributes of power, legitimacy and urgency are the pivotal factors for predicting the overall performance of an organisation in terms of reducing the conflicts and problems, and managing the external risks (Olander, 2007, Mitchell et al., 1997). Thus, the stakeholder attributes are applicable to predicting the overall performance of every organisation including Local Councils. However, the role of stakeholder attributes on natural disaster damage and on stakeholder proactive and reactive approaches has yet to be examined in natural disaster risk management studies. Damage refers to the economic loss of society, physical and environmental assets due to natural disasters (Hochrainer, 2006, Davidson, 1997). The second research question in this study is as follows:

2- How do stakeholder attributes influence natural disaster damage, and stakeholder proactive and reactive approaches to natural disaster risk management?

While scholars and practitioners have developed indices pertinent to natural disaster risk management (Simpson and Katirai, 2006, Davidson and Lambert, 2001, Davidson, 1997), comparatively few attempts have been made to develop measurement tools to assess stakeholders' approaches to cope with natural disasters. In particular, no research has been found to measure stakeholder proactive and/or reactive approaches to natural disaster risk management. Having considered the importance of stakeholder attributes in the context of natural disaster risk management, the third research question addressed in this research is as follows:

3- How do natural disaster risk management activities have relationships with stakeholder attributes to developing an index to measure stakeholder proactive, reactive and overall approaches to natural disaster risk management?

1.3 Research aim and objectives

Based on the research problems, the aim of this research is to investigate the role of stakeholder attributes on: (i) flood damage; and (ii) stakeholder approaches to flood risk management in transport infrastructure in NSW, Australia. With Local Councils in NSW as the stakeholders in this study, the specific objectives are to:

(i) develop a theoretical framework for the role of stakeholder attributes on flood damage, and stakeholder proactive and reactive approaches to flood risk management;

(ii) analyse the exposure and vulnerability of Australian states and territories to flood risk by considering the socio-economic, coastal buildings and transport infrastructure conditions simultaneously;

(iii) test the theoretical framework and investigate the effects of inter-relationships between stakeholder attributes, approaches and flood risk management in transport infrastructure;

(iv) investigate the mediating effects of the socio-economic and transport infrastructure conditions on the relationship between stakeholder attributes and flood damage; and

(v) develop a stakeholder disaster response index that measures stakeholder proactive, reactive and overall approaches to flood risk management in transport infrastructure.

There are different types of natural disasters including floods, earthquakes, storms, bushfires, landslides and hurricanes (see EM-DAT (2012) and (Guha-sapir et al., 2010) for a full list of natural disasters). Flood was selected as the indicative natural disaster for this study as floods are the most frequent and lethal type of natural disaster (Sohn, 2006, Alexander, 1997). EM-DAT (2004) reported that floods killed at least 8 million people all over the world over the past century while there are approximately 70 million people currently living in flood-prone areas across the world (UNISDR, 2011). Australia is one of the countries most susceptible to flood damage. For example, Australia has faced huge economic damage from floods over the past decade (Blong, 2004) and almost one third of future damage from climate change to the Australian economy will stem from with rising sea levels and flooding (Department of Climate Change and Energy Efficiency, 2011).

The eight states and territories in Australia are not equally exposed to flood disasters. NSW was chosen as the geographical area for this study because, apart from its susceptibility to flooding, it is the most populous state in Australia and contains a considerable proportion of Australia's built environment. Of the many different components of the built environment including buildings (residential, commercial and industrial), transport infrastructure, water supplies, energy networks, other physical infrastructure, and green spaces (Roof and Oleru, 2008), transport infrastructure in NSW was selected for this study because 24% of Australia's roads and bridges are located in NSW (Bureau of Transport Economics, 2001).

There are many stakeholders involved in flood risk management in Australia including the federal government (Bureau of Meteorology), state government (such as Department of Planning and Environment, Roads and Maritime Services and State Emergency Service in NSW), local government, the private sector including insurance companies, the non-government sector and the community. This study focuses on local government because Local Councils play an important role in flood risk management and are responsible for providing infrastructure, preparing and responding to natural disasters, developing and enforcing planning, and connecting national government programs with local communities (UNISDR, 2011, Huq et al., 2007). In particular, NSW Office of Environment and Heritage (OEH) mentioned that Local Councils are responsible for developing and implementing flood risk management plans including land use planning, mitigation work construction, maintenance, and restoring a major portion of roads and bridges across NSW (OEH, 2005).

1.4 Definition of terms

Major terms used throughout this thesis are defined as below:

(i) Natural disaster risk management

Natural disaster risk management consists of processes for designing, planning, implementing and evaluating strategies, policies and measures to ameliorate our understanding of natural disaster risk, promote natural disaster risk reduction by practicing mitigation activities and transfer and stimulate a continuous improvement in natural disaster management by practicing preparedness, response and recovery activities.

(ii) Flood risk management

Natural disaster risk management includes flood risk management which the primary objective of flood risk management is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods (OEH, 2005).

(iii) Socio-economic condition

In this study, socio-economic condition is defined as an economic and sociological combined total measure of a region's exposure and vulnerability to natural disaster, based on income level, Gross Domestic Product (GDP), age structure, population density and other relevant measurement indicators. Hence, socio-economic condition encompasses both the exposure and vulnerability of a region’s economy and society to natural disaster (Mileti, 1999).

(iv) Built environment condition

Built environment is a combination of facilities and infrastructure that people use as a core foundation for developing a society. Built environment draws upon a broad variety of established disciplines including natural sciences, social sciences, engineering and management (Amaratunga et al., 2002). It includes physical assets, residential and non-residential buildings, commercial and industrial buildings, public buildings, transport infrastructure and utilities, all of which can potentially be exposed and vulnerable to natural disasters. Built environment condition is defined as the exposure and vulnerability of the built facilities and infrastructure of a region to natural disaster.

This study focuses on both exposure and vulnerability, referred to as condition.

(v) Transport infrastructure

Transport infrastructure, consisting of roads, bridges, ports, railways and airports, is a critical ingredient in economic development at all levels of income by transporting goods and people between locations. It supports personal well-being and economic growth.

(vi) Natural disaster damage

Damage refers to the economic loss of society, physical and environmental assets due to natural disasters. In this study, disaster damage refers to the loss of assets and built environment associated with natural disaster (OEH, 2005).

(vii) Stakeholder

Stakeholders are individuals, groups or organisations who may affect, be affected by or who perceive themselves to be affected by the impact of natural disasters (adopted from Freeman, 1984). Any kind of entity actively involved in managing natural disasters before, during and after the events, or whose interests may be negatively affected by a natural disaster, can be a stakeholder in natural disaster risk management. Actual or potential stakeholders can include the three levels of government (federal, state and local), emergency organisations, financial institutions, communities, individuals and even the natural environment. Local Councils in New South Wales, Australia are selected as stakeholders in flood risk management for this study because the primary responsibility for flood risk management rests with Local Councils, which are provided with financial and technical support by the State Government (OEH, 2005).

(viii) Stakeholder attributes

Power, legitimacy and urgency are the three distinct stakeholder attributes in this study. Power allows a stakeholder to carry out its own will despite resistance to managing natural disasters. The power of a stakeholder may arise from its ability to mobilise social and political forces as well as its ability to withdraw resources from the organisation in natural disaster situations. Legitimacy gives opportunity to a stakeholder to identify some sort of beneficial or harmful risk pertinent to its organisation in natural disaster risk management. Urgency is the degree to which a stakeholder is able to call for immediate attention in natural disaster risk management (Mitchell et al., 1997). Local Councils as stakeholders using those attributes to influence their organisations in flood risk management.

(ix) Stakeholder approaches to natural disaster risk management

Approaches to natural disaster risk management can be classified as either proactive or reactive. A proactive approach refers to activities such as mitigation and preparedness that are planned and conducted before a natural disaster occurs, whereas response and recovery activities conducted during and after a natural disaster represent a reactive approach (Moe and Pathranarakul, 2006).

(x) Construct

Constructs measure concepts that are abstract, complex and cannot be directly observed by means of measurement indicators (Hair et al., 2014b). This study defines constructs as factors that contribute to natural disaster damage and stakeholder risk management approaches. 12 constructs are identified in this study:

flood characteristics, socio-economic conditions, transport infrastructure condition, flood damage, Local Council stakeholder attributes, mitigation, preparedness, response and recovery activities, proactive and reactive approaches, and finally, the Local Council overall approach to flood risk management. From these constructs, 14 hypotheses are formulated and constructed in the form of a structural model to test the inter-relationships between the constructs and measurement indicators.

(xi) Measurement indicators

Measurement indicators are the observed variables that are used to assess or measure the value of each respective construct, which could consist of a single indicator or multiple indicators (Hair et al., 2014b).

1.5 Research hypotheses

Based on the research aim and objectives, there are 14 hypotheses that form the foundation of this research as an empirical investigation. They are set out as follows:

H1: Flood characteristics have a direct effect on the magnitude of flood damage.

The implication of this hypothesis is to understand whether or not the flood characteristics affect the magnitude of flood damage in terms of economic damage to community and transport infrastructure. If H1 is supported, the results will deliver evidence of a relationship between the characteristics of flood and flood damage in terms of economic damage to the society and transport infrastructure, and as a consequence, provide constructive information to enable stakeholders to manage flood risks proactively and thus mitigate the economic damage caused by floods.

H2a: The socio-economic condition mediates the relationship between stakeholder attributes and flood damage, and

H2b: The transport infrastructure condition mediates the relationship between stakeholder attributes and flood damage.

The aim of these two hypotheses is to understand the mediating role played by the socio-economic and transport infrastructure conditions on the relationship between stakeholder attributes and flood damage. Stakeholder attributes would most likely have a direct effect on flood damage, but external and environmental factors would mediate the strength of this relationship. Although previous studies have shown that the exposure and vulnerability of the socio-economic and built environment conditions have a direct impact on natural disaster damage, no empirical and statistical tests have as yet been conducted to scrutinise the mediating role of these conditions on the relationship between stakeholder attributes and natural disaster damage. If *H2* is supported, the results will provide important insights for flood risk management policy makers to not only focus on enhancing institutional and stakeholder attributes, but also on alleviating the exposure and vulnerability of society, the economy, and the built environment against flood as well.

H3a: Stakeholder attributes have a direct effect on stakeholder mitigation activities in flood risk management,

H3b: Stakeholder attributes have a direct effect on stakeholder preparedness activities in flood risk management,

H3c: Stakeholder attributes have a direct effect on stakeholder response activities in flood risk management, and

H3d: Stakeholder attributes have a direct effect on stakeholder recovery activities in flood risk management.

These four hypotheses test that the stakeholder attributes of power, legitimacy and urgency would most likely affect flood risk management activities including mitigation and preparedness, and response and recovery. If *H3a-3d* are supported, the results will deliver a rewarding insight into flood risk management in the built environment and indicate that enhancing stakeholders' power, legitimacy and urgency would lead to more efficient mitigation planning, sufficient preparedness before floods, higher levels of responsiveness during floods, and more effective recovery tasks during and after floods.

> **H4:** Mitigation activities have a direct effect on a stakeholder proactive approach to flood risk management.

> **H5:** Preparedness activities have a direct effect on a stakeholder proactive approach to flood risk management.

These two hypotheses test the extent of a stakeholder's proactive approach to natural disaster risk management. There has been debate by policy makers in natural disaster risk management over the predictors of proactive approaches. If *H4* and *H5* are supported, the results would encourage policy makers, local government, insurance institutions, emergency organisations and other stakeholders to emphasise mitigation and preparedness activities in order to take a more proactive approach to flood risk management.

> **H6:** Response activities have a direct effect on a stakeholder reactive approach to flood risk management.

> **H7:** Recovery activities have a direct effect on a stakeholder reactive approach to flood risk management.

Similarly, these two hypotheses test the idea that response and recovery activities are predictors of a stakeholder reactive approach to managing flood risks. If *H6* and *H7* are supported, the results will help explain why stakeholders have a tendency to reactive approaches where stakeholders are implementing more response and recovery activities in flood risk management. In addition, natural disaster risk management has often been viewed as a reactive practice because activities such as response and recovery are regularly implemented by stakeholders.

> **H8:** A proactive approach has a direct effect on a stakeholder's overall approach to flood risk management.

> **H9:** A reactive approach has a direct effect on a stakeholder's overall approach to flood risk management.

These two hypotheses test the role of proactive and reactive approaches in examining the stakeholder's overall approach to managing flood risk, which has not yet been tested empirically. If *H8* and *H9* are supported, the results open a new avenue for policy makers to understand the stakeholder overall approach and to design an index to measure the level of a stakeholder's overall approach.

> **H10:** Stakeholder attributes have a direct effect on a stakeholder's overall approach to flood risk management.

This hypothesis tests the role of stakeholder attributes in determining the stakeholder's overall approach. If *H10* is supported, the results will indicate that there is a direct relationship between stakeholder attributes and stakeholder overall approach; hence, enhancing stakeholder attributes would most likely improve a stakeholder's overall approach in flood risk management.

1.6 Research method

The research process of this study was divided into the following five phases: (i) reviewing literature; (ii) establishing a theoretical framework and the operationalisation of the respective constructs in the theoretical framework; (iii) designing the research method and selecting the methods of data analysis; (iv) analysing data and validating the results; and (v) summarising the results and drawing conclusions. With reference to the research objectives stated in Section 1.3, this study used a survey research design to research the time period from 1992 to 2012. It provides a relatively prompt and efficient method of collecting information from targeted samples and addressing research objectives. The decision to focus on a 20-year time period is because natural disasters occur over time and the exposure and vulnerability of a specific region to natural disaster are dynamic and depend on unstable conditions such as economic, social, geographic, demographic, cultural, institutional, governance and environmental factors which change over time (IPCC, 2012). In addition, stakeholder attributes and approaches are volatile and would most likely change over time (Olander, 2007). Thus, observing stakeholder attributes over time is essential for deducting a valid conclusion. Furthermore, flood characteristics, socio-economic measurement indicators and transport reconstruction projects due to flooding were recorded several times over the past 20 years in the relevant Australian databases. Data was collected from two sources: (i) historical archive databases for the period of 1992 to 2012; and (ii) Local Councils' flood risk management experts with the aid of a structured questionnaire.

Multi-attribute decision-making (MADM) using a non-parametric Technique for the Order Preference by Similarity to Ideal Solution (Bootstrap-TOPSIS) method was used to fulfil the second research objective, and Structural Equation Modelling (SEM) using Partial Least Square (PLS) estimation as implemented in Smart-PLS 2.0 software was utilised to address the third to fifth objectives of this study.

1.7 Research significance

This research contributes to knowledge by investigating the potential application of stakeholder attributes to flood risk management in the context of the built environment, while its importance is realised by the theoretical, practical and methodological significance discussed below.

Firstly, this research develops a theoretical framework for studying stakeholder attributes and approaches to flood risk management in transport infrastructure by applying stakeholder theory (Freeman, 1984) and decision-making paradigms (Tversky and Kahneman, 1983). This research bridges the theoretical gaps in previous studies of natural disaster risk management in the built environment by explaining how three stakeholder attributes of power, legitimacy and urgency form a new theoretical perspective developed from stakeholder management literature (Mitchell et al., 1997, Donaldson and Preston, 1995) and how they affect natural disaster damage and stakeholder proactive and reactive approaches. It appears to be the first empirical research that integrates flood characteristics and exposure and vulnerability of society, the economy and the built environment with stakeholder attributes to investigate: (i) flood damage; and (ii) stakeholder proactive and reactive approaches to flood risk management. This research also explores the inter-relationships between constructs to develop an index to measure stakeholder overall approach (proactive and reactive) to flood risk management, and to investigate stakeholder attributes in defining this index.

Secondly, this research also has practical significance because the findings provide an empirical understanding of the pivotal factors for reducing flood risks and what kind of constructs would be needed for stakeholders to take a more proactive approach rather than a reactive approach. It also offers natural disaster risk management policy makers and practitioners an insight into high level natural disaster planning and resource allocation, including stakeholders' roles in practising mitigation and preparedness tasks rather than response and recovery activities. Furthermore, the proposed index allows for a direct comparison of different stakeholders, such as Local Councils, involved in the tasks of planning, constructing, maintaining and restoring the built environment. For instance, this index could help local government and policy makers plan resources before, during and after natural disasters.

Finally, the methodology of this research can be applied to multi-attribute decision-making (MADM) and Structural Equation Modelling (SEM) in the context of natural disaster risk management and the built environment. Natural disaster risk management involving numerous constructs can complicate any investigation, and MADM is an optimisation technique that can resolve any predicaments in conflict conditions involving diverse attributes. It selects the most desirable alternative with the highest degree of satisfaction for all the relevant attributes. Furthermore, SEM is also a powerful technique that can simultaneously predict multiple and interdependent relationships, as well as measuring concepts that are abstract, complex, and cannot be directly observed by means of indicators, such as stakeholders' attributes and approaches, without being contaminated by measurement errors (Hair et al., 2014a). Although SEM has been extensively used in social and behavioural research to develop and test theories, its application in construction management, particularly natural disaster risk management in the built environment, has been limited.

1.8 Structure of the thesis

This thesis is structured into three parts and ten chapters as follows:

Part One consists of Chapters 1 to 4 which present the background of this research, a literature review, and the theoretical framework. Part Two consists of Chapters 5 to 8 which contain the research method and empirical findings. Part Three consists of Chapters 9 and 10 which validate the main findings, summarise and conclude the work.

Chapter 2 reviews natural disaster risk management in the built environment by providing a taxonomy of natural disaster risk management, exposure and the vulnerability of the socio-economic and built environment conditions with a focus on stakeholder natural disaster management. It also defines key concepts pertinent to natural disaster studies. This chapter concludes with a review and discussion of the tools and techniques applied in natural disaster risk management studies.

Chapter 3 reviews the literature on theories underpinning disasters, presents a theoretical framework for the study, and discusses the applications of disaster theories in the context of the built environment. The proposed theoretical framework incorporates 12 constructs by amalgamating the constructs of natural disaster risk management, organisational management and the built environment disciplines. Current knowledge of natural disaster risk management, stakeholder theory and decision-making paradigms are used as pillars to underpin the theoretical framework.

Chapter 4 discusses the operationalisation of the 12 key constructs of flood risk management in transport infrastructure by introducing measurement indicators for each construct and development of the research hypotheses.

Chapter 5 describes the research method used in this study. It presents the following: (i) the research process; (ii) the selection of research design; (iii) the sampling frame; (iv) the data collection techniques that include secondary historical data and data collected from a structured questionnaire; and (v) the questionnaire administration.

Chapter 6 presents the background of data analysis methods adopted in this study. This is followed by the justification for selecting the relevant analytical approaches. Details of Bootstrap-TOPSIS and PLS-SEM analytical methods are described in this chapter. Finally, it introduces the importance-performance matrix analysis for developing the stakeholder disaster response index.

Chapter 7 presents a multi-attribute decision-making technique to analyse the exposure and vulnerability of Australian states and territories to flood risk by considering the socio-economic, coastal buildings and transport infrastructure simultaneously.

Chapter 8 presents the second part of the empirical data analysis by specifying the structural and measurement models. This chapter tests the research hypotheses and interprets and discusses the results in the light of theory. The reliability and validity of structural and measurement models are also explained in this chapter through the PLS-SEM technique. This chapter concludes by developing a stakeholder disaster response index, with discussion of the results.

Chapter 9 validates the results reported in Chapters 7 and 8 and presents the robustness of developed index in Chapter 8 relevant to understanding a stakeholder overall approach to flood risk management.

Chapter 10 presents a summary of the findings, followed by a discussion and an evaluation of the hypotheses. It highlights the theoretical and practical implications of this study and the research limitations, with recommendations for future research.

CHAPTER

2

Natural Disaster Risk Management: Socio-economic and Built environment Conditions

2.1 Introduction

This chapter starts by defining the key concepts inherent in natural disaster risk management (Section 2.2) and then developing a taxonomy of previous research on natural disaster risk management in the built environment (Section 2.3). This is followed by a description of different phases, activities, and approaches in natural disaster risk management (Section 2.4). The subsequent sections focus on the impact of natural disasters on the socio-economic (Section 2.5) and built environment (Section 2.6), and conclude with a review of the analytical tools, techniques, and pertinent natural disaster risk management indices (Section 2.7).

2.2 Key concepts and definitions

The concepts and definitions presented in this research consider a number of existing sources (e.g., IPCC, 2012, UNISDR, 2011, Guha-sapir et al., 2010), and the fact that concepts and definitions evolve as knowledge, needs, and contexts vary. There are a number of academic and technical terminologies that define climate change, hazards, disasters, natural hazards, and natural disasters. Committees and scholars at the World Conference on Disaster Reduction held at Kobe, Japan in 2005 acknowledged that climate change was an underlying threat relative to hazards and natural hazards have increased in this century (Helmer and Hilhorst, 2006). Natural hazards are associated with climate changes because: (i) climate change alters weather patterns; (ii) CO^2 emissions and global warming may cause average worldwide temperatures to fluctuate; (iii) deforestation and desertification in some parts of the world lead to imbalances in global hydrological cycles; and (iv) a rise in sea level due to global warming, greenhouse gas emissions, and polar ice caps melting may increase flooding in coastal areas

(Burton, 1997). Scheidegger (1994) explains that prompt changes in long-term behaviour caused by minute changes in the initial conditions can be attributed to hazards. A hazard is an extreme geophysical event that can cause a disaster (Alexander, 2000), but a hazard may cause a disaster only if it interacts with a vulnerable human settlement (Albala-Bertrand, 1993). Maccollum (2006) explains that a risk is created when a hazard and vulnerability interact. The term hazard is often associated with different agents or processes such as atmospheric, hydro-logic, biologic and techno-logic (Alcantaraayala, 2002).

There is a difference between a hazard and a natural hazard. Although there are hydrological hazards, geological hazards, meteorological hazards, biological hazards, technological hazards, and man-made hazards; natural hazards have relationships with geological and hydrological concepts (Alcantaraayala, 2002). Natural hazards are part of the world around us, and their occurrence is inevitable. For instance, floods, hurricanes, tornadoes, winter storms, earthquakes, tsunamis, volcanoes, landslides, sinkholes, and other extreme events are uncontrollable natural phenomena. Alexander (2000) defines natural hazards as extreme events that originate in the biosphere, lithosphere, hydrosphere or atmosphere. He also believes this term is very useful because it distinguishes them from technological and social hazards.

A natural hazard and a natural disaster are not the same. A natural hazard becomes a natural disaster as soon as society, human beings, infrastructure, or other forms of tangible or intangible capital are threatened and/or destroyed by that hazard (Alexander, 1997). Thus, a natural disaster would appear to stem from natural hazards and it can occur when a natural vulnerability and human vulnerability coincide in time and space (Alcantaraayala, 2002, Alexander, 2000, Smit et al., 2000, Alexander, 1997).

The most comprehensive definition of a natural disaster was provided by the Centre for Research on the Epidemiology of Disasters (CRED 2007 cited in Guha-sapir et al., 2010), and is consistently used by many scholars in their research (e.g., Noy, 2009, Ibarrarán et al., 2007, Alcantaraayala, 2002). It defines natural disasters as events that have natural causes and result in ten or more mortalities, affect 100 or more people, or result in a call for international assistance or the declaration of a state of emergency. The disaster breakdown structure (DBS, see Figure 2-1) is one of the most suitable tools for classifying disasters because the types and scope of the disaster can be sub-divided into smaller and more manageable elements that result in a structured vision of what must be managed (Guha-sapir et al., 2010). The DBS also provides policy makers with information appropriate to each level so they can track the budget allocations, disaster damage and the resources and responsibilities for each category of disaster. The DBS is used to link the organizational units responsible for managing disasters. Its first level includes two predominant sources of disasters, namely natural and technological. The focus of this study is on natural disasters.

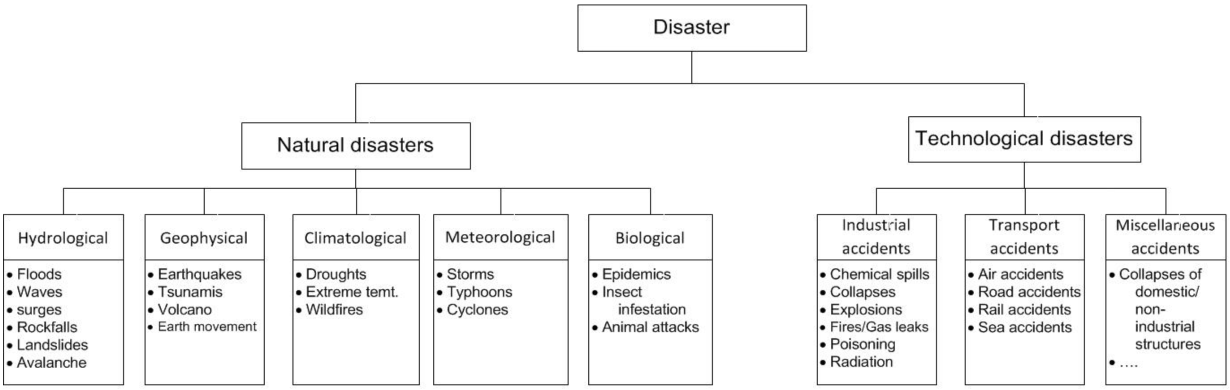


Figure 2-1: Disaster Breakdown Structure (source: Guha-sapir et al., 2010)

Natural disasters are becoming more frequent, expensive and jeopardizing globally. Table 2-1 shows the people affected and damage that resulted from natural and technological disasters between 1900 and 2012. It can be seen that 99.88% of people were affected by natural disasters while only 0.12% of affected people stemmed from technological disasters. In fact, the worldwide economic expenditure associated with natural disasters has increased 14-fold since the 1950s (Guha-sapir et al., 2010, Masozera et al., 2007); this represents an exponential increase over the past decades. The number of natural disasters has increased almost 300% globally over the past three decades (CRED 2007 cited in Guha-sapir et al., 2010), representing an increase of 2300% between 1980 and 2011.

Table 2-1: Natural and technological disasters 1900-2012 (source: EM-DAT, 2012)

Disaster type	Affected people	Damage (USD ,000)
Natural disasters	6,632,135,911 (99.88%)	2,239,780,595 (98.86%)
Technological disasters	7,981,091 (0.12%)	25,726,859 (1.14%)

Recent evidence suggests that scholars and practitioners need to focus specifically on natural disaster risk management in society and the built environment to reduce their devastating impact (e.g., IPCC, 2012, Bosher, 2008, Wilby, 2007). Although the scope of natural disaster risk management is broad, a taxonomy of previous research is proposed in the next section that focuses on topics related to natural disaster risk management, particularly before any disasters occur, and the integration of socio-economic and built environment during and after disasters.

Finally it is important to distinguish between exposure and vulnerability in natural disaster risk management context. Many terms and definitions associated with natural disaster risk management, exposure and vulnerability have become fashionable over the past decades (Crozier et al., 2006, Alexander, 2000). Exposure is referred to the presence of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected by natural disaster. However, the propensity or predisposition to be adversely affected is called vulnerability (Davidson, 1997). Exposures and vulnerability are dynamic and depend on economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors (IPCC, 2012). For example, the built environment exposure is the presence of physical asset and infrastructure-residential buildings, non-residential, commercial buildings and industrial buildings, public buildings, roads and bridges, and utilities, which can potentially be affected by natural disasters. Therefore, this study focuses on both exposure and vulnerability hereinafter referred to as condition, for example, socio-economic condition means socio-economic exposure and vulnerability, and similarly, built environment condition encompasses exposure and vulnerability.

2.3 Taxonomy of previous research on natural disaster risk management

A review of literature related to natural hazards or natural disasters indicates that previous research mainly dealt with three research streams, namely: (i) natural disaster risk management; (ii) the impact of natural disasters on socio-economic; and (iii) the impact of natural disasters on the built environment. Figure 2-2 shows the taxonomy of previous research into natural disasters and the connections between the various research streams. These three research streams are described in detail in subsequent sections (sections 2.4 to 2.6). Literature on the impact of natural disasters has traditionally concentrated on the short-term response of socio-economic and built environment conditions to disasters, although evidence on the long-term effects of natural disasters on both socio-economic and built environment conditions does exist (Hystad and Keller, 2008, O' Brien and Leichenko, 2000). Natural disaster risk management phases, particularly prediction, warning, and emergency management

(EM) relief have a direct relationship to socio-economic condition, while rehabilitation and reconstruction phases have substantial ties with built environment condition via socio-economic condition (IPCC, 2012, UNISDR, 2011). It is also evident that high level of disaster planning and effective stakeholder participation in the planning process lessens the impact of natural disasters on the socio-economic and built environment (Burby, 2003). Finally, some previous studies on the development of tools and techniques for managing natural disasters have also considered the socio-economic and built environment conditions (see Section 2.7). Carrying out a detailed literature review based on developed taxonomy (Figure 2.2) and then a proper synthesis and analysis will clarify what has been done and what needs to be done in natural disaster risk management. This shows that there is a systematic extraction of main elements of any argument for the purpose of evaluation from the existing literature in the current thesis.

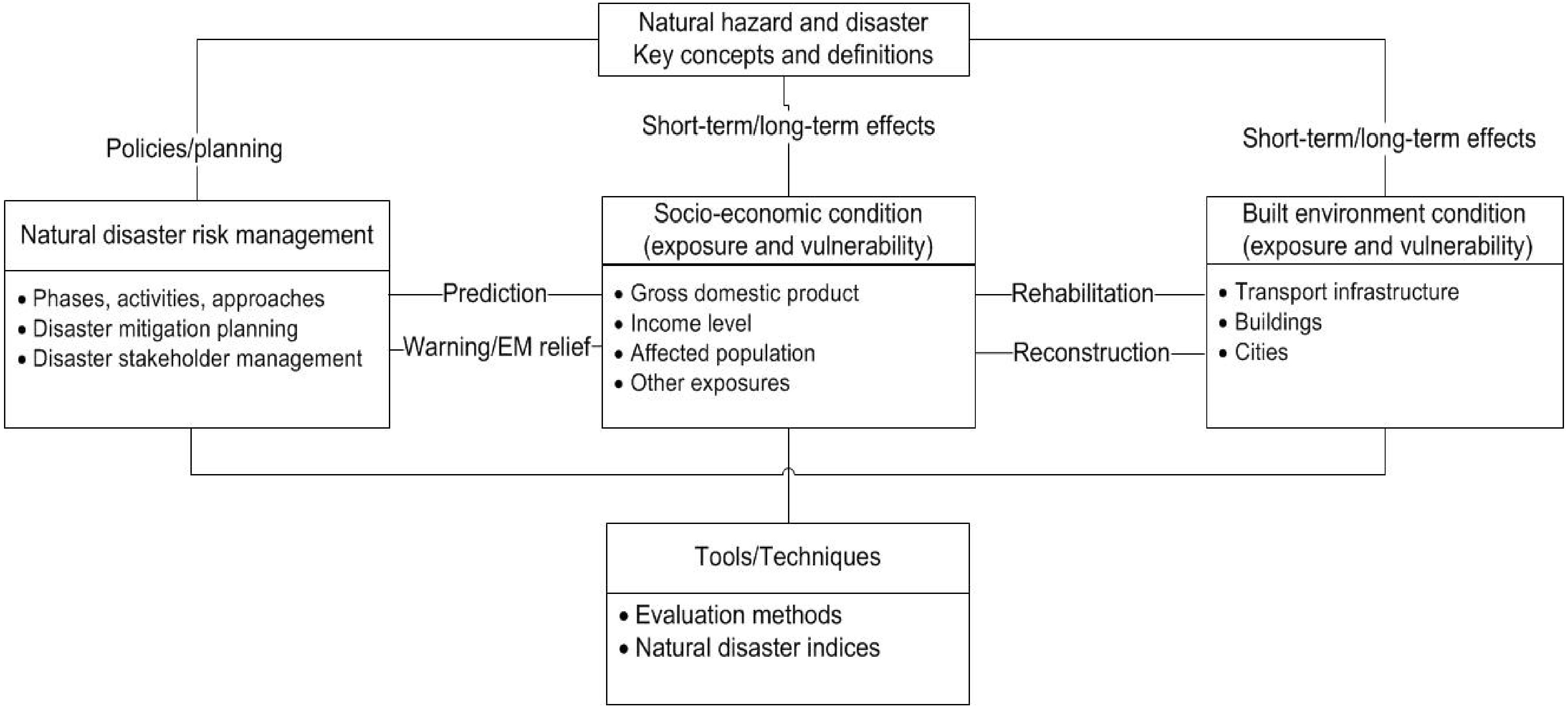


Figure 2-2: Taxonomy of previous research on natural disaster risk management

2.4 Natural disaster risk management

Natural Disaster Risk Management (NDRM) consists of processes for designing, implementing, and evaluating strategies, policies, and measures to improve our understanding of natural disaster risk, promote natural disaster risk reduction and transfer, and stimulate a continuous improvement in natural disaster mitigation, preparedness, response and recovery activities (IPCC, 2012). The main purpose of NDRM is to decrease the exposure and vulnerability of society, the economy and the built environment, while also increasing our security, well-being, quality of life, resilience and sustainable development (IPCC, 2012, UNISDR, 2011, IPCC, 2007). Current approaches to NDRM typically involve two distinct components, namely (IPCC, 2012, Carreño et al., 2007, Carreño et al., 2006): (i) Natural Disaster Risk Reduction (NDRR); and (ii) Natural Disaster Management (NDM).

There is a substantial difference between NDRR and NDM because they have different activities. NDRR includes mitigation activity while NDM contains preparedness, response and recovery activities. NDRR is a systematic development of mandates, strategies, and practices to minimise the impact of vulnerabilities and disasters throughout society and the environment. This includes lessening the vulnerability of people, including their livelihoods and assets, while ensuring an appropriate and sustainable management of land, water and other components of the environment (UNISDR, 2004). It covers disaster risk identification and risk transfer (IPCC, 2012). Disaster risk identification involves individual perception, an evaluation of risk and social interpretation (Carreño et al., 2006). Risk transfer is related to financial protection of public investment (Mercer, 2010). NDRR, on the other hand denotes a policy goal or objective, including the strategic and instrumental measures used to anticipate future disaster risk, whilst reducing existing exposure, vulnerability and improving resilience (Birkmann and von Teichman, 2010). NDM, on the other hand, refers to the social processes used for designing, implementing and evaluating strategies, policies and measures that promote and improve the preparedness, response and recovery activities at different organizational and societal levels (IPCC, 2012). In order to reduce the adverse economic impact of natural disasters, investment in NDRR is firmly advocated by governments and the insurance sector (Linnerooth-Bayer et al., 2005, Gurenko, 2004, Kreimer and Arnold, 2000).

NDRR has stronger connotations with proactive approaches. However, NDM focuses mostly on preparedness, response and recovery phases which for many scholars have weaker connotations of proactive and stronger connotations with reactive approaches to dealing with disasters (e.g., IPCC, 2012, Hellmuth et al., 2007, Moe and Pathranarakul, 2006). Although there has been an increasing amount of literature on disaster mitigation planning in recent years, researchers have not scrutinised proactive approaches to NDRM in much detail. Proactive approaches in NDRM can help reduce the adverse impacts of disaster and pave the way for a sustainable and resilient future (IPCC, 2012, UNISDR, 2011). Finally, NDM has often been viewed as a reactive profession because activities such as mitigation is rarely seen as urgent (Bosher et al., 2007a, Schneider, 2002).

In accordance with above definitions of NDRM and the breakdown of NDRM into the NDRR and NDM, NDRM is defined as the following in this thesis:

"Natural disaster risk management consists of processes for designing, planning, implementing and evaluating strategies, policies and measures to ameliorate our understanding of natural disaster risk, promote natural disaster risk reduction by practicing mitigation activities and transfer and stimulate a continuous improvement in natural disaster management by practicing preparedness, response and recovery activities.”

2.4.1 Phases, activities and approaches

Moe and Pathranarakul (2006) proposed an integrated approach to NDRM consisting of the phases, activities, components and approaches that stakeholders should take before, during and after natural disasters as shown in Figure 2-3. Moe et al. (2007) argued that NDRM includes five phases: prediction, warning, emergency relief, rehabilitation and reconstruction. Past research has placed more focus on mitigation activities rather than preparedness, response and recovery activities. Altay and Green (2006) reviewed almost 100 operational research and management science papers in disaster operation management and noted that 44% of previous works addressed mitigation activities, 21.1% and 23.9% of published articles focused on preparedness and response activities respectively, while only 11% of the papers contributed to recovery activities. This means scholars have not paid equal attention to all the four activities of NDRM.

Response Time	Natural Disaster Risk Management Phases	Natural Disaster Risk Management Activities	Natural Disaster Risk Management Components	Natural Disaster Risk Management Approaches
Before	Prediction	Mitigation	Natural Disaster Risk Reduction (NDRR)	Proactive
		Preparedness	Natural Disaster Management (NDM)	
During	Warning Emergency Relief	Response		Reactive
After	Rehabilitation Reconstruction	Recovery		

Figure 2-3: An integrated approach to NDRM (adapted from Moe and Pathranarakul, 2006)

Approaches toward NDRM can be classified as either proactive or reactive. Moe and Pathranarakul (2006) stated that a proactive approach referred to activities such as mitigation and preparedness that were planned and conducted before any natural disasters occurred, in order to alleviate their adverse impacts, whereas response and recovery activities conducted during and after natural disasters represent a reactive approach. Figure 2-3 shows that proactive approach deals with both NDRR and NDM while reactive approach mainly deals with NDM. A resilient and sustainable future depends on proactive measures that promote more appropriate strategies and transformations including adaptive management, learning, innovation and leadership to manage risks and uncertainty (IPCC, 2012). Previous research has focussed on disaster mitigation planning instead of promoting a more proactive approach (e.g., Bosher et al., 2009, Godschalk et al., 2003, Burby and May, 1997). It was only in 1999 that the National Policy on Disaster Management in Mozambique began to shift from a reactive to a proactive approach with an aim to develop a culture of prevention (IPCC, 2012, Hellmuth et al., 2007).

A few studies exist on stakeholder proactive and reactive approaches toward NDRM in the built environment (see Section 2.6). For instance, Loosemore (1998) investigated reactive crisis management in construction projects and Brilly and Polic (2005) studied a case in Slovenia to provide an integrated flood mitigation decision-making process by considering stakeholder approaches. Moe et al. (2007) proposed a balanced scorecard technique that considered proactive and reactive approaches in order to continually assess the performance of a NDRM project in each life cycle phase. Another example of a proactive approach in NDRM is where climate change is currently being incorporated into the 2015 version of the National Building Code in Canada to help ensure that future infrastructure is built to a more appropriate standard and that adaptive measures are incorporated into the design and building of any new infrastructure (IPCC, 2012).

Bosher et al. (2009) claimed there was a need to proactively address strategic weaknesses in maintaining the built environment from a range of disasters. They stated that there was still not enough evidence to demonstrate that key construction stakeholders were playing a proactive role in mitigating flood risk. They further pointed out that pre-construction phase of a building's life cycle was the most critical stages where key stakeholders such as architects, designers, structural and civil engineers, urban planners, specialist contractors and emergency or risk managers need to adopt natural hazard mitigation strategies. Their survey on the integration of FRM in the UK's built environment indicated that knowledge and awareness of integrated NDRM was poor. Key recommendations in their work include: (i) built environment stakeholders should become more involved in group decision-making and planning; (ii) professional training for stakeholders such as architects, planners, engineers, developers, etc., that is pertinent to risk and disaster awareness should be systematically organised; and (iii) performance-based contracting, and product or service oriented procurement decisions should be taken in order to make designers and contractors think about the long-term implications and performance of the buildings and structures. Existing research into the proactive and reactive approaches of NDRM in the built environment is limited because these approaches are closely aligned with sustainable development issues. For example, mitigation and preparedness activities provide the best opportunity for introducing sustainable development strategies through immediate responses and more structural and long-term institutional capacity (Saldaña-Zorrilla, 2008, Berke, 1995).

2.4.2 Natural disaster mitigation planning

In recent years, disaster mitigation planning scholars have focused on NDRR as an essential tool for local governments to identify and coordinate the efforts of stakeholders to reduce and eliminate risks associated with natural disasters (Lyles et al., 2013, Berke and Godschalk, 2009, Godschalk, 1999, Brower and Beatley, 1989). Natural disaster mitigation planning includes three generic dimensions: context, process and outputs where stakeholders play an indispensable role in coordinating activities to develop and implement plans, agreements, procedures and provisions (Lyles et al., 2013). It is firmly recognised that a comprehensive land use planning with considering high-quality elements such as sustainable development, public participation and infrastructure programming have been the most reliable and effective tools for mitigating the adverse impact of natural disasters over the past decades (Lyles et al., 2013, Nelson and French, 2002, Burby et al., 1999, Mileti, 1999). Land use planning is a way of locating society and the built environment in less hazardous areas in order to reduce the risk of natural disasters by monitoring and controlling development regulations, public facility policies, land and property accusation, taxation and fiscal policies and the distribution of information (Lyles et al., 2013, Burby et al., 1999, Gillespie and Streeter, 1987). However, land use planning and other traditional methods for reducing the impact of natural disasters have their own weaknesses. For example, Burby and Dalton (1994) argued that building codes were developed to reduce the likelihood of loss from calamities only up to certain magnitudes, while issues associated with lack of stakeholder participation and proactive approaches are the main weaknesses in land use planning (Kang et al., 2010, Tang et al., 2008, Brody, 2003, Brody et al., 2003, Burby, 2003, Nelson and French, 2002, Olshansky, 2001, Burby, 1998).

Stakeholder participation in the natural disaster mitigation planning process has been another major concern for policy makers over the past decades. In the case of NDRM, plans will be better and proposals will be more effective, proactive and comprehensive if a broad array of stakeholders participate in the planning process (Burby, 2003). He claimed that by involving stakeholders, planners could increase public understanding of predicaments associated with natural disasters and convince potential communities of the need for collective action. Consequently, the effective participation of stakeholders means that planners can develop better plans and increase the potential of achieving some degree of agreement between the affected parties. The involvement of stakeholders in the planning process can be conceptualised into NDRM in two ways (Pearce, 2003): (i) involvement of a local planner in the official NDRM committee; and (ii) involvement of diverse stakeholders in the official planning committee responsible for developing the plan. The present review suggests that stakeholders who are planners should consider proactive approaches as part of the overall process of preparing and reviewing their natural disaster mitigation plans. This would most probably improve the performance of NDRM (Kang et al., 2010).

Disaster mitigation planning can be classified into two main practices namely; (i) structural mitigation; and (ii) non-structural mitigation. Structural mitigation practices referred to the strengthening of buildings and infrastructure exposed to natural disasters via building codes, engineering design and construction practices for resilient built environment, but non-structural mitigation practices referred to directing new development away from known hazard locations through land use planning and regulations, and relocating existing developments to safer areas (e.g., Bosher et al., 2009, Bosher, 2008, Alexander, 1997). These non-structural mitigation initiatives can have significant impact on risk and cost reduction and is critical in advocating the proactive rather than reactive approach to NDRM (Bosher et al., 2007b, Godschalk, 1999).

Stakeholders, particularly local governments, must be more proactive at focusing on preventative land use for hazard mitigation (Lyles et al., 2013). According to Rossi et al. (1982), Stakeholder interest in proactive activities against natural disasters is generally low; for example, land use planning was neglected by stakeholders during the 1950s and 1970s. A case study in the US showed that citizens expressed no interest in participating in natural disaster mitigation policies (Godschalk et al., 2003). Furthermore, little is known about the role of government planning mandates on stakeholder participation in planning (Brody et al., 2003, Burby, 2003). In order to encourage stakeholders to adopt proactive approaches to prospective disasters, they must be given an opportunity to participate in local planning processes in a proactive way. Brody et al. (2003) examined the strengths and weaknesses of citizen involvement mandates in planning and explained to what extent these mandates and associated planning practices had led to stakeholder participation during the planning process. They found that these mandates enabled stakeholders to prepare themselves in advance, rather than taking reactive approaches in disaster situation. In order to immerse stakeholders, especially citizens, in proactive approaches, the recommended actions include (Godschalk et al. (2003): (i) conducting natural disaster mitigation education programs; (ii) coordinating natural disaster mitigation plans with comprehensive planning elements; (iii) connecting mitigation policies with quality of life planning; (iv) preparing small area plans for high risk locations; and (v) devising creative participation programs.

This review shows that previous studies in the field of NDRM fell under specific topics including: natural disaster mitigation planning, public participation in natural disaster mitigation planning, land use planning and structure versus non-structural approaches to natural disaster mitigation, whereas little attention has been paid to natural disaster stakeholder identification, classification and management, and a proactive and reactive classification of stakeholder approaches in NDRM. Although some scholars (e.g., Lyles et al., 2013, Burby, 2003, Godschalk et al., 2003, Burby and May, 1997) have argued about the importance of stakeholder involvement in creating comprehensive NDRM plans, they did not indicate how to measure stakeholders proactive and reactive approaches, particularly their overall approach to natural disasters. Different stakeholders have different attributes, all of which affect the outcome and quality of plans, and therefore it is essential to have a unique definition of stakeholders, stakeholder attributes, disaster stakeholder management in the field of NDRM.

2.4.3 Disaster stakeholder management

For the first time, Freeman (1984) borrowed the notion of a memo from Stanford Research Institute in 1963 to define a stakeholder. The memo defined a stakeholder as an entity without the support of which an institution would not survive. Stakeholders have an interest in the actions of an organisation, and have the ability to influence or be affected by the achievement of the organization's objectives (Donaldson and Preston, 1995, Savage et al., 1991, Freeman, 1984). There are other definitions in literature, the latest of which describes a stakeholder as a person or an entity who gives an input into decision-making as well as one who benefits from the results of decision-making (Phillips et al., 2003). Therefore, stakeholders in NDRM are individuals, groups, or organizations who may affect, be affected by or who perceive themselves to be affected by the impact of natural disasters. Indeed, any kind of entity that is actively involved in managing natural disasters before, during, and after the events, or whose interests may be negatively affected by a natural disaster can be a stakeholder in NDRM. Local people, groups, organizations, institutions, societies, and even the natural environment, is generally thought to qualify as actual or potential stakeholders.

By borrowing Freeman (1984) idea and the latest definition of a project stakeholder management by the Project Management Institute (2013), disaster stakeholder management includes the processes: (i) to identify the people, groups, or organisations that could impact or be impacted by the consequences of natural disasters; (ii) to analyse stakeholders' expectations and their impact on the natural environment, society, and the built environment; and (iii) to develop appropriate NDRM plans that effectively engage stakeholders in NDRM. These processes require continuous communication with stakeholders to understand their needs and expectations, addressing issues as they occur, managing conflicting interests, and fostering appropriate stakeholder engagement in all NRDM phases, activities and approaches before, during, and after natural disasters. The purpose of natural disaster stakeholder management is to devise methods to manage the myriad groups and relationships that result in a strategic proactive approach. However, the involvement of many different stakeholders in NDRM process is a complicated issue that must be addressed early in a policy making process (Prater and Lindell, 2000). Hence, an understanding of stakeholder attributes and their classification is required in the NDRM process. In Freeman (1984) stakeholder theory, power, legitimacy and urgency are the three distinct stakeholder attributes (see Section 4.7). Based on these three stakeholder attributes, Mitchell et al. (1997) classified and defined stakeholders into seven main groups as: (i) dormant stakeholders; (ii) discretionary stakeholders; (iii) demanding stakeholders; (iv) dominant stakeholders; (v) dangerous stakeholders; (vi) dependent stakeholders; and (vii) definitive stakeholders (see Section 10.6 for definitions).

Natural disaster risk management is a very broad area of research including: climate change adaptation, risk and uncertainty management, mitigation planning, emergency and crisis management, complex humanitarian emergency, sustainability, resilience, etc. The focus of this study is on stakeholder attributes borrowed from stakeholder theory (Freeman 1984) and the precious work of Mitchell et al. (1997). They have introduced three stockholder attributes (power, legitimacy and urgency) on their work and their idea has never been used in natural disaster risk management so far. Olander (2007) claimed that stakeholder institutional attributes are essential factors in defining their overall performance. He also argued that stakeholder attributes are not the only factors to predict the overall performance of an organisation, the external environmental factors should also be considered. The subsequent two sections scrutinise the exposures and vulnerabilities of natural disasters on the socio-economic and the built environment, respectively. It will also examine the extent to which scholars and practitioners have attempted to integrate different exposures and vulnerabilities in evaluating the impact of natural disasters.

Previous studies indicated that reducing the impact of natural disasters was mainly influenced by the capacity of stakeholders (Raschky, 2008). The institutional capacity of stakeholders is critical for effective implementation of structural and non-structural responses in natural disaster risk management (Brody et al., 2010). Stakeholders' organisational capacity is important for mitigating the impact of natural disasters and facilitating the development of resilient communities. Stakeholders' organisational capacity predicts the failure and success factors of stakeholders in an organisation (Savage et al., 1991) and it is then generalised in various contexts based on administrative (organisational) theories such as stakeholder theory (Jensen, 2010, Phillips et al., 2003, Donaldson and Preston, 1995).

Most previous studies have focused on the role of stakeholder involvement in FRM (Brilly and Polic, 2005). Only a few studies have scrutinised stakeholders' views and perspectives in FRM, such as (e.g., Almoradie et al., 2013, Bosher et al., 2009, Vari et al., 2003). For instance, Brody et al. (2010) investigated the role of key characteristics of organisational capacity including financial resources, staffing, technical expertise, communication, leadership and commitment to FRM. Recently Ha and Ahmad (2015) examined key institutional and regulatory frameworks as well as measures to manage disasters, including pre-disaster planning and post-disaster recovery in Bangladesh.

2.5 Socio-economic condition

Early studies into the different types of disaster commenced in the U.S. at the beginning of the 1950s and since then scholars and researchers have reviewed the impact of natural disasters (or disasters) on various socio-economic constructs in the 20th century, including human behaviour (Fritz and Marks, 1954); psychological consequences (Phifer, 1990, Perry and Lindel, 1978); macroeconomic variables (Tol and Leek, 1999, Albala-Bertrand, 1993, O'Keefe et al., 1976, Dacy and Kunreuther, 1969); age and elderliness (Kilijanek and Drabek, 1979); and race and ethnicity (Fothergill and Peek, 2004). This section focuses on recent studies pertinent to the socio-economic exposure and vulnerability of natural disasters. Table 2-2 shows the credible publications from the year 2000 onwards on the socio-economic exposure and vulnerability of natural disasters in different regions. It can be seen that the majority of previous studies focused on conducting empirical studies on developing countries to evaluate the impact of natural disasters on socio-economic condition. Moreover, floods, hurricanes and earthquakes that have dominated natural disasters in the 21st century have been the focus of previous studies, whereas much less attention has been given to natural disasters such as tsunamis.

Table 2-2: Summary of recent studies for impact of natural disasters on socio-economic condition

Region	Research design	Natural disaster	Credible publication
OECD	Case study	Hurricane	Masozera et al. (2007)
	Empirical study	Flood	Jonkman and Kelman (2005)
Developing countries	Case study	Storm, flood, earthquake	(Tas et al. (2007), Haque (2003), Martine and Guzman (2002))
	Empirical study	Flood, cyclone, drought, storm	(Crespo Cuaresma et al. (2008), Heger et al. (2008), Brilly and Polic (2005), Brooks et al. (2005), Rasmussen (2004), Wei (2004), Charvériat (2000), Winchester (2000))
Worldwide	Case study and empirical study	General natural disasters	(Barredo (2009), Noy (2009), Kellenberg and Mobarak (2008), Raschky (2008), Toya and Skidmore (2007), Kahn et al. (2005), Benson and Clay (2004), Skidmore and Toya (2002), O' Brien and Leichenko (2000))

Table 2.3 shows the three key measurement indicators (or termed as dependent or independent variables) for socio-economic condition construct examined in these studies are: (i) Gross Domestic Product (GDP); (ii) income level; and (iii) affected population such as population, population density, education, and age structure. These socio-economic measurement indicators will be examined in subsequent sections.

Table 2-3: Summary of dependent and independent socio-economic variables in previous studies

Author(s)	Socio-economic dependent variables	Socio-economic independents variables	Natural disasters	Geographical coverage of study
Wei (2004)	Number of people affected and total cost of damage	Population and GDP	All natural disasters	China
Anbarci et al. (2005)	Fatalities	Magnitude of the earthquake, population, land area, frequency, GDP, and country's land-based Gini	Earthquake	Worldwide
Pérez-Maqueo et al. (2007)	Mortality rate	Coastal population, frequency, life expectancy, adult literacy, GDP, HDI, natural, semi-altered, croplands, urban and built, liberty index, press freedom index, equality index	Hurricane	Worldwide
Masozera et al. (2007)	Economic damage	Household income, housing values, elevation and flood levels	Hurricane, and flood	USA
Kellenberg and Mobarak (2008)	Number of people killed	GDP, income, urbanization, frequency of disaster	Floods, earthquakes, landslides, windstorms, extreme temperature	Worldwide (133 countries)
Raschky (2008)	Disaster fatalities and monetary damage (Damage/GDP)	GDP, affected people, population, land area, government stability and investment climate	All natural disasters	Worldwide
Noy (2009)	Annual GDP growth	Disaster damage, affected population, institutional strength, illiteracy rate, inflation rate, imports and exports, financial crisis,	All natural disasters	Worldwide (109 countries)

2.5.1 Gross Domestic Product (GDP)

Skidmore and Toya (2002) investigated the long-term relationships between natural disasters, capital accumulation, total factor productivity and GDP and showed that climatic disasters were positively correlated with economic growth and investment in human capital, while geological disasters were negatively correlated with growth. They also recognised that the growth rate differed from disaster to disaster.

Reductions in the growth of GDP typically take place in a year where some natural disasters occur, with a potential for both sharp decreases or increases in subsequent years (Ibarrarán et al., 2007). For instance, Hurricane Allen in the Dominican Republic in 1979 caused a sharp (20%) fall in their GDP because it had a significant impact on the tourism industry, transport infrastructure, water supply and energy infrastructure, (Ibarrarán et al., 2007, Thomalla et al., 2006, Albala-Bertrand, 1993). Other scholars also found that GDP had generally increased in the periods immediately following a natural disaster (e.g., Toya and Skidmore, 2007, Skidmore and Toya, 2002). Skidmore and Toya (2002) believed this occurred because most of the damage caused by disasters were reflected in the loss of capital and durable goods, whereas stocks of capital are not measured in the periods immediately after a natural disaster.

On the other hand, Albala-Bertrand (1993) showed that natural disasters can have a positive impact on macroeconomic variables immediately after these events. He examined the relationship between a natural disaster and its potential effects on the growth rate of output by applying a macroeconomic model and stated that the loss in capital in a natural disaster was unlikely to affect GDP. In addition, Noy (2009) studied the macroeconomic consequences of natural disasters in short-term and found that there was no correlation between disaster population variables (fatalities and affected people) and GDP growth. He also claimed that the amount of property damage incurred during a natural disaster was a negative determinant of GDP growth. Moreover, countries with higher literacy rates, better institutions, higher per capita income, larger governments, and higher degrees of openness to trade appeared to be better able to bear the initial shock of a natural disaster and prevent its effects spilling deeper into the macro-economy.

In addition, Benson and Clay (2004) found a direct positive relationship between the population density and deteriorating GDP when natural disasters occur. Also, there is a positive correlation between the frequency of natural disasters and long-term economic growth in developing countries (Crespo Cuaresma et al., 2008). They showed that natural disasters in developing countries provided opportunities to update the capital equipment and adopt new technologies, and these resulted in economic growth in developing countries after natural disasters.

2.5.2 Income level

Apart from research on the impact of natural disasters on GDP, there has been a considerable amount of research devoted to evaluating the relationship between natural disasters and different income levels. Toya and Skidmore (2007) analysed the relationship between natural disasters and income levels in Organization for Economic Co-operation and Development (OECD) and developing countries. They showed that income was a significant factor in determining economic damage due to natural disasters, but its magnitude in developing countries was smaller than in the OECD. They also showed that income was not the only factor reducing economic damage from natural disasters; higher education, greater openness, a strong financial sector, and a smaller government were also important.

Income distribution is a critical factor in determining the death toll in natural disasters. Although a statistical analysis shows that rich and poor countries are both susceptible to natural disasters (Kahn et al., 2005), the poor suffer higher mortality rates after natural disasters (Ibarrarán et al., 2007, Kahn et al., 2005, Pelling and Uitto, 2001) because they have less resources to cope and their social networks also suffer during and after a natural disaster (Ibarrarán et al., 2007). Moreover, countries with a higher Gini coefficient experience a higher death toll from natural disasters. Therefore, improving income distribution is crucial because a more equitable distribution of income is usually associated with better coping abilities (Ibarrarán et al., 2007). Research on the human costs of natural disasters shows that poor communities suffer disproportionately in terms of mortality and injury (Zahran et al., 2008, Fothergill and Peek, 2004).

Qualified infrastructure, sufficient healthcare, rich evacuation system, appropriate communication and enough food and water resources which could ameliorate the situation after an injury and property damage due to natural disasters, are not accessible to the poor (e.g., Ibarrarán et al., 2007, Pelling and Uitto, 2001, O' Brien and Leichenko, 2000). There is also evidence suggesting that the poor do not have enough money to buy a qualified house so they just migrate to marginal areas and coastal regions which are prone to damage from natural disasters (e.g., Ibarrarán et al., 2007, Vaux and Lund, 2003, O' Brien and Leichenko, 2000). The economic impact of natural disasters in developing countries with low income levels such as Latin America and the Caribbean regions has been significant and has resulted in widespread destruction of the productive economy (Heger et al., 2008).

Many scholars believe that there is a negative relationship between income per capita and measures of risk from natural disasters (e.g., Toya and Skidmore, 2007, Anbarci et al., 2005, Kahn et al., 2005). Another study by Kellenberg and Mobarak (2008) showed that there was a positive non-linear relationship between deaths by disaster and income level. For example, they also found that in those countries with a GDP per capita level below 4500-5500 USD, deaths by disaster increased with income, but began to fall once they became richer than that pivotal point. A data analysis of Hurricanes Katrina and Rita in the U.S. in 2005 showed that these natural disasters affected people with different income levels unequally (Zahran et al., 2008). Natural disasters harm minorities and the poor more, indeed economic disadvantage, lower human capital, limited access to social and political resources, residential choices, and evacuation dynamics are the social factors that contribute to the very real differences in disaster vulnerability with race, ethnicity and economic class (Fothergill and Peek, 2004).

2.5.3 Affected population

One of the most distinguishing features of natural disasters is a population exposure to natural disasters that includes casualties (deaths and injuries). Many of the socio-economic and demographic variables are highly correlated to the deaths and injuries associated with natural disasters (Haque, 2003). Natural disasters killed around 3 million people between 1970 and 2002 worldwide (Yang, 2008). According to the United Nations (UN), since 2000, around 1.6 billion people lost their homes, livelihoods, or have suffered other damages due to natural disasters. The United Nation's Integrated Regional Information Network (IRIN) notes, "While the number of lives lost has declined in the past 20 years – 800,000 people died from natural disasters in the 1990s, compared with 2 million in the 1970s – the number of people affected has risen. Over the past decade, the total affected by natural disasters has tripled to 2 billion." (IRIN, 2005, page 3). According to data from the Spatial Hazard Events and Losses Database for the U.S., floods claimed the lives of 2,353 people from 1970–2000 (Zahran et al., 2008). This data also indicated that the risk of death by natural disasters is greater in areas with higher degree of socio-economic vulnerabilities. The other major factors affecting community in natural disasters is population density (e.g., Heger et al., 2008, Brooks et al., 2005, Pelling and Uitto, 2001); many scholars have investigated empirically that natural disasters can affect more people in highly populated regions (e.g., Noy, 2009, Wei, 2004, Haque, 2003). Age structure is another important population exposure indicator in natural disaster situations (Bolin and Stanford, 1991, Kilijanek and Drabek, 1979). Kilijanek and Drabek (1979) argued that the elderly and children are susceptible to face devastating consequences of disasters more than the others.

2.5.4 Other socio-economic indicators

Scholars have also considered many other socio-economic variables (either as dependent or independent) in their analyses including psychological and political. According to Lindell and Prater (2003), emotional distress caused by natural disasters often results in short-term and long-term psychological impact that cannot be measured in a census or in other official surveys. They also claim that the short-term psychological effects of natural disasters are much greater than the long-term effects. Race, ethnicity, age, and gender contribute to differing psychological reactions to natural disasters (Ibarrarán et al., 2007, Aptekar et al., 2000). The social network is an essential base for providing the necessary information resources prior to a natural disaster and a suitable source of support in the recovery period (Comfort et al., 1999a). Indeed, Ibarrarán et al. (2007) claimed that access to social networks prior to and during natural disasters reduces social vulnerability.

There is also enough evidence to suggest that natural disasters can cause political disruption (e.g., Bates and Peacock, 2008, Lindell and Prater, 2003, Bolin and Stanford, 1991). For example, Lindell and Prater (2003) showed that the construction of temporary housing leads to complaints not only by the residents, but also by other neighbours, particularly during the recovery periods. Eventually, this phenomenon can have a political impact when victim groups begin to mobilise. Bates and Peacock (2008) measured the cross-cultural impact of natural disasters on community conflicts and political instability in developing countries. Apart from political complaints in developing countries, Bolin and Stanford (1991) claimed there were political and social conflicts in the reconstruction phase of natural disaster management in the U.S.

Recently some scholars have done resrach on the role of insurance in natural disatsre risk management. For example, Peng et al. (2014) considered a multi-stakeholder perspective in developing a model to integrate the roles of insurance and retrofit in natural disaster risk. They suggested that it is possible to design insurance policies in which all stakeholders manage natural disasters effectively. Paudel et al. (2015) also scrutinised the relationship between insurance and socio-economic condition in flood risk management. They found that extreme climate change with a high sea level rise has a higher impact on flood insurance premiums compared with future socio-economic development.

2.6 Built environment condition

The term built environment came into broad usage in social science research in the 1980s. It emerged as a collective term describing the human-made surroundings that provide the setting for human activities (Crowe, 1997). Couple of years later, Amaratunga et al. (2002) emphasised that built environment draws upon a broad variety of established disciplines including natural sciences, social sciences, engineering and management. In addition, (Griffiths, 2004, P 721) described, "a range of practice-oriented subjects concerned with the design, development and management of buildings, spaces and places". Accordingly, the 2008 Research Assessment Exercise in the UK defined the built environment as encompassing the fields of architecture, building science and building engineering, construction, landscape, surveying, and urbanism (HEFCE, 2008). Although there have been different definitions of the built environment over the past three decades, Bartuska (2007) defined the built environment in the context of natural disaster risk management by synthesising four characteristics, including: (i) built environment is a broad concept and provides the foundation for all human endeavours, i.e., everything humanly designed, created, modified, constructed and maintained; (ii) built environment is intended to support human needs and values; (iii) built environment is created to help us, to mediate or change the environment for human comport and well-being; and (iv) each and all of the individual elements of built environment contribute either positively or negatively to the overall quality of an environment. The term 'built environment' refers to the products and processes made by humans for their activities (Roof and Oleru, 2008). It is a combination of facilities and infrastructure that people use as a core foundation for developing a society (Vanegas, 2003). It includes buildings, cities, transport infrastructure, water supplies, energy networks, green spaces, and other physical infrastructure (Roof and Oleru, 2008).

Having considered all above different definitions, in this thesis, the built environment is described as "Built environment is a combination of facilities and infrastructure that people use as a core foundation for developing a society. It draws upon a broad variety of established disciplines including natural sciences, social sciences, engineering and management. It includes physical assets, residential and non-residential buildings, commercial and industrial buildings, public buildings, infrastructure and utilities, all of which can potentially be exposed and vulnerable to natural disasters". Hence, infrastructure is regarded as a sub-set of the built environment in the context of this thesis.

Built environment is a significant segment of a national economy, for example, approximately 8% of GDP in the U.S. results in built environment architecture, engineering, and construction activities (Vanegas, 2003). Designing and building a resilient built environment needs a profound understanding of the expertise and knowledge of avoiding and mitigating the impact of natural disasters (Bosher, 2008, Lorch, 2005). Built environment draws upon a broad variety of established disciplines including natural sciences, social sciences, engineering and management (Amaratunga et al., 2002).

With socio-economic progress, the built environment becomes more vulnerable to natural disasters in terms of community loss and economic and infrastructure damages (Bosher, 2008, Menoni, 2002), because of the high construction cost of built facilities, especially in developed nations that used sophisticated design and high technology. Bartuska and Young (1994) categorised the significance of the built environment in the context of natural disasters into four groups as being: (i) the built environment is an extensive area which covers all human needs; (ii) the built environment is a product of human minds and purposes; (iii) the built environment protect us from disasters and changes of the environment for our comfort; and (iv) all the elements of the built environment contribute either negatively or positively to the overall quality of the environment.

The consequences of climate change in cities, buildings, and transport infrastructure include natural disasters such as wind storms, floods, and extreme weather, all of which have a direct and indirect impact on the built environment (Wilby, 2007). He collated the reviews of climate change and related natural disasters to four different areas, namely: (i) urban ventilation and cooling; (ii) urban drainage and flood risk; (iii) water resources; and (iv) outdoor space. His proposals to reduce the impact of climate change and related natural disasters on the built environment include: (i) appropriate building design and climate sensitive planning; (ii) avoidance of high-risk areas through more stringent development control; (iii) incorporation of climate change allowances in engineering standards applied to flood defences and water supply systems; and (iv) allocation of green space for urban cooling and flood attenuation. However, Hunt and Watkiss (2010) highlighted that the impact of natural disasters on energy, transport, and built infrastructure had received little attention from researchers over the previous decades. Table 2-4 shows the credible publications from the year 2000 onwards regarding the impact of natural disasters on different types of built environment facilities and infrastructure. Similar to socio-economic condition, scholars have studied the impact of flood disasters in the built environment more than other types of disasters. Furthermore, transport systems, buildings and cities have been identified as major built environment facilities and infrastructure that would be affected by natural disasters (see Sections 2.6.1 and 2.6.2 for detailed discussion). Bosher et al. (2007a) found that the most significant threats to the built environment in the UK were considered to be floods.

Table 2-4: Previous research on the built environment condition

Natural disaster	Built environment type	Credible publication
Flood	Dam, transport system, building	(Kim et al. (2012), Lertworawanich (2012), Zahran et al. (2008), Brody et al. (2007), Sohn (2006), Suarez et al. (2005), Merz et al. (2004))
Earthquake	Building, port and harbour, transport system,	(Okeil and Cai (2008), Roberts (2008), Tas et al. (2007), Nicholls (2004), Chang (2003b), Kim et al. (2002), Wood et al. (2002), Chang and Nojima (2001), Chang (2000), Cho et al. (2000))
Hurricane	Bridge	Okeil and Cai (2008)
All natural disasters	City, transport system, building	(Hochrainer and Mechler (2011), Blong (2004), Hoshiya et al. (2004), Lisø et al. (2003), Torres-Vera and Antonio Canas (2003), Menoni (2002))

2.6.1 The impact of natural disasters on transport infrastructure

London Climate Change Partnership (LCCP) in 2002 conducted a study to investigate the impact of natural disasters on the London transport infrastructure (LCCP, 2005). The major areas of impact include: (i) increased disruption to transport systems by extreme weather; (ii) higher temperatures and reduced passenger comfort in the London Tube; and (iii) damage to infrastructure through buckled rails and rutted roads.

There are also a few studies that scrutinised the impact of natural disasters on transportation networks, roads and bridges (e.g., Lertworawanich, 2012, Sohn, 2006, Kim et al., 2002, Cho et al., 2000). Sohn (2006) analysed the significance of highway networks in Maryland, U.S. due to flooding. An accessibility score was used to quantify the potential impact of flood damage on the state transportation system and distance and traffic flow criteria were used to determine the significance of highway network links. He showed that the significance of highway network links assessed by the distance-only and distance-traffic volume criteria appeared to be quite different when accessibility loss at the country level was compared.

Okeil and Cai (2008) conducted a comprehensive survey of short and medium-span bridge damages caused by Hurricane Katrina in 2005. The bridges covered in their study included road and railway bridges, movable and stationary bridges, reinforced or pre-stressed concrete and steel bridges. Another study noted that in the second half of 2011, more than 3,330 national highways were damaged by floods in Thailand, where some roads were destroyed while others were only partially damaged and emergency relief could not access the flooded areas (Lertworawanich, 2012). He also presented a decision model for sequential highway network restoration when budgets and resources were unknown.

Wood et al. (2002) reported that ports and harbours are elements of transport systems that are particularly vulnerable to natural disasters such as earthquakes, landslides and tsunami inundation because they are located in sea level areas. They claimed that very little attention had been given to developing natural hazard mitigation and preparedness strategies for ports and harbours despite the fact they are key community resources. Chang (2000) explored the impact of earthquakes on ports by focusing on international container traffic, he claimed that mitigation or preventive action provided the best solution for dealing with the impact of natural disasters on ports. Pre-disaster mitigation or preventative actions for transport system identified in the literature include (Chang, 2000, Werner et al., 2000, Eguchi, 1996): (i) soil strengthening; (ii) seismic design; (iii) retrofit inter-modal facilities; and (iv) pre-disaster mitigation tasks. This study focuses on transport infrastructure, namely roads and bridges as the built environment type.

2.6.2 The impact of natural disasters on cities and buildings

The two most recent Intergovernmental Panel on Climate Change (IPCC) reports, in 2007 and 2012, drew conclusions about the effects of (i) climate change and (ii) natural disasters associated with climate change from a city-scale perspective. The effects of a rise in sea level on coastal cities, and extreme events (tropical cyclone, heat waves, and flooding, etc.) on built infrastructure, on energy use and on the availability of water and resources were reported as the most important impacts that climate change and related natural disasters would have on cities (Hunt and Watkiss, 2010, Wilby, 2007, Kreimer et al., 2003). Hunt and Watkiss (2010) presented a comprehensive study that addressed the impact of climate change such as natural disasters, and a formulation of appropriate responses at a city-scale for two cities, i.e. London and New York, that are relatively advanced in the assessment of climate risks and adaptation. The high population density of these cities and their importance for economic and social activities, including their roles as centres of administrative governance, highlights the value of city-scale assessments. They found that most studies to date had primarily focused in qualitative assessments on coastal cities, and also claimed that natural disasters due to climate change produced potentially significant factors that must be considered when making medium-to-long-term decisions relating to patterns of development in infrastructure. Sherbinin et al. (2007) compared the climate vulnerabilities of three coastal megacities: Mumbai, Rio de Janeiro, and Shanghai, and reported that damages from natural disasters were approximately 0.1% of Gross Regional Product (GRP) annually at the city scale. Similarly, Brody et al. (2007) examined the relationship between the built environment and the impact of floods in Texas, and stated that alterations to the wetlands, impervious surfaces and dams had played an important role in mitigating flood damage at the city level.

Natural disasters such as extreme weather, flooding, earthquakes, bushfires and storms have devastating effects on buildings (Blong, 2004). New buildings will need to be designed to cope with the effects of climate change and natural disasters (ARUP, 2006). However, construction of a building is a complex process involving various actors, especially in non-residential buildings, who may optimise their own part of the process, and there is often no system to optimise the total building process (Roberts, 2008, United Nations Environment Programme UNEP, 2007). For residential buildings, on the other hand, stakeholders focus only on the short-term displacement of population based on emergency management models (McEntire, 2005). Permanent housing along with concerns about vulnerability, housing availability and land development have not been considered by natural disaster management planners (Levine et al., 2007). ARUP (2006) claimed that more resistant residential buildings could be constructed in areas prone to natural disasters, particularly flood and storm. Mitigation measures identified in the literature included (Roberts, 2008): (i) avoiding the use of plasterboard and gypsum-based materials; (ii) fitting anti-back flow valves in sewer and drain pipes; (iii) designing buildings to allow for easy drainage and quick drying; (iv) insulating buildings against extreme weather; and (v) avoiding glass patio doors, large windows and conservatories with large areas of glass because they are susceptible to damage due to hydrostatic and hydrodynamic forces.

2.7 Tools and techniques

In the literature, the tools and techniques that were of assistance in NDRM over the past two decades are: (i) natural disaster evaluation techniques and (ii) natural disaster indices, both of which are presented next.

2.7.1 Natural disaster evaluation techniques

There has been an increasing interest in utilising quantitative techniques to evaluate the impact of natural disasters on the socio-economic and built environment conditions. The natural disaster evaluation approaches by scholars over the 21st century can be broadly classified into: (i) statistical approaches; (ii) macroeconomic models; and (iii) decision-making approaches. Table 2-5 summarises the techniques for evaluating natural disasters and the analytical or modelling tools. Statistical approaches, particularly regression models, are the dominant techniques in literature. While natural disaster risk modelling using statistical approaches is very common, estimating and modelling the consequences of natural disasters with macroeconomic models is a challenging task, with fewer studies identified in literature. Albala-Bertrand (1993) examined the relationship between a natural disaster situation and its potential effects on the growth rate of output by applying macroeconomic models. Barredo (2009) normalised flood losses by considering the effects of changes in population, wealth and inflation at the country level by adjusting the losses for purchasing power parties. Skidmore and Toya (2002) investigated long-term relationships between natural disasters, capital accumulation, total factor productivity, and economic growth by taking advantage of the Cobb-Douglas production function.

Table 2-5: Natural disaster evaluation techniques in NDRM studies

Evaluation technique	Analytical/modelling tool	Authors/researchers
Statistical approaches	Hausman-Taylor, three-step regression, gravity equation, log-log regression, stepwise linear regression, Pearson's correlation coefficient, negative binominal estimation, multiple regression, Structural Equation Modelling	(Chen et al. (2012), Crespo Cuaresma et al. (2008), Heger et al. (2008), Kellenberg and Mobarak (2008), Raschky (2008), Masozera et al. (2007), Tas et al. (2007), Toya and Skidmore (2007), Anbarci et al. (2005), Brilly and Polic (2005), Brooks et al. (2005), Haque (2003), Winchester (2000))
Macroeconomic models	Herfindahl-Hirschman index, macroeconomic catastrophe simulation	(Hochrainer and Mechler (2011), Barredo (2009), Heger et al. (2008), Skidmore and Toya (2002), Albala-Bertrand (1993))
Decision-making approaches	DEA, Delphi, BSC, DSS, PSO	(Chen et al., 2012, Lertworawanich (2012), Mirfenderesk (2009), Moe et al. (2007), Brooks et al. (2005), Wei (2004), Hall et al. (2003), Vaughan and Spouge (2002))

Some attempts have been made to use decision-making models to analyse the impact of natural disasters on the socio-economic and built environment conditions; for example, the Delphi survey and Balanced Scored Card (BSC), which are widely accepted and used in the context of business management, have occasionally been utilised to interpret climate related disaster indicators through expert judgment (e.g., Moe et al., 2007, Brooks et al., 2005, Vaughan and Spouge, 2002). However, little attention has been given to the use of decision-making models in analysing the impact of natural disasters in the built environment. Lertworawanich (2012) used the particle swarm optimisation (PSO) technique to provide practical solutions to the problem of recovering sequential highway networks after flooding. Wei (2004) used a data envelopment analysis (DEA)-based model for assessment of regional vulnerability to natural disasters. He included a range of variables, both economic and social in the DEA, without the need to generate weights for attribute for ranking regional vulnerabilities to flooding in China. In Australia, flood management authorities began using computer and communication technologies to develop a Decision Support System (DSS) that can control flood emergency operations more effectively (Mirfenderesk, 2009).

2.7.2 Natural disaster indices

Indices have been widely applied in social capital and capacities which measure the quality of life, human development, social vulnerability and preparedness for emergency (Simpson and Katirai, 2006, Davidson and Lambert, 2001, Davidson, 1997). In NDRM studies, researchers have named their indices differently, these include: Hurricane Disaster Risk Index (HDRI), Coastal City Flood Vulnerability Index (CCFVI), Risk Management Performance Index (RMI), Vulnerability Index (VI) and Disaster Preparedness Index (DPI). Table 2-6 shows some NDIs that have been developed over the past two decades for planning and decision-making purposes.). In essence, they are considered Natural Disaster Index (NDI) in this study. The NDI plays an important role in measuring natural disaster preparedness, resilience, natural disaster mitigation efforts, social vulnerability to natural disasters and hazard exposure. NDI also supports natural disaster resource allocation, high level planning decisions and public education efforts in NDRM (Davidson and Lambert, 2001). They explained that NDIs are appealing because they summarised a substantial amount of technical information in a way that people could easily understand. The benefits include (Simpson and Katirai, 2006, Cutter et al., 2003, Davidson and Lambert, 2001): (i) providing a more dynamic picture of a natural disaster; (ii) allowing a comparison of vulnerability among different communities; (iii) facilitating an efficient allocation of scarce resources; (iv) assessing disaster risk more effectively and accurately; and (v) understanding community preparedness.

Table 2-6: Recent publications in natural disaster indices

Author(s)	Natural disaster	Details of index
Balica et al. (2012)	Flood	Coastal City Flood Vulnerability Index (CCFVI) is based on exposure, susceptibility and resilience to coastal flooding. The index demonstrates vulnerability of coastal flooding with considering hydro-geological, socio-economic and politico-administrative conditions. The CCFVI is obtained as: $CCFVI = \frac{E \times S}{R}$ E, S, and R stand for exposure, susceptibility, and resilience, respectively. CCFVI provides a means of obtaining a broad overview of flood vulnerability and the effect of possible adaptation options. This, in turn, will allow for the direction of resources to more in-depth investigation of the most promising strategies.
Carreño et al. (2007)	Any natural disaster	A NDRM performance index was developed to integrate four policies namely disaster risk identification, risk reduction, disaster management, and governance and financial protection. The index is obtained as: $RMI = \frac{\sum_{i=1}^{N} w_i I_{ic}^{t}}{\sum_{i=1}^{N} w_i}$ Where w_i is the weight assigned to each indicator, corresponding to each indicator for the territorial unity taken into consideration and in the time period t.
Peduzzi (2006)	Flood, cyclone, drought, earthquake	They developed multiple logarithmic regression model for natural disasters to measure the number of killed from catastrophes. The developed formula for flood disaster index is as follows: $Ln(K) = 0.905Ln(PhExp) - 0.697Ln(GDP_{cap})4.799$ Where K is the number of killed from floods, PhExp is the physical exposure to floods and GDP per capita is the normalized GDP per capita.
Davidson and Lambert (2001)	Hurricane	Hurricane Disaster Risk Index (HDRI) is developed to compare the risk of hurricane disaster in U.S. coastal counties. They introduced HDRI as follows: $HDRI = H \times E \times V \times [0.1(1-a) \times R + a]$ where the variables H, E, V, and R represent the hazard, exposure, vulnerability, and emergency response and recovery factor indices, respectively. The HDRI is intended to support local, state, and national government agencies as they: (i) make resource allocation decisions (ii) make high level planning decision, and (iii) raise public awareness of hurricane risk

Apart from the benefits of developing NDIs, there are some issues and problems in their development including issues related to subjectivity, bias, weighting, mathematical combinations, and selection of indicators and data sources (e.g., Davidson and Lambert, 2001, Cobb and Rixford, 1998, Cutter, 1996). Although expert opinion increases subjectivity in generating weights for indicators, mathematical modelling is more objective in nature. Mathematical modelling reduces the level of subjectivity for weighting by utilising mathematical procedures such as a standard regression analysis or a factor analysis (Dwyer et al., 2004). Davidson (1997) utilised a regression and factor analysis to reduce the subjectivity and weighting issues in NDI.

2.8 Summary

This chapter has presented a taxonomy of previous research on natural disaster risk management and its connections with the exposure and vulnerability of socio-economic and built environment to natural disaster. The review shows that most studies in the field of disaster mitigation planning have fallen under specific topics such as: natural disaster mitigation planning, public participation in natural disaster mitigation planning, land use planning and structure versus non-structural approaches to natural disaster mitigation. There is not enough attention in literature on disaster stakeholder management in terms of stakeholder definition, classification, attributes, and stakeholder proactive and/or reactive approaches to managing natural disasters. In addition, no research has been found that investigated the role of stakeholder attributes on (i) natural disaster damage on the socio-economic and built environment and (ii) stakeholder proactive and reactive approaches in natural disaster risk management.

The second part of this review found that, natural disaster damage has dramatically increased over the past decades. This phenomenon happens because countries with a vulnerable age structure, lower income and GDP, poor institutions, vulnerable population and high density of population suffer more from the impact of natural disasters. Level income has direct relationship with natural disaster impact. For example, rich nations experience less natural disaster damage comparing with low level income society. This review also found that the majority of the scholars have evaluated the impact of natural disasters on the socio-economic and built environment conditions separately. Transport infrastructure, buildings and cities, have been identified as major types of built environment that are affected by natural disasters. It is found that in recent years, flood was the leading cause of damages in society, economy, and that transport infrastructure has been identified as one of the most vulnerable built environment types against flooding. While flood cannot be eliminated, resilient built environments are those where the stakeholders manage natural disasters proactively by practicing more mitigation and preparedness activities. Above all, although researchers and practitioners have developed different tools and techniques particularly natural disaster indices, there is a significant gap in investigating how natural disaster risk management activities interrelate with stakeholder attributes to developing an index to measure stakeholder proactive, reactive, and overall approaches. In addition, the developed natural disaster indices have not considered stakeholder approaches and their mitigation, preparedness, response and recovery activities. These activities in natural disaster risk management have a direct impact on stakeholder proactive and reactive approaches and will be modelled in this thesis. Furthermore, an index that measures the proactive and/ or reactive approaches of prospective stakeholders in natural disaster risk management is another focus of this study.

CHAPTER

3

Theoretical Framework

3.1 Introduction

This chapter begins with the concepts and theories that underpin disaster risk management (Section 3.2). The content of this section is applicable for both natural and technological disasters; thus, disaster has been used as a general term. The theoretical framework is proposed in the following section (Section 3.3). After which, the role of stakeholder attributes in disaster risk management is highlighted (Section 3.4), followed by an integration of theories and paradigms into the proposed theoretical framework (Section 3.5).

This chapter addresses the first research objective, which is to develop a theoretical framework for the role of stakeholder attributes on natural disaster damage, and stakeholder proactive and reactive approaches to NDRM.

3.2 Theoretical underpinnings of disasters

Scholars have studied the impact of natural disasters on the socio-economic and built environment conditions quite extensively as presented in Chapter 2, but there are still two issues that suggest further theoretical development is needed. First, there is a lack of stakeholders' mitigation and preparedness activities before and during natural disasters (Bosher et al., 2007b, Pearce, 2003, Perry and Lindel, 1978). Bosher et al. (2009) noted there is still not enough evidence to indicate that key stakeholders are playing a proactive role in NDRM in the built environment, and that proactiveness is absent from their decision-making processes. In addition, little attention has been given to systematically theorising the approaches taken by stakeholders to manage natural disaster risks. Second, many researchers have focused on similar underlying theories and heuristics in the context of NDRM (Sementelli, 2007, McEntire, 2004). For example, crisis and chaos theory has become an increasingly fundamental theory used by scholars to support their research into NDRM (Ritchie, 2004, Pearson and Clair, 1998, Pauchant and Douville, 1993, Pearson and Mitroff, 1993, Shrivastava, 1993). Furthermore, previous research has tended to fall into the realm of rules, procedures, and policies that apply similar theories rather than integrating other administrative theories to address approaches and decisions made by stakeholders before, during, and after natural disasters.

3.2.1 Overview of disaster theories and their applications

Many theories have been used in literature for theorising disasters, and indeed administrative and leadership theories have been fundamental pillars for building organisational capabilities through crisis management activities (Wooten and James, 2008, Boin and Hart, 2003). Paraskevas (2006) used complexity theory to introduce a complexity-informed framework to design an effective crisis response system for organisations in disastrous situations. This means that disaster studies should be expanded to incorporate a political and administrative perspective on crisis management (Rosenthal and Kouzmin, 1997). Stallings (2002) claimed that sociological theory, including conflict theory, political sociology, and the application of Max Weber's political sociology, could provide important insights into disaster studies because the structure of a society, which is hidden in everyday affairs, is vulnerable to disasters. Gotham (2007) used critical theory to explore the processes and conflict over efforts to present tragic events as spectacles, by focusing on the Hurricane Katrina disaster. Interestingly, over the past decade, there has been a significant emphasis on disaster risk management studies in the tourism industry from proactive pre-crisis planning through strategic implementation (Hystad and Keller, 2008, Ritchie, 2004, Faulkner, 2001).

Sementelli (2007) reviewed extensive literature on the theories of disasters by focusing on a concern for tools and a process to categorise them into four groups, namely: (i) decision theories; (ii) administrative theories; (iii) economic theories; and (iv) social theories. Decision theories use a series of stages, steps, heuristics or procedures to cope with disasters. Administrative theories tend to emphasise processes as well as tools. Economic theories tend not to focus on process or tactical outcomes, but instead present abstractions to cope with the long-term economic impact of disasters. Finally, social theories try to tackle disasters by process-oriented actions. Sementelli (2007) urges that substantial advancements are needed in the development of theory and theorising in disasters and crises, and suggests that decision and administrative theories could help managers attain an acceptable solution to the problem.

Crisis management theory has become an increasingly dominant theoretical pillar for scholars to support their research on disaster risk management (e.g., Ritchie, 2004, Pearson and Clair, 1998, Pauchant and Douville, 1993, Pearson and Mitroff, 1993). Shrivastava (1993) identified the urgency of decision, large impacts and restrictions in a system as the fundamental characteristics of crisis. Parsons (1996) suggested three types of crises, namely: (i) an immediate crisis where little or no warning exists; (ii) an emerging crisis which is slow to develop; and (iii) a sustained crisis that last a long time. Ritchie (2004) argued that strategies to deal with these three crisis situations would vary depending on the time pressure, the extent of control and their magnitude. Crisis management theory is a holistic process involving prevention, planning, acute response, and recovery and learning (Boin and McConnell, 2007). There are, however, some limitations to applying crisis management theory to disaster risk management perspectives (Boin and McConnell, 2007, McConnell and Drennan, 2006, Kumar, 2000), these include: (i) preventing all disasters is impossible; (ii) there are political, cognitive, informational, cultural and resource barriers to prevent every possible disaster; (iii) crisis planning cannot solve all the problems or make all situations better, and (iv) crisis management cannot cover all phases of a disaster risk management. Although approaches of stakeholders who are involved in NDRM should be systematically analysed and anticipated in managing natural disasters (Bosher et al., 2007b, Hsu et al., 2004), there is little evidence from previous studies into NDRM that ideas from stakeholder theory have been borrowed. In addition, despite the variety of applications of theories to disaster risk management, very little attention has been given to the built environment.

3.2.2 Disaster theories and the built environment

Emergency management theory has been widely used into disaster risk management in the built environment (Sementelli, 2007, McEntire et al., 2002, McEntire, 2001). It refers to management of resources and responsibilities for dealing with all aspects of emergencies, in particularly preparedness, response and recovery (McEntire, 2001). Emergency management involves plans, procedures and mandates established to immerse the normal endeavours of government, voluntary and private agencies in a thorough and coordinated way to respond to the whole spectrum of emergency needs (McEntire, 2004).

However, there is a huge gap between theory and practice that needs to be bridged by focusing on human, technology, and buildings (Janssen et al., 2010). There are two fundamental problems to apply emergency management theory to NDRM in the built environment (Covington and Simpson, 2006, McEntire et al., 2002): (i) it explains what emergency situations are, but not natural disasters and (ii) it focuses on emergency management which makes the field reactive and limits its applicability for a proactive approach. In other words, emergency management deals with response and recovery activities or reactive approach and the proactive approach including mitigation and preparedness activities are absent in emergency management.

In fact, numerous researchers have doubted any real theoretical disciplinary development for NDRM in the built environment because most of the contributions do not have the specific aim of creating a comprehensive approach to NDRM (e.g., Haigh and Amaratunga, 2010, Bosher, 2008, Alexander, 1997). The uniqueness of communities and individuals and multi-disciplinary nature of the built environment make the situation complicated for developing a comprehensive theory for NDRM. Indeed, NDRM is still an under-developed area in the built environment (e.g., Brandon and Lombardi, 2010, Knight and Ruddock, 2009, Covington and Simpson, 2006, Loosemore, 1999, Betts and Lansley, 1993). Haigh and Amaratunga (2010) presented an integrated review of the literature to explore the potential role of the built environment in the development of society's resilience to natural disasters. Their review supports the calls for a multi-sector and interdisciplinary approach to natural disaster risk management in the built environment. They urged for the development of a theoretical framework for disaster risk management in the built environment in which the first step should involve the amalgamation and juxtaposition of an interdisciplinary strategy for disaster risk management. A suitable theoretical framework should explore the interaction between the built environment, its disciplines and the process of disaster risk management. Furthermore, it is important to understand the nature of the stakeholders involved in the creation and maintenance of the built environment to theoretical development, because stakeholders have a vital role to play in effective disaster planning (Haigh and Amaratunga, 2010). Therefore a theoretical framework with considering the role of stakeholders and their attributes and approaches is highly required in the natural disaster risk management context which is developed in this thesis in the next section.

3.3 Theoretical Framework

The context for this study is the stakeholder attributes and approaches to NDRM in the built environment (see Sections 2.4 and 2.6). Figure 3-1 depicts the proposed theoretical framework that demonstrates the inter-relationships between 12 constructs. These constructs are discussed in turn in Chapter 4. It can be seen that the proposed theoretical framework was constructed in two main segments. Segment one is on the role of: (i) natural disaster characteristics; (ii) exposure and vulnerability of socio-economic; (iii) exposure and vulnerability of the built environment; and (iv) stakeholder attributes in determining the damage from natural disasters. Segment two focuses on the effect of stakeholder attributes on their proactive and/or reactive approaches. Stakeholder theory and decision-making paradigms are the theoretical pillars used to justify the proposed theoretical framework.

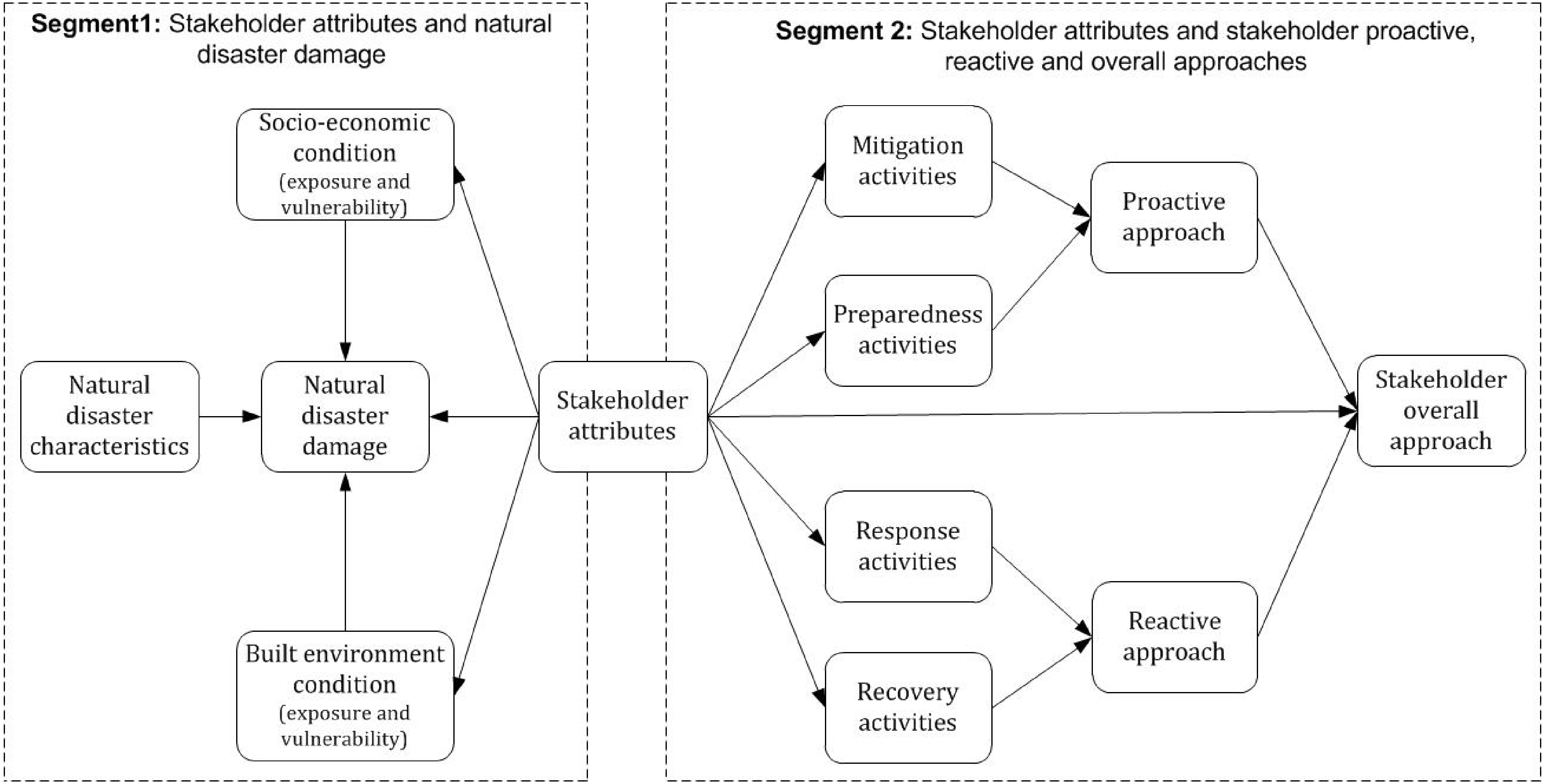


Figure 3-1: The proposed theoretical framework

3.4 Underpinning theories of the theoretical framework

Based on the two issues on theoretical development (see Section 3.2) and review of theories used, stakeholder theory and decision-making paradigms are theoretical pillars for justifying the theoretical framework in this study. They were evaluated carefully to discuss whether both theory and paradigms could be used to justify the proposed theoretical framework.

3.4.1 Stakeholder theory

The issue of organizational performance has always been the matter of controversy by strategic management scholars (Harrison et al., 2010). They have tried to explain why some firms outperform others, and eventually they have found that stakeholder concepts played an important role in this discussion (e.g., Harrison et al., 2010, Phillips et al., 2003, Rumelt et al., 1994). Similarly, the idea of stakeholder theory is borrowed in this study to explain what stakeholder attributes play an indispensable role in (i) natural disaster damage and (ii) stakeholder proactive and reactive approaches in NDRM. Stakeholder theory is a theory of organisational management and ethics, and distinguishes the pivotal attributes leading to organisational performance (Phillips et al., 2003). Freeman (1984) introduced power, legitimacy and urgency as three distinct stakeholder attributes which are playing essential role in a firm's performance.

Although some other organisational theories also cover the concept of power and legitimacy, most of them explain their roles independently, they do not explain stakeholder classification and justify why power and legitimacy are important factors in defining stakeholder approaches (e.g., Phillips, 2003, Mitchell et al., 1997, Donaldson and Preston, 1995). Furthermore, urgency is not the main focus of any organisational theory (Mitchell et al., 1997), therefore stakeholder theory overshadows the other organisational theories in terms of considering all three stakeholder attributes in an integrated framework (Mojtahedi and Oo, 2014b).

By utilising stakeholder theory, pivotal stakeholders in NDRM can be identified, by considering their power, legitimacy and urgency attributes. A generic set of stakeholders in managing natural disasters in the built environment would include local government, general contractors, subcontractors, suppliers, architects/designers, structural and civil engineers, urban planners, emergency relief organisations, financial institutions, insurance companies and the affected local community (Bosher et al., 2009, Moe and Pathranarakul, 2006). Power and legitimacy help stakeholders bring about the outcomes they desire (Mitchell et al., 1997), so these attributes are crucial for stakeholders to take proactive approaches against natural disasters in the built environment. In other words, a combination of power and legitimacy can create authority for stakeholder organisations to take proactive responses independently (Phillips et al., 2003). For a reactive approach, however, urgency helps stakeholders to respond in a timely fashion during or after natural disasters.

Stakeholders, whether individuals or groups, choose how to cope with natural disasters in their natural, society and built environments (Peek and Mileti, 2002). Simon (1991) used decision-making paradigms to justify how stakeholders behave acceptably, but not often optimally, based on their limited knowledge and within constraints set by the social system in which they live (Simon, 1991). Stakeholders are becoming increasingly frustrated not only with being excluded from the decision-making process, but also with being excluded from disaster management planning (Pearce, 2003, Rubin and Barbee, 1985). Apart from stakeholder attributes, the decision-making process can definitely induce stakeholders to conduct proactive and/or reactive approaches. Harrison et al. (2010) claimed that stakeholder theory should consider the role of the decision-makers and decision-making paradigms, including their decisions and who takes advantage of the outcomes of those decisions. In the next section, how decision-making paradigms can affect stakeholder attributes and approaches in NDRM is explained.

3.4.2 Decision-making paradigms

In a decision-making process, one is supposed to choose one, or some choices over different alternatives, while considering the deficiency of knowledge and future uncertainty (Shih et al., 2007). Decision-making theories have been an imperative pillar for theorising about crises and disasters; they emerged from studies by many researchers, particularly Simon (1976)/1945, Allison and Zelikow (1971), and Cohen et al. (1972). Context of perception, information access, and data quality have been the main research areas using decision theories in disasters and crises (Sementelli, 2007). The kind of decision-making with which this body of theory deals is as follows: given the two possible approaches to a decision-maker, into either one a stakeholder may put himself, the stakeholder chooses proactive rather than reactive (or vice versa). The theory of decision-making is a theory about how to predict such decisions (Edwards, 1954). Prospect theory introduced by Kahneman and Tversky (1979) significantly advanced decision-making theory by considering the theory of risky choices. This theory enriches the decision-making theory by addressing three principles, namely: (i) expectation; (ii) asset integration; and (iii) risk aversion. All the above mentioned theories in decision-making have utilised two decision-making paradigms, namely: (i) the value maximisation paradigm and (ii) the intuitive reasoning paradigm (Ariely, 2009). These two paradigms help decision-makers realise a stakeholder behavioural approaches to disasters, albeit the domain of decision theory is extensive and includes different attributes and paradigms such as risk perception, uncertainty, and complexity (Sementelli, 2007). The first paradigm assumes that humans have a tendency to maximise the value of selected alternatives based on their desires, while the latter paradigm assumes that decisions by humans are influenced by complicated factors. Therefore, in value maximisation paradigms, people behave rationally, but in intuitive reasoning paradigms they might involve irrelevant factors in their decision-making process (Ariely, 2009, Levy, 1992). There are not enough formal models to estimate the probabilities of events such as the result of an election, the future value of money, the impact of disasters, so an intuitive reasoning paradigm is the only practical method for assessing uncertainty (Tversky and Kahneman, 1983). Based on the concept of expected utility, the value maximisation paradigm proposes that a decision-maker will choose the alternative that maximises the weighted factors obtained by utility functions (Ariely, 2009). Von Neumann Morgenstern Theory (VNMT), under the value maximisation paradigm, explains that a person or unity is rational if, and only if, their behaviour maximises the expected value of the set of possible outcomes (Von Neumann and Morgenstern, 1945).

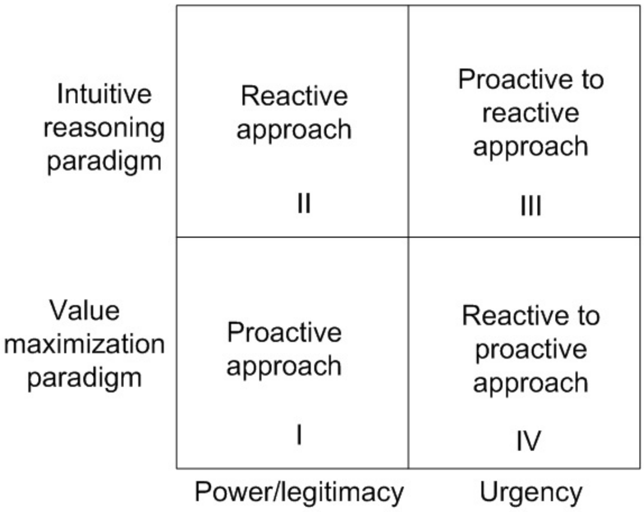
The notion of decision-making paradigms in realising stakeholders' different decisions in coping with natural disasters has not been evaluated adequately in the literature, indeed little is known about the different paradigms involved in the stakeholders' decision-making process in NDRM activities and approaches. Therefore, an integration of stakeholder theory and decision-making paradigms in justifying the relationships between stakeholder attributes, natural disaster damage, NDRM activities and stakeholder proactive and reactive approaches is provided in the next section.

3.5 Integration of theories into the theoretical framework

In supporting the proposed theoretical framework, stakeholder theory was enriched by decision-making paradigms in order to justify how stakeholder attributes result in proactive and /or reactive approaches and natural disaster damage reduction. The nature of stakeholder theory suggests that the relative importance of stakeholders in decision-making process depends on their attributes (Mitchell et al., 1997), whereas decision-making theory assumes that humans have a tendency to maximise the value of selected alternatives based on their desires (Tversky and Kahneman, 1983). However, decisions by humans are influenced by complicated factors and therefore stakeholders behave rationally in their decision-making, but on some occasions they might involve irrelevant factors in selecting alternatives (Ariely, 2009, Levy, 1992, Von Neumann and Morgenstern, 1945).

Although the application of decision theory in disaster risk management is quite clear, it offers little from the perspective of theory development, possibly because disaster risk management is still in its infancy and developing (Sementelli, 2007). A combination of stakeholder theory and decision-making paradigms would open the way to justify the role of stakeholder attributes on natural disaster damage, and on stakeholder proactive and reactive approaches.

Figure 3-2 presents the matrix of stakeholder attributes and decision-making paradigms that consists four boxes on their implications on stakeholder proactive and reactive approaches. Power is the key attribute affecting stakeholder decision-making, and legitimacy is another important attribute which enables stakeholders to take risks in their decision-making (Olander, 2007).



	Power/legitimacy	Urgency
Intuitive reasoning paradigm	Reactive approach II	Proactive to reactive approach III
Value maximization paradigm	Proactive approach I	Reactive to proactive approach IV

Figure 3-2: Matrix of decision-making paradigms with stakeholder attributes

It is obvious that the power and legitimacy of stakeholders does not guarantee a proactive and/or a reactive approach, it occurs because power and legitimacy do not necessarily lead to noticeable decisions by stakeholders (Mitchell et al., 1997). The power and legitimacy of stakeholders results in a proactive approach if they consider a value maximisation paradigm in their decision-making process (Box I), that is, they opt for mitigation and preparedness activities before disasters in order to minimise the negative consequences of disasters. Although the power and legitimacy attributes of stakeholders help them to take proactive approaches against disasters, they might be reactive by making irrational decisions in their strategies based on intuitive reasoning paradigms (Box II). Despite stakeholders have a tendency to taking a proactive approach in NDRM, they might take a reactive approach because of the intuitive reasoning paradigm involved in their decision-making process.

Urgency is the third stakeholder attribute, which contributes to migrating from a reactive to a proactive approach and vice versa in NDRM. Mitchell et al. (1997) argued that time sensitivity and criticality are two criteria that arise from urgency. Time sensitivity defines the degree to which stakeholders delay in approaching claims or disasters before events and criticality is the importance of claims or disaster activities. Stakeholders behave acceptably, but not often optimally, based on their limited knowledge and within constraints set by the social system in which they live (Simon, 1991); hence, they might shift from a proactive to a reactive approach because of urgency and the intuitive reasoning paradigm. In other words, if stakeholders prioritise their claims in the wrong order, their decisions lead to a reactive approach based on intuitive reasoning paradigms (Box III). Furthermore, stakeholders may attempt to maximise the value of their decisions in emergency cases in order to learn how to be proactive rather than taking a reactive approach (McEntire, 2001). Urgent stakeholders can shift from a reactive approach to more proactive behaviour if they consider value maximisation paradigms in their decision-making (Box IV).

3.6 Summary

This chapter proposed a theoretical framework to theorising the role of stakeholder attributes in determining natural disaster damage in society, the economy, and the built environment in one hand, and in determining stakeholder proactive and reactive approaches in another hand. The theoretical framework has proposed that there is a relationship between stakeholder attributes and natural disaster damage by considering other environmental factors including: natural disaster characteristics and exposure and vulnerability of the socio-economic and built environment. At the same time, the relationship between stakeholder attributes and NDRM activities including:

mitigation, preparedness, response and recovery has been also considered. These relationships have not been empirically investigated in literature.

In addition, the proposed theoretical framework advocated the need to simultaneously consider the socio-economic and built environment exposures in NDRM studies (i.e. research problem 1). Stakeholder theory and decision-making paradigms have been utilised in this study to justify the above mentioned relationships in the proposed theoretical framework. The power and legitimacy of stakeholders results in a proactive approach if they consider value maximisation paradigms in their decision-making process, but powerful and legitimate stakeholders cannot always take a proactive approach because they may make a wrong decision based on the intuitive reasoning paradigm. Urgency can cause stakeholders to shift from a proactive approach to reactive behaviour by including intuitive reasoning paradigm in their decisions. Alternatively, urgency can pave the way for less proactive stakeholders to migrate from response and recovery activities to mitigation and preparedness activities by considering value maximisation paradigms in their built environment NDRM strategies.

In addressing the first research objective (Section 1.3), the next chapter presents a review of the identified key constructs and measurement indicators for flood risk management in transport infrastructure across NSW, Australia, by operationalizing the proposed theoretical framework. In addition, relevant hypotheses are developed in the next chapter.

CHAPTER

4

Operationalisation of Theoretical Framework into Flood Risk Management in Transport Infrastructure

4.1 Introduction

This chapter focuses on flood risk management (FRM), transport infrastructure and the operationalisation of the respective constructs in the proposed theoretical framework (Sections 4.2 to 4.13). For each construct, the corresponding section presents a review of the literature on its concept and a specification of its measurement indicators. Finally, hypotheses are developed in the relevant sections.

4.2 Operationalisation of theoretical framework into FRM

The context of this study is on natural disaster risk management in the built environment focusing on the stakeholder attributes and approaches of Local Councils as stakeholders to FRM in transport infrastructure. Although some scholars have scrutinised stakeholder involvement in FRM (e.g., Bosher et al., 2007a, Hall et al., 2003, Vari et al., 2003), no research has been found that investigated stakeholder attributes of power, legitimacy, and urgency in flood damage and stakeholder proactive and reactive approaches in FRM. Figure 4-1 depicts the operationalisation of the proposed theoretical framework (see Section 3.3) into FRM in transport infrastructure that demonstrates the inter-relationships between 12 constructs with 14 hypotheses.

Table 4-1 shows the constructs and the measurement indicators operationalised by various studies that have been included in this study in FRM context, and the data sources for the indicators including three databases from the Australian Bureau of Statistics (ABS), Bureau of Meteorology (BoM) and Roads and Maritime Services (RMS) (see Section 5.5) and the survey questionnaire of Local Councils (see Section 5.6).

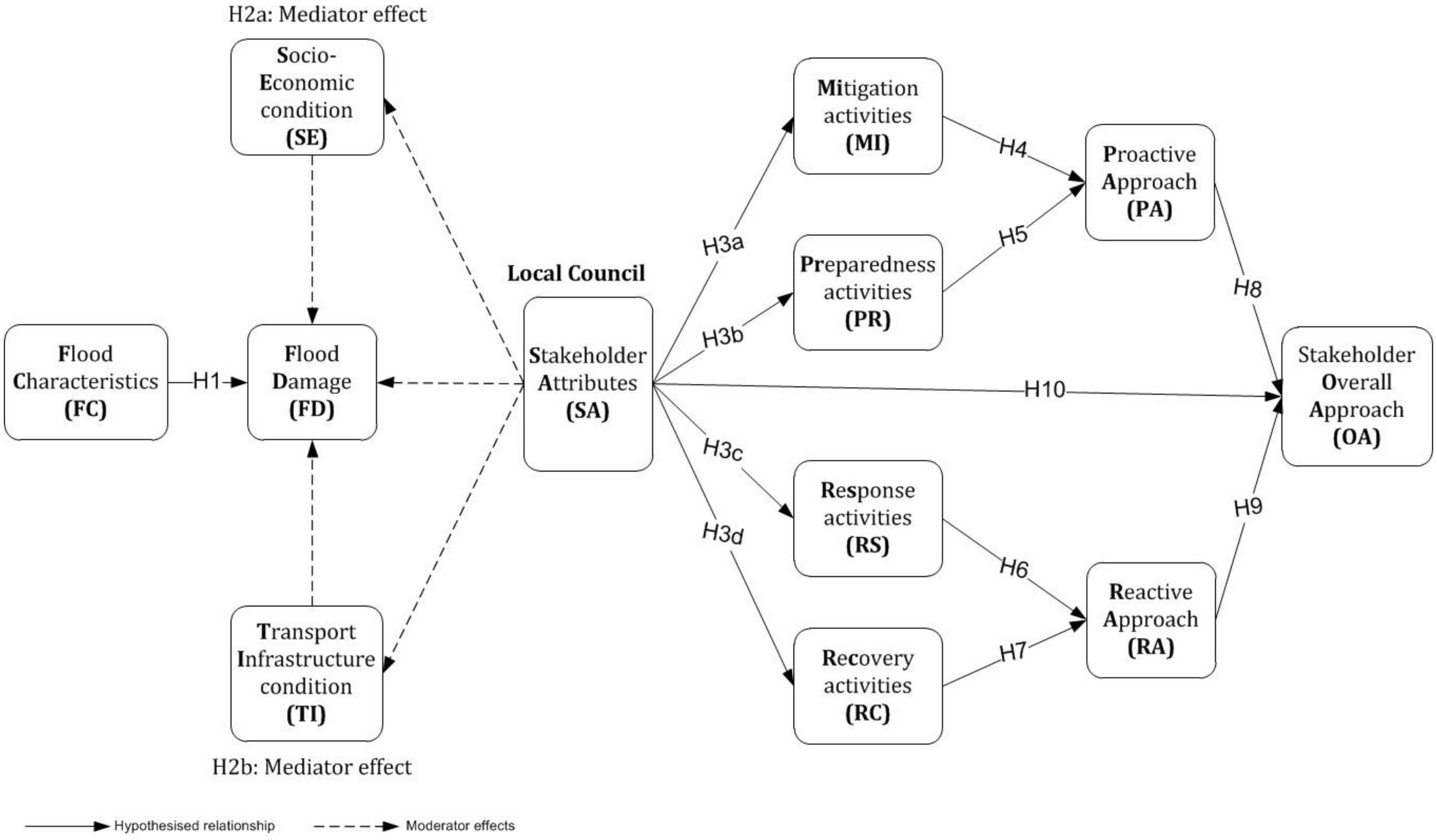


Figure 4-1: Theoretical framework and hypotheses

Table 4-1: Measurement indicators for flood risk management in transport infrastructure

Construct	Indicator	Measurement indicators	Data source[a]	Reference
Flood Characteristics (FC)	FC1	Major flooding	SQ	Balica et al. (2012); Lamond et al. (2012); BOM (2010); Mirfenderesk (2009); Nicholls and Tol (2006); Emergency Management Australia (1999);
	FC2	Moderate flooding		
	FC3	Minor flooding		
	FC4	Rainfall annual mean	BOM	
	FC5	Frequency of major flooding	SQ	
	FC6	River flooding		
	FC7	Ocean flooding		
	FC8	Flash flooding		
	FC9	Human cause of flooding		
	FC10	Elevation (m)	BOM	
	FC11	Coastal area (m^2)		
Flood Damage (FD)	FD1	Socio-economic loss	SQ	(Sohn, 2006);(Haque, 2003); (Chang, 2000); (Albala-Bertrand, 1993)
	FD2	Transport infrastructure loss	RMS	
Socio-economic condition (SE) Exposure	SE1	Density (person/km^2)	ABS	(IPCC, 2012); (Noy, 2009); (Raschky, 2008); (Ibarrarán et al., 2007); (Masozera et al., 2007); (Kahn et al., 2005); (Haque, 2003)
	SE2	Gross Regional Product (GRP) per capita		
	SE3	Population		
	SE4	Age structure		
Vulnerability	SE5	Population at risk from flood	SQ	
	SE6	Income level	ABS	
Transport Infrastructure condition (TI) Exposure	TI1	Local urban roads (km)	RMS	(Meyer, 2008); (Sohn, 2006); (Suarez et al., 2005); (Chang, 2003b, Chang, 2000)
	TI2	Local non-urban sealed roads (km)		
	TI3	Local non-urban unsealed roads (km)		
	TI4	Total bridge and culverts length on local roads		
Vulnerability	TI5	Roads and bridges at risk from flood	SQ	Discussion with experts from RMS and Local Councils
	TI6	Response time for reconstruction		
Stakeholder Attributes (SA)	SA1	Power	SQ	(Olander, 2007); (Phillips et al., 2003); (Freeman, 1984); (Mitchell et al., 1997)
	SA2	Legitimacy		
	SA3	Urgency		
Mitigation activities (MI)	MI1	Training and education on FRM	SQ	(Brody et al., 2010); (Kang et al., 2010); (Altay and Green, 2006); (Moe and Pathranarakul, 2006); (Brilly and Polic, 2005); (Pearce, 2003); (Prater and Lindell, 2000)
	MI2	Analysing risks to measure the potential areas for floods		
	MI3	Zoning and land use controls to prevent building of roads in flood prone areas		
	MI4	Insuring roads and bridges to reduce the financial impacts of floods		
	MI5	Developing a master plan for FRM		
	MI6	Developing FRM information system among stakeholders		
	MI7	Developing engineering design standards for resilient roads and bridges		
	MI8	Providing timely and effective information related to FRM		
	MI9	Constructing flood retarding basins, barriers, culverts, levees and drainage		

Table 4-1 (Contd.) Measurement indicators for flood risk management in transport infrastructure

Construct	Indicator	Measurement indicators	Data source[a]	Reference
Preparedness activities (PR)	PR1	Recruiting personnel for flood emergency services	SQ	(Altay and Green, 2006); (Covington and Simpson, 2006); (Haigh et al., 2006); (Moe and Pathranarakul, 2006); (Simpson and Katirai, 2006); (Gillespie and Streeter, 1987)
	PR2	Developing flood emergency management systems		
	PR3	Developing strategies for public education		
	PR4	Budgeting for flood emergency equipment		
	PR5	Maintaining flood emergency supplies		
	PR6	Locating places for emergency operation centres		
	PR7	Developing prediction and warning communications		
	PR8	Conducting FRM exercises to train personnel and test capabilities		
	PR9	Using technology to identify and assess floods, and damaged roads and bridges		
	PR10	Developing coordination and collaboration procedures with other stakeholders		
Response activities (RS)	RS1	Activating the flood emergency operations plans and operations centres	SQ	(Lamond et al., 2012); (Altay and Green, 2006); (Haigh et al., 2006); (Nicholls and Tol, 2006); (Kelly, 1995); (Ofori, 2002)
	RS2	Evacuating threatened populations and vehicles		
	RS3	Operating shelters and provision of mass care		
	RS4	Estimating economic damage		
	RS5	Establishing procedures to prevent and suppress secondary hazards		
	RS6	Documenting lessons learned and best practices		
	RS7	Implementing effective coordination with other stakeholders (e.g. RMS)		
	RS8	Implementing effective logistics management (e.g. supply of equipment and services to flooded areas)		
	RS9	Implementing effective mobilisation and disbursement of resources		
	RS10	Providing information on flooded areas to public		
Recovery activities (RC)	RC1	Cleaning flood disaster debris	SQ	(Mojtahedi and Oo, 2012); (Altay and Green, 2006); (Haigh et al., 2006); (Kates et al., 2006);(Freeman, 2004); (Barakat, 2003); (Chang, 2000); (Ofori, 2002); (Bolin and Stanford, 1991)
	RC2	Considering sustainability in post-disaster reconstruction		
	RC3	Shortening reconstruction time by applying quick mobilisation		
	RC4	Selecting reconstruction contractors from a predetermined list of contractors		
	RC5	Constructing temporary roads and bridges		
	RC6	Implementing execution plan for post-disaster reconstruction		
	RC7	Documenting lessons learned and best practices		
	RC8	Applying lean construction in post-flood reconstruction (e.g. waste minimisation, get it right first time)		
	RC9	Realigning roads and relocating bridges to lower flood hazard locations		
	RC10	Acquiring stakeholders' approval (e.g. RMS) on road reconstruction projects		
Proactive	PA1	Proactive approach to flood risk management	SQ	(IPCC, 2012); (Bosher et al., 2009); (Moe and Pathranarakul, 2006)
Reactive	RA1	Reactive approach to flood risk management		
Overall approach	OA1	Overall level of approach to flood risk management		

[a] **ABS**: Australian Bureau of Statistics; **BOM**: Bureau of Meteorology; **RMS**: NSW Roads and Maritime Services; **SQ**: Survey Questionnaire

A campaign entitled “Making Cities Resilient – My City is Getting Ready” was launched in 2010 by UNISDR (UNISDR, 2012). There are a very large amount of local authorities across the world which has signed up to this campaign including several in Australia including some of the Local Councils that have been chosen to this study. This campaign has developed ‘ten essentials’ to enable local governments to make their cities more disaster resilient : Essential 1: Institutional and Administrative Framework ; Essential 2: Financing and Resources ; Essential 3: Multi---hazard Risk Assessment---Know your Risk ; Essential 4: Infrastructure Protection, Upgrading and Resilience ; Essential 5: Protect Vital Facilities: Education and Health ; Essential 6: Building Regulations and Land Use Planning ; Essential 7: Training, Education and Public Awareness; Essential 8: Environmental Protection and Strengthening of Ecosystems ; Essential 9: Effective Preparedness, Early Warning and Response ; Essential 10: Recovery and Rebuilding Communities. It is important to note that all these 10 essentials are covered in this study as listed in Table 4-1

4.3 Flood characteristics construct and measurement indicators

4.3.1 Flood as a type of natural disaster

According to IPCC (2012), p 175, a flood is “the overflowing of the normal confines of the stream or other body of water, or the accumulation of water over areas that are not normally submerged”. Flood was selected as a natural disaster because floods occur more often than many other types of natural disasters (Sohn, 2006), and are regarded as the most lethal of all natural disasters (Alexander, 1997). During the past century, floods killed at least 8 million people all over the world (EM-DAT, 2004). Approximately 800 million people currently live in flood-prone areas across the world, and about 70 million people currently living in flood-prone areas are, on average, exposed to floods each year (UNISDR, 2011).

Australia is one of the most susceptible countries to natural disasters in the world. It has had A$38 billion in economic damage from natural disasters over the past three decades, while floods have caused approximately A$13 billion of the total damage (EM-DAT, 2012). Almost one third of climate change damage to the Australian economy will stem from sea level rising and flooding (Department of Climate Change and Energy Efficiency, 2011). Furthermore, more than A$226 billion in residential, commercial and industrial buildings, and transport infrastructure are potentially exposed to inundation and erosion hazards due to a 1.1 metre high rise in sea level in a 2100 scenario (Mojtahedi and Oo, 2014a, Department of Climate Change and Energy Efficiency, 2011). The exposure of coastal assets to flooding associated with a rise in sea level and climate change is widespread in all states and territories in Australia, and these hazards are expected to increase into the future. Therefore, flooding remains the most costly natural disaster faced by Australia (Blong, 2004). Figure 4-2 shows the percentage breakdown of economic damage from natural disasters from 1992 to 2012, and reveals that floods contributed almost 29% of all economic damage (EM-DAT, 2012).

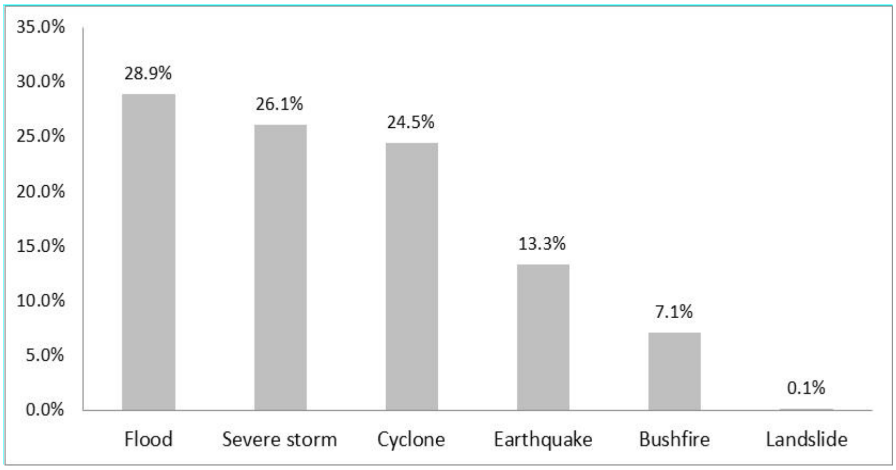


Figure 4-2: Australian natural disaster economic damage, 1992-2012 (source: EM-DAT (2012)

4.3.2 Flood characteristics

Flood characteristics are important components used to understand damages caused by flood disasters. Leroy (2006) stated that time, area and societal characteristics tend to amplify natural disasters. Ho et al. (2008) showed that the type of natural disaster is a good predictor of damages incurred by a specific natural disaster. Merz et al. (2004) proposed that flood type, the flood-generating process, the region or zone, and frequency are common characteristics of flood disasters. Middelmann-Fernandes (2010) conducted a comprehensive literature review on flood characteristics and their relationships with flood damage, and found that numerous parameters contribute to damages, including the depth of water, flow velocity, duration of inundation, contamination, sediment or debris load, age and materials. Finally, a number of studies found that flood types, severity and frequency are three distinct characteristics of flood disasters in predicting flood damage (Balica et al., 2012, IPCC, 2012, Lamond et al., 2012, Mirfenderesk, 2009, Nicholls and Tol, 2006, Emergency Management Australia, 1999).

Measurement indicators for flood characteristics in this study are flood severity defined as major flooding (FC1), moderate flooding (FC2) and minor flooding (FC3); rainfall annual mean (FC4); flood frequency (FC5); flood type defined as river flooding (FC6), ocean flooding (FC7), flash flooding (FC8) and human cause of flooding (FC9); elevation (FC10) and coastal area (FC11). They are regarded as the most effective measurement indicators of flood characteristics (Balica et al., 2012, IPCC, 2012, Lamond et al., 2012, Mirfenderesk, 2009, Nicholls and Tol, 2006, Emergency Management Australia, 1999). Minor flooding causes inconvenience because low lying areas next to watercourses are inundated, which may require the removal of stock and equipment, minor roads may be closed and low level bridges submerged. In moderate flooding, some houses may be evacuated, main traffic routes may be covered, and the area of inundation in rural areas can be so great that stock must be removed. In major flooding, extensive rural areas and/or urban areas are inundated, properties are usually isolated and major traffic routes are likely to be closed, and people must be evacuated from flooded areas (BOM, 2010).

Flood types include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods and glacial lake obstruction floods. Fatalities and economic losses have mostly been from river, ocean, flash and human cause of flooding (McKenzie et al., 2005), which means river flooding is more likely to be a problem than other types of flooding. In Australia, the most common form of flooding is along rivers after heavy rainfall (BOM, 2010). Jonkman et al. (2009) showed that flood damage in USA was highest in areas near rivers and in areas with large water depths or with lower elevation; hence, rainfall and elevation of a region are also important flood characteristics in determining flood damage. In addition, Nicholls and Tol (2006) noted rainfall annual mean as another important flood characteristic to understand flood damage.

4.4 Flood damage construct and measurement indicators

The most basic division of flood damage is into tangible and intangible damage categories (OEH, 2005). Tangible damages are financial in nature and can be readily measured in monetary terms, while intangible damages include the increased levels of emotional stress and mental and physical illness caused by the flood episode (OEH, 2005). The focus of this study is on the tangible cost of flood damage. In NDRM studies, scholars and practitioners have measured tangible flood damage by socio-economic loss including death, injury, homelessness, impact of GDP, and business interruption (e.g., Ibarrarán et al., 2007, Haque, 2003, Lindell and Prater, 2003), and the built environment loss including structural damage to buildings, roads and bridges, contents of buildings, removal of flood debris, and loss of other urban infrastructure (e.g., Hunt and Watkiss, 2010, Bosher, 2008, Wilby, 2007). For example, Chang (2000) and Sohn (2006) estimated the potential impact of flood damage on transport infrastructure in the USA by measuring the direct cost of flood damage on affected roads and bridges. Socio-economic loss (FD1) and transport infrastructure loss (FD2) were selected to measure flood damage in this study (see Table 4-1).

A large number of previous studies have shown the strong positive effects of natural disaster characteristics on natural disaster damage (e.g., Merz et al., 2010, Merz et al., 2004, Choi and Fisher, 2003). For instance, Choi and Fisher (2003) constructed regression relationships between flood damage and socio-economic indicators, and then concluded that an increase in flood characteristics, such as types, severity and frequency, would lead to an increase in flood loss in terms of society, the economy, and loss of physical assets. Therefore, in this study flood characteristics were conceptualised as influencing flood damage in terms of socio-economic and built environment economic damage. Hochrainer (2006) pointed out that for effective natural disaster risk management, information is needed about (i) the characteristics of natural disaster; and (ii) natural disaster economic damage. Thus, the following hypothesis is tested in this study:

H1: Flood characteristics have a direct effect on the magnitude of flood damage.

4.5 Socio-economic condition construct and measurement indicators

Exposure and vulnerability to damage are dynamic and depend on economic, social, geographic, demographic, cultural, institutional, governance and environmental factors (IPCC, 2012). Exposure and the vulnerability of the socio-economic conditions are the main drivers of economic losses due to some climate extremes and disasters. Many studies, (e.g., IPCC, 2012, Nicholls and Tol, 2006, O' Brien and Leichenko, 2000), showed that increases in exposure and vulnerability will result in higher direct economic losses from natural disasters.

It is essential to investigate the role of stakeholder attributes in exacerbating or ameliorating the exposure and vulnerability of the socio-economic condition of a specific region. The stakeholder attributes of power, legitimacy and urgency could be important in reducing the devastating consequences of natural disasters. Size of Local Council whether they are big or small is an important factor that can influence the Local Councils' stakeholder attributes (Power, Legitimacy and Urgency) and corresponding approaches (Proactive and Reactive).This factor has been considered in the Socio-economic variables of each individual Local Councils such as (i) Density; (ii) Gross Regional Product (GRP); (iii) Population; and (iv) Income Level. For example, a Local Council with higher GRP has more power and legitimacy in compare with other Local Councils with lower GRP. Therefore, the size of a Local Council has been measured by their density, population, income level and most importantly with their GRP. Hence, the size of Local Councils have been modelled in the socio-economic condition which might mediates the relationship between stakeholder attributes and flood damage.

Furthermore, apart from a direct relationship between stakeholder attributes and flood damage, the socio-economic exposure and vulnerability (socio-economic condition) would most likely play a mediating role in the relationship between stakeholder attributes and flood damage. Thus, these relationships are formulated as a mediator effect in the following hypothesis:

H2a: The socio-economic condition mediates the relationship between stakeholder attributes and flood damage.

Table 4-1 shows the measurement indicators operationalised by other studies in evaluating socio-economic exposure and vulnerability against natural disasters extracted from previous studies (see Section 2.5), and the data collected from pertinent data sources (see Section 5.5). The indicators are population density (SE1), Gross Regional Product (SE2), population (SE3), age structure (SE4), population at risk (SE5) and income level (SE6). These measurement indicators were reviewed in Chapter 2 (see Section 2.5). Data for measurement indicators of socio-economic condition was extracted from Australian Bureau of Statistics (ABS) data. As population at flood risk (SE5) was not recorded by the ABS, relevant information was collected from Local Councils in NSW through the survey questionnaire (see Section 5.6).

4.6 Transport infrastructure condition construct and measurement indicators

All types of built environments, such as buildings (residential, commercial and industrial), transport infrastructure of roads, railways, bridges, airports and ports, and water and power infrastructure, can be at risk of direct damage from natural disasters. For example, transport infrastructure is vulnerable to extremes in temperature, precipitation, river floods and storm surges, which can lead to damage in road, rail, airports and ports (IPCC, 2012). In this study, transport infrastructure condition includes exposure and vulnerability.

Transport infrastructure is considered to be vulnerable to flooding, but the exposure and impact will vary by region, location, elevation and condition of the infrastructure (UNCTAD, 2009, Humphrey, 2008). Roads, bridges and culverts are the most vulnerable elements in transport infrastructure in US research with projected increases in flooding, because the lifetime of these rigid structures is longer than most road surfaces and they are costly to repair or replace (Meyer, 2008).

Although there are different types of categorisation of infrastructure, based on Australian Government, Department of Infrastructure and Regional Development, Australian infrastructure is classified by transport (roads, rail, ports, etc), energy (electricity and gas transmission networks, etc), telecommunications networks, and supply and distribution networks (BITRE, 2012).Transport infrastructure in NSW including roads and bridges was selected as the built environment type for this study. Since 2001, infrastructure construction has increased strongly, mainly due to sharp increases in the construction of transport and energy infrastructure. Figure 4-2 shows that the construction of transport infrastructure is increasing rapidly. Growth in the construction of transport infrastructure slowed around the end of 2009, but 2010-11 was a year of strong growth.

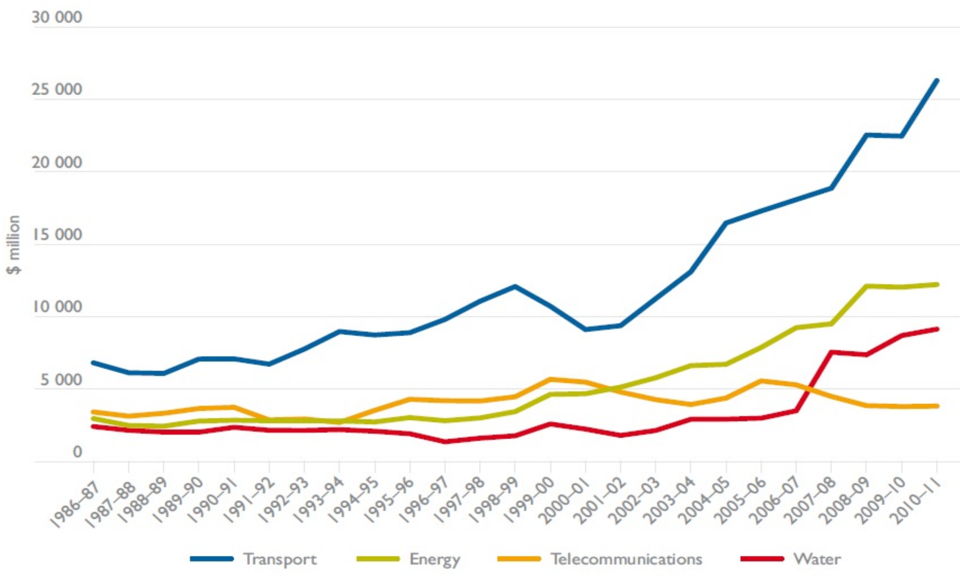


Figure 4-3: Australian infrastructure construction activity, 1986/7 to 2010/11 (source: BITRE, 2012)

Present research has tended to focus on the socio-economic condition rather than the exposure and vulnerability of the built environment. Natural disasters are expected to have a large impact on infrastructure, although detailed analyses of potential and projected damage are limited to a few countries, types of infrastructure, and sectors (Altay and Green, 2006, Chang, 2003a, Pelling, 2003). One condition may influence other conditions or exacerbate their effects in natural disaster damage (Buzna et al., 2006). The exposure and vulnerability of the transport infrastructure would probably play a mediating role in how stakeholder attributes affect flood damage. In other words, the potential positive consequences of stakeholder attributes can be mediated in important ways by reducing the exposure and vulnerability of the transport infrastructure. Therefore, the following hypothesis is tested:

> **H2b:** The transport infrastructure condition mediates the relationship between stakeholder attributes and flood damage.

This hypothesis predicts that the transport infrastructure will mediate the relationship between stakeholder attributes and flood damage such that this relationship is weaker when there is poor transport infrastructure condition in a specific region.

Granger (2003) claimed that areas with higher density of roads (more road length) are more vulnerable to flood damage, but researchers have not treated road types, whether they are located in urban or rural areas or they are sealed or non-sealed, in much detail. Most of the measurement indicators were identified during preliminary interviews with Roads and Maritime Services (RMS) (see Section 5.5.3), Local Councils in NSW and through the pilot study (see Section 5.6.1.3). The indicators include local urban roads (TI1), local non-urban sealed roads (TI2), local non-urban unsealed roads (TI3) and average response time for post-disaster reconstruction (TI6). Other measurement indicators were extracted from the literature review including total bridge and culverts length on local roads (TI4) and roads and bridges at risk from flood disaster (TI5).

4.7 Stakeholder attributes construct and measurement indicators

Previous studies indicated that reducing the impact of natural disasters was mainly influenced by the capacity of stakeholders (Raschky, 2008). The institutional capacity of stakeholders is critical for effective implementation of structural and non-structural responses in natural disaster risk management (Brody et al., 2010). Stakeholders' organisational capacity is important for mitigating the impact of natural disasters and facilitating the development of resilient communities. Stakeholders' organisational capacity predicts the failure and success factors of stakeholders in an organisation

(Savage et al., 1991) and it is then generalised in various contexts based on administrative (organisational) theories such as stakeholder theory (Jensen, 2010, Phillips et al., 2003, Donaldson and Preston, 1995).

Most previous studies have focused on the role of stakeholder involvement in FRM (Brilly and Polic, 2005). Only a few studies have scrutinised stakeholders' views and perspectives in FRM, such as (e.g., Almoradie et al., 2013, Bosher et al., 2009, Vari et al., 2003). For instance, Brody et al. (2010) investigated the role of key characteristics of organisational capacity including financial resources, staffing, technical expertise, communication, leadership and commitment to FRM. They measured organisational capacity characteristics on an ordinal scale of 0-5, where 0 is not present and 5 is very strong, and concluded that organisational capacity is a significant factor contributing to the effective implementation of FRM activities. However, the role of stakeholder attributes was not investigated in the previous FRM studies.

In Freeman (1984) stakeholder theory, power, legitimacy and urgency are the three distinct stakeholder attributes. The power of a stakeholder allows them to mobilise social and political forces and to withdraw resources from an their own organisation (Olander, 2007, Post et al., 2002). Legitimacy allows a stakeholder to tolerate beneficial or harmful risk pertinent to an organisation (Phillips et al., 2003). Urgency refers to the degree to which a stakeholder's claims to coordinate immediate actions (Olander, 2007, Mitchell et al., 1997). The attributes of power, legitimacy and urgency cause stakeholders to take proactive or reactive approaches in their decision-making process. Stakeholder theory amalgamates the power, legitimacy and urgency attributes to propose dynamism in the systematic identification of stakeholders (Olander, 2007). Only one study has considered the power attribute in the context of natural disaster risk management (Bosher, 2005). He showed that stakeholders with high access to key social institutions (potential power) will be relatively the least vulnerable stakeholders.

Therefore, as depicted in Table 4-1, power (SA1), legitimacy (SA2) and urgency (SA3) were selected as measurement indicators for the stakeholder attribute construct in this study.

4.8 Mitigation activities construct and measurement indicators

Mitigation refers to structural and non-structural activities aimed at eliminating and reducing the probability and consequences of natural disasters to the environment, society and infrastructure before they occur (e.g., Weichselgartner, 2001, Godschalk, 1999, Alexander, 1993). Structural activities focus on activities associated with strengthening buildings and other infrastructure exposed to natural disasters, while non-structural activities aim to avoid building infrastructure in natural disaster prone areas, relocating existing assets to safer zones, and maintaining the protective features of the natural environment (Bosher et al., 2009, Trim, 2004, Pelling and Uitto, 2001). Mitigation activities attempt to keep natural disasters away from society and the built environment by constructing resilient infrastructure and developing practical managerial measures (Alexander, 2000). Mitigation refers to actions that attempt to limit further adverse conditions once a natural disaster has materialised. Mitigation activities focus on lessening the potential adverse impact of natural disaster through actions that reduce the natural disasters, exposure and vulnerability (IPCC, 2012). In NDRM practice, ‘mitigation’ refers to the amelioration of disaster risk by reducing existing hazards, exposure or vulnerability (IPCC, 2012). Because no empirical studies have examined the relationship between the stakeholder attributes of power, legitimacy and urgency and mitigation activities, this study seeks to discover what effects, if any, stakeholder attributes have on mitigation activities before a disaster. Hence, the following hypothesis is tested:

> **H3a:** Stakeholder attributes have a direct effect on stakeholder mitigation activities in flood risk management.

Altay and Green (2006) reviewed disaster risk management and related disciplines including management science, supply chain management and operation management. They argued that training and education (MI1), insurance (MI4), master plans (MI5), information management systems (MI6) and engineering design (MI7) are the most applicable indicators to measure mitigation activities. However, other scholars argued that zoning and land use controls (MI3) and constructing flood retarding basins, barriers, culverts, levees and drainage (MI9) are essential mitigation activities (Brody, 2003, Burby and Dalton, 1994). Finally, Moe and Pathranarakul (2006) indicated providing timely and effective information before natural disaster (MI8) and natural disaster risk assessment (MI2) should be included in mitigation activities in NDRM. Apart from reviewing the literature, these measurement indicators for mitigation activities were discussed with NSW Local Councils in the pilot study process in order to be applicable in FRM in transport infrastructure (see Section 5.6.1.3).

4.9 Preparedness activities construct and measurement indicators

Preparedness activities include developing emergency procedures and stakeholder institutional capability, in advance, to ensure an effective response to the impact of natural disasters. Activities include developing warning systems, identifying evacuation routes and shelters, maintaining emergency supplies and communication systems, and conducting natural disaster exercises to train and educate personnel, citizens and community leaders (Altay and Green, 2006, Moe and Pathranarakul, 2006, Peek and Mileti, 2002). A high level proactive approach to natural disasters helps to reduce deaths, injuries, property damage and loss of dollars. Preparedness accepts the existence of residual, unmitigated risk, and attempts to support society in eliminating certain adverse effects that could be experienced once a physical event occurs (IPCC, 2012).

In addition, this study seeks to discover what effects, if any, stakeholder attributes of power, legitimacy and urgency have on preparedness activities before and during a natural disaster. Hence, the following hypothesis is tested:

> **H3b:** Stakeholder attributes have a direct effect on stakeholder preparedness activities in flood risk management.

Emergency management covers many preparedness activities. For example, (Altay and Green, 2006) found that recruiting appropriate people (PR1), having an emergency management system (PR2), public education (PR3), emergency equipment (PE4), supplies (PR5) and suitable locations for emergency centres (PR6) play a vital role in supply chain operation in a disaster situation. Developing a prediction and warning communications system (PR7) and conducting natural disaster exercises to train personnel have also been identified as preparedness activities in previous studies (Covington and Simpson, 2006, Simpson and Katirai, 2006). In addition, under no circumstances should application of technology (PR9) be ignored (Moe and Pathranarakul, 2006). Developing coordination and collaboration procedures (PR10) with other stakeholders would decrease the conflicts in disaster situations and make the community more prepared (Haigh et al., 2006).

4.10 Response activities construct and measurement indicators

Response refers to the activities taken immediately during and following a natural disaster. The main aim of an effective response to a natural disaster is to save the community and minimise damage. Response activities provide assistance during or immediately after a natural disaster to meet the life preservation and basic subsistence needs of those people affected. (Moe and Pathranarakul, 2006). Examples of response activities include activating the emergency operation plan and centres, evacuating and sheltering victims, searching, rescuing and providing medical care (Peek and Mileti, 2002).

This study seeks to discover the effects of stakeholder attributes on response activities during and after a natural disaster. Hence, the following hypothesis is tested:

> **H3c:** Stakeholder attributes have a direct effect on stakeholder response activities in flood risk management.

Altay and Green (2006) in their comprehensive literature review indicated that activating emergency centres properly (RS1), evacuating threatened populations and vehicles (RS2), operating shelters (RS3), estimating economic damage (RS4), implementing effective logistics management (RS8) and implementing effective mobilisation and disbursement of resources (RS9) are highly essential during response activities. Effective collaboration between natural disaster response stakeholders including the local population, Local Councils and humanitarian organisations is an essential part of response activities (RS7) (McEntire et al., 2002). Appropriate knowledge and good practices in land, property and construction should be recorded and shared and lessons learned and best practices in response and recovery phases should be documented (RS6) (Haigh et al., 2006). This results in enhancing knowledge and raising awareness among practitioners in NDRM.

Ofori (2002) claimed that a key missing element in natural disaster response is awareness among stakeholders. Thus, establishing procedures to prevent and suppress secondary risks in response time is vital (RS5). Ofori (2002) noted that the best place to start is at universities, through appropriate curriculum design and delivery, as well as continuing professional development for practitioners.

4.11 Recovery activities construct and measurement indicators

Recovery activities involve rehabilitation (short-term) and reconstruction (long-term) endeavours aimed at restoring vital support systems and returning life to normal. Activities include rebuilding residential and non-residential buildings, roads, bridges and infrastructure, and coordinating governmental activities (Altay and Green, 2006, Moe and Pathranarakul, 2006, Peek and Mileti, 2002). Stakeholders often take reactive approaches to managing natural disasters (Bosher et al., 2009, Brilly and Polic, 2005, Loosemore and Hughes, 1998). Post-disaster recovery (IPCC, 2012) provides an opportunity for reducing the risk of natural disasters and for improving adaptive capacity. Post-disaster lean reconstruction (Mojtahedi and Oo, 2012) eliminates waste, improves the quality of the built environment, smoothes the work flow and enhances the performance of post-disaster reconstruction in NDRM.

Finally, this study empirically investigates the effects of the stakeholder attributes of power, legitimacy and urgency on recovery activities during and after a natural disaster. Hence, the following hypothesis is tested:

H3d: Stakeholder attributes have a direct effect on stakeholder recovery activities in flood risk management.

Altay and Green (2006) found that constructing temporary facilities (RC5), implementing an execution plan for post-disaster reconstruction (RC6), and documenting lessons learned are the activities most practised by stakeholders in the recovery stage after disasters (RC7). Some researchers argued that post-disaster reconstruction should be a more prominent part of recovery activities after natural disaster (Freeman, 2004, Barakat, 2003, Bolin and Stanford, 1991), and did not focus on debris removal before reconstruction. However, Luther (2006) showed that debris removal was an issue after Hurricane Katrina, so cleaning flood disaster debris (RC1) should be an integral task in the recovery stage. In addition, no research has been found that surveyed a lean approach to post-disaster reconstruction. IPCC (2012) emphasised considering sustainability in post-disaster reconstruction (RC2) in NDRM activities by policy makers. Mojtahedi and Oo (2012) conducted exploratory research to understand the lean construction components in post-disaster reconstruction; hence, lean construction in post-flood reconstruction (such as waste minimisation and get it right first time) (RC8), shortening reconstruction time by applying quick mobilisation (RC3), and selecting reconstruction contractors from a predetermined list of contractors (RC4) were used as recovery measurement indicators in this study as well. Finally, during pilot testing (see Section 5.6.1.3), two more measurement indicators were added to the recovery activities construct including realigning roads and relocating bridges to lower flood hazard locations (RC9) and requiring RMS approval on road reconstruction projects (RC10).

Previous researchers, such as (e.g., Brody et al., 2010, Altay and Green, 2006, Akter and Simonovic, 2005), have measured mitigation, preparedness, response and recovery activities on either 0-5 or 0-7 ordinal Likert scales by distributing survey questionnaires to relevant NDRM experts.

4.12 Proactive, reactive and stakeholder overall approaches construct and measurement indicators

Moe and Pathranarakul (2006) defined a proactive approach to natural disaster risk management as activities such as mitigation and preparedness that are planned and conducted by stakeholders before disasters in order to mitigate the adverse impacts of disasters.

A proactive approach means that better solutions can be used to reduce the adverse impacts of natural disasters on society, the economy and the built environment by conducting mitigation and preparedness activities (e.g., Vogel and O'Brien, 2004, Comfort et al., 1999b, Susman et al., 1983). Mitigation and preparedness at the community level by local government and NGOs help to guide and thus reduce the longer term impact of natural disasters (IPCC, 2012). To reduce the overall cost of natural disasters, investment in mitigation and preparedness, or proactive approaches, is firmly encouraged by governments and the insurance sector (Linnerooth-Bayer et al., 2005, Gurenko, 2004, Kreimer and Arnold, 2000). Indeed the acquisition and documentation of knowledge must focus on shifting the emphasis from reactive approaches to proactive approaches by strengthening mitigation and preparedness (IPCC, 2012). In accordance with previous studies, mitigation and preparedness tasks would likely result in a proactive approach, so the following hypotheses are tested to empirically investigate the extent to which mitigation and preparedness activities can define a stakeholder's proactive approach to FRM:

> **H4:** Mitigation activities have a direct effect on stakeholder proactive approach to flood risk management.

> **H5:** Preparedness activities have a direct effect on stakeholder proactive approach to flood risk management.

Response and recovery activities conducted by stakeholders during and after natural disasters represent a reactive approach (Moe and Pathranarakul, 2006). Although there are two approaches to addressing disasters – proactive and reactive – most studies have claimed that stakeholders often resolve the predicaments that arise in disasters by reactive approaches (Bosher et al., 2009, Brilly and Polic, 2005, Loosemore and Hughes, 1998).

Legislation and mandates have led to a focus on building an institutional capacity to increase resilience to natural disasters at different levels, but even then stakeholders retain a strongly reactive approach (IPCC, 2012, O'Brien et al., 2008). This attitude has been attributed to a deficiency in the institutional capacity for NDRM, and stakeholders implementing response and recovery activities. In accordance with previous studies, response and recovery tasks would likely result in a reactive approach, so the following hypotheses are tested:

> **H6:** Response activities have a positive effect on stakeholder reactive approach to flood risk management.

H7: Recovery activities have a positive effect on stakeholder reactive approach to flood risk management.

Although it would be impossible to totally eliminate reactive approaches, stakeholders should emphasise more proactive rather than reactive approaches to pave the way for a resilient built environment in the future (IPCC, 2012). Thus, both proactive and reactive approaches to managing natural disasters are essential.

The many scholars and practitioners associating NDRM principally with disaster response and recovery activities, and not with mitigation and preparedness activities, has contributed to the view that the proactive and reactive approaches are essentially different (IPCC, 2012, Lavell, 2011, Mercer, 2010). Therefore, both proactive and reactive approaches would most likely lead to an improved or more effective overall approach by stakeholders in managing natural disasters. The following hypotheses are therefore tested:

H8: Proactive approach has a direct effect on stakeholder overall approach to flood risk management.

H9: Reactive approach has a direct effect on stakeholder overall approach to flood risk management.

Olander (2007) claimed that stakeholder institutional attributes are essential factors in defining the overall performance of stakeholders. He empirically investigated that power, legitimacy and urgency are the three main attributes based on stakeholder theory (Mitchell et al., 1997, Freeman, 1984), which could enhance stakeholders' overall response and performance. Hence, the direct effect of stakeholder attributes in defining their overall approach to disasters is hypothesised in this study as follows:

H10: Stakeholder attributes have a direct effect on stakeholder overall approach to flood risk management.

A high level of natural disaster risk management by stakeholders, defined as both proactive and reactive approaches to natural disaster, reduces deaths, injuries, damage to property and loss of dollars. Both proactive and reactive approaches in NDRM can help prevent future risks and natural disasters without just lessening existing risks, once they have become manifest, as is the case with a reactive approach (IPCC, 2012, UNISDR, 2011, Lavell and Mansilla, 2003).

A proactive approach to FRM (PA1), a reactive approach to FRM (RA1), and the overall level of approach to FRM (OA1) are the measurement indicators for the proactive approach, reactive approach and stakeholder overall approach constructs, respectively.

Since this study is exploratory and the role of stakeholder approaches in the context of NDRM has not yet been investigated, the use of single-indicator measures was unavoidable. The problems associated with single-indicator measures and the solutions adopted are discussed in Chapter 6 (see Section 6.4.4.2).

4.13 Summary

Although most previous studies have focused on the role of stakeholder involvement in flood risk management, only a few studies have scrutinised stakeholders' views and perspectives, and the role of stakeholder attributes has not yet been investigated. This chapter operationalised the developed theoretical framework (see Chapter 3) into flood risk management in transport infrastructure to fill the research gap in natural disaster risk management in the built environment. A review of the literature for each construct and respective measurement indicators was presented.

The review of the literature suggests that most of the key constructs are multi-indicator constructs, which comprise more than one measurement indicator. Of the 12 constructs, only three constructs were measured by single indicators including proactive approach, reactive approach and stakeholder overall approach. The justification for using single indicators and the analysis is provided in Section 6.4.4.2.

The measurement indicators for each respective construct have been developed from a thorough literature review on flood risk management in transport infrastructure. All measurement indicators of individual constructs identified in the literature were subjected to further scrutiny through a pilot study in the initial phase of this study, before being incorporated into the data collection instrument as detailed next in Chapter 5.

Finally, 14 hypotheses were developed in this chapter to examine: (i) the effects of flood characteristics on flood damage; (ii) the mediator effects of socio-economic and transport infrastructure conditions on the relationship between Local Councils' stakeholder attributes and flood damage; (iii) the effect of Local Councils' stakeholder attributes on flood risk management activities including mitigation, preparedness, response and recovery; (iv) the effect of mitigation and preparedness activities on Local Councils' proactive approach; (v) the effect of response and recovery activities on Local Councils' reactive approach; and (vi) the effect of proactive and reactive approaches on stakeholder overall approach in flood risk management in transport infrastructure.

CHAPTER

5

Research Method

5.1 Introduction

This chapter starts with the research framework and process of this thesis (Section 5.2). The research design and justification for selecting survey research design over others are discussed (Section 5.3) and the appropriate sampling frame for this research is also highlighted (Section 5.4). The next section discusses the data collection method that used secondary historical data and a structured questionnaire (Section 5.5). The administration process for the questionnaire is also explained in the last section (Section 5.6).

5.2 The research process

This section describes the systematic approach used for empirical investigation where the components were extracted primarily from the social sciences, where empirical research is the predominant mode (Flynn et al., 1990). Figure 5-1 provides an overview of the process used to investigate the role of stakeholder attributes in flood damage and stakeholder approaches to FRM in transport infrastructure; this process has, five phases.

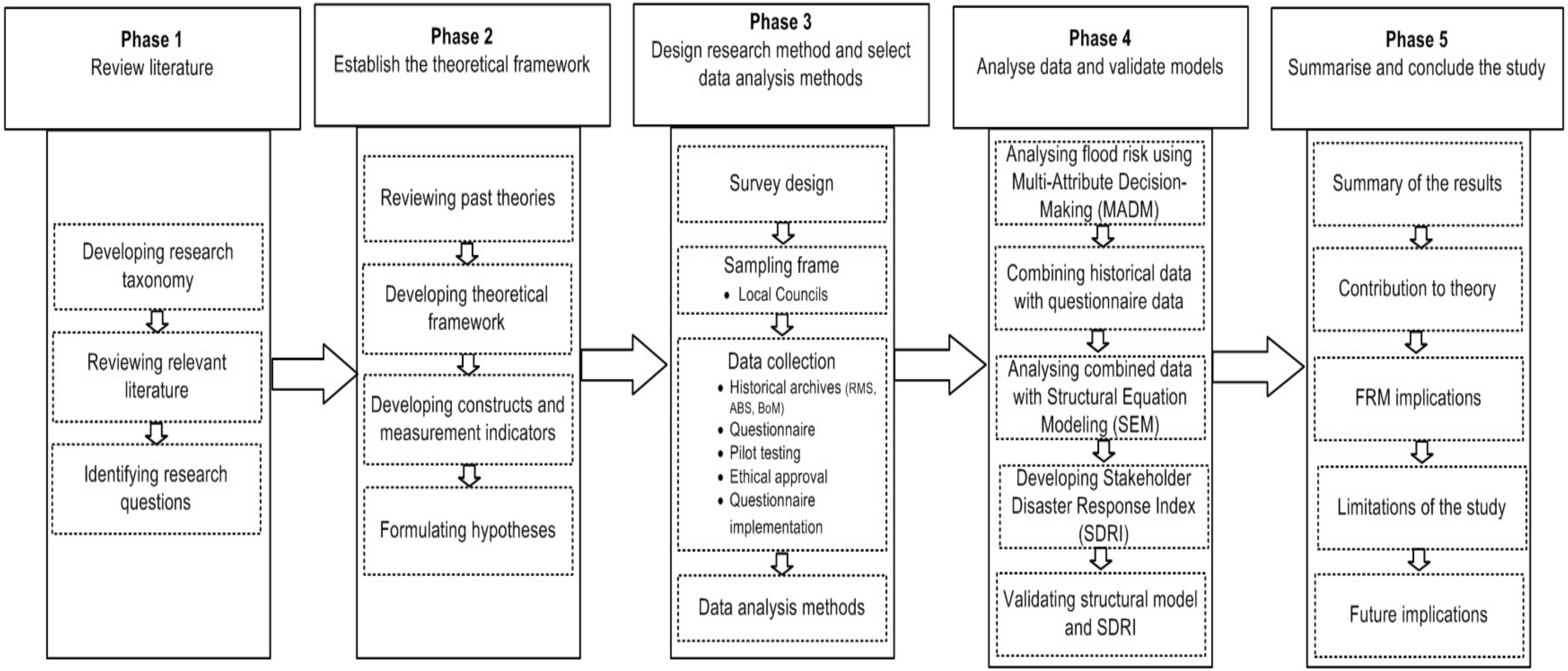


Figure 5-1: The five-phase research process

The first phase is a comprehensive literature review to develop research taxonomy and identify the research problems. The second phase consists of establishing a theoretical framework, reviewing past theories, operationalising the constructs and measurement indicators into the theoretical framework and formulating hypotheses. The third phase is an overview of a number of research designs that may be appropriate for empirical studies including the selection of an appropriate research design and data collection procedures and the selection of data analysis techniques. The fourth phase presents the implementation of data analysis and validation, including data preparation, flood risk analysis using Bootstrap-TOPSIS, empirical data analysis using PLS-SEM, development of stakeholder disaster response index (SDRI) and validation of results. The fifth phase includes the conclusion and summary of results, including research findings, the contribution to theory and practice, limitations and future research implications.

5.3 *Selecting the research design*

Choosing the research design is essential to the philosophy underpinning the research and any contributions it is likely to make (Knight and Ruddock, 2009). The research design explains how the data will be gathered and assessed in order to address the research questions posed and to build a framework for undertaking the research (Bryman and Bell, 2011). It embraces two fundamental dimensions: (i) specifying precisely what is to be investigated and (ii) determining the best way to execute it (Babbie, 2012).

There are three types of research, namely (Shadish et al., 2002): (i) experimental; (ii) quasi-experimental; and (iii) non-experimental. These classifications were discussed to select the most appropriate research design needed to achieve the research objectives stated in Section 1.3.

5.3.1 Experimental research

Experimental research enables researchers to control the situation so one or more independent variables can be randomised and manipulated in order to test the hypotheses, or to determine their effects on the dependent variable (Zikmund, 2003, Kerlinger and Lee, 1964). Experimental research encompasses social sciences studies conducted in a laboratory where human subjects are utilised (Rosenbaum, 2002). Albeit the researchers can manipulate the conditions to test the hypotheses, a hypothetical scenario rather than real life cases may increase the ambiguity of the external validity of the results of experimental research (Cook et al., 1979). Furthermore, Babbie (2012) claimed that generalising the findings of experimental research to the real world is not easy and experimental research is appropriate for research with limited and well-developed concepts.

Experimental research was not appropriate in this study because: (i) stakeholder approaches in managing flood risks are complex and complicated to model in a laboratory; (ii) floods cannot be controlled in an experiment; (iii) the concept of stakeholder attributes is multi-faceted and is yet to be well defined in the context of FRM; and (iv) the complexities involved in stakeholder approaches require real life investigation rather than experiments. Therefore, the logic of experimental research is inappropriate in this study.

5.3.2 Quasi-experimental research

Unlike experimental research, randomisation is not a subject in quasi-experimental research because researchers do not have enough control over the independent variables to compare them with experimental design (Dooley, 2001). Quasi-experimental designs typically allow the researcher to control the assignment to the treatment condition (Campbell et al., 1963). Estimating the causal impact of an intervention on its target population is the main focus of a quasi-experimental research design (Shadish et al., 2002). Non-equivalent control groups design, case-control study and panel analysis are the most used research designs in quasi-experiment research because the cause can be manipulated and it happens before the effect is measured. Unfortunately quasi-experimental designs cannot remove the possibility of confounding bias, which can hamper the ability to draw causal inferences and quasi-experimental control groups may differ from the treatment condition in many systematic (non-random) ways other than the presence of the treatment (Shadish et al., 2002). Quasi-experimental research would not be appropriate in this study because: (i) floods cannot be evaluated in case-control study or panel analysis and (ii) causal relationships are not considered in the operationalisation of the theoretical framework into FRM.

5.3.3 Non-experimental research

Non-experimental research does not allow a researcher to manipulate and control selected independent variables to investigate their impact on the dependent variable (Kerlinger and Lee, 1964), although they also claimed that non-experimental research is usually the only way to investigate various real world institutional phenomena. Case studies and survey research designs are prevalent in non-experimental research (Flynn et al., 1990). In case study research design, researchers investigate a particular phenomenon within a real life situation. Case study is of particular interest to exploratory studies that need a deep understanding of the context of the research (Eisenhardt, 1989), but in the context of FRM it is not appropriate because: (i) researchers cannot control floods; (ii) it is not easy to generalise the findings of one specific flood event as a case study in the context of FRM in the built environment; and (iii) the requirements for a case study in FRM makes the research process costly and time consuming.

Survey research design refers to a group of methods which focuses on quantitative and qualitative analysis, where data for a large number of variables of interests are collected through questionnaires, interviews, published statistics and archive data (Gable, 1994). Survey research design is undoubtedly one of the most commonly used research designs in the built environment and construction management research (Dainty, 2008). It relies on self-reports of factual data, as well as opinion (Flynn et al., 1990) and is probably the best method for collecting original data from a sizable population in a cost efficient fashion (Babbie, 2012). It is a very suitable research design to generalise research findings based on the sample involved (Robson, 2002). In the survey research design data can be obtained from primary or secondary sources (Sekaran and Bougie, 2010). Primary data refers to information obtained first-hand by the researchers on the variables of interests for the specific purpose of the study. Secondary data refers to information collected from sources that already exist. Primary data can be collected by interviews, surveys (questionnaires) and observations (Sekaran and Bougie, 2010). Despite its advantages, survey research design has limitations in the quality of collected data such as systematic bias, a non-response rate, a social desirability response and missed data (Babbie, 2012, Flynn et al., 1990). The strategies used to mitigate these problems are described in Chapter 6 (Section 6.4.5). In this study, survey research design is preferred over other research designs.

5.3.4 Justification for using survey research design

This study used survey research design for the following reasons:

(i) Data pertinent to flood characteristics has been recorded over time and maintained in the relevant databases. This makes it easy to collect secondary historical data unless, a single flood needs to be scrutinised as a case study.

(ii) The exposure and vulnerability of a specific region against flood are dynamic and depend on unstable conditions such as economic, social, geographic, demographic, cultural, institutional, governance and environmental factors which constantly change over time and are kept in databases (IPCC, 2012). Therefore, survey research is a suitable research design to collect secondary data from existing sources (Sekaran and Bougie, 2010)

(iii) Stakeholder attributes and approaches are first-hand information that is volatile and probably changes over time (Olander, 2007), they cannot be controlled in experimental study and designing a case study to collect them is expensive.

(iv) FRM activities (mitigation, preparedness, response and recovery) should be collected by organising interviews or distributing questionnaires to relevant stakeholders.

5.3.5 Time horizon: Cross sectional versus longitudinal studies

Since data collection is based on time, research designs also falls into: (i) cross sectional and (ii) longitudinal research categories (Babbie, 2012). Cross-sectional design collects data at one time while longitudinal research collects data over an extended period of time (Sekaran and Bougie, 2010). Cross-sectional surveys are considered to be biased because of common method variance and are limited in their degree of causal inference. Thus, longitudinal data collection is often recommended to overcome these limitations. A longitudinal survey design is suitable when the temporal nature of the phenomena is obvious and when alternative explanations cannot be controlled with a cross-sectional approach (Rindfleisch et al., 2008). The time horizon in this study is cross sectional because the research data was collected at one time.

5.4 *Sampling frame and selection process*

Most Australian roads and bridges are located in coastal areas, where they are more vulnerable to rises in sea level and localised flooding. As highlighted in Section 4.6, NSW is one of the most susceptible areas for flood damage, particularly its transport infrastructure (Bureau of Transport Economics, 2001). Table 5-1 shows the breakdown of road lengths across eight Australian states and territories and indicates that almost 24% of Australian roads are located in NSW, which has the highest amount of transport infrastructure across Australia.

Table 5-1: Roads lengths across Australia (BITRE, 2012)

State/territory	Road lengths	Portion (%)
New South Wales (NSW)	184,761	23.55%
Queensland (QLD)	183,036	22.13%
Western Australia (WA)	153,999	18.62%
Victoria (VIC)	152,900	18.49%
South Australia (SA)	97,433	11.78%
Northern Territory (NT)	22,224	2.69%
Tasmania (TAS)	19,845	2.40%
Australian Capital Territory (ACT)	2,894	0.35%

Roads in NSW are divided into three main categories: (i) state roads; (ii) regional roads; and (iii) local roads. Funding for restoration against natural disasters on state roads is the responsibility of the Road and Maritime Services (RMS), while funding for restoration works on regional and local roads is the responsibility of Local Councils (RMS, 2012). Local Councils are responsible for investing, constructing, maintaining and restoring a major portion of regional and local roads and bridges across NSW, they were selected as stakeholders or sampling frame in this research.

As of November 2005, there are 152 Local Councils in NSW, as shown in Appendix B. Since not all Local Councils are susceptible to flood disaster, the sampling frame was filtered by focusing on Local Councils who are members of the Flood Management Association (FMA). Only 75 of them have been affected by flood disasters over the past decades and they are members of the FMA. The FMA promotes appropriate development within floodplain areas and helps to reduce the risk of flooding to life and property. The FMA has over 100 members, ranging from Local Councils, catchment management authorities and businesses and professionals who are involved in all aspects of urban and rural FRM, but this study only focused on 75 Local Councils across NSW that are FMA members.

5.5 The data collection procedure and secondary data sources

Historical archive data was considered to be appropriate because most data pertinent to flood characteristics, socio-economic and the exposure and vulnerability of transport infrastructure in a specific region or local area were recorded in Australian data sources. The archival data was unbiased because the providers had no awareness of being observed (Flynn et al., 1990), but collecting all the data needed for the theoretical framework from archival data sources was impossible so it was usually utilised with a survey or panel study (Flynn et al., 1990).

Data collection was divided into two phases; phase one involved collecting historical archive data from secondary data sources pertinent to FRM in NSW transport infrastructure and phase two collected primary data using a structured questionnaire (see Section 5.6 for the questionnaire administration). Three secondary data sources were used to obtain historical archival data over a period of 20 years between 1992 and 2012. This study period was selected because data and information pertinent to NDRM were not kept in RMS databases before 1992 and recent research about Australian NDRM revealed that there are barriers to recording and keeping data related to natural disasters (Deloitte, 2014). This really limited the ability of various stakeholders to understand the exposure and vulnerability of different communities and the true extent of losses that might arise from a natural disaster. The report developed by Deloitte (2014) revealed that these issues are compounded by barriers which restrict access by end users to critical data. These barriers include (i) a reluctance to share data; (ii) the high costs of collection; (iii) a lack of co-ordination and standardisation; and (iv) high cost of providing accessibility and transparency.

5.5.1 Bureau of Meteorology (BoM)

The BoM is Australia's national weather, climate and water agency and it deals with the realities of the natural environment, including drought, floods, fires, storms, tsunamis, and tropical cyclones. The Bureau contributes to national social, economic, cultural and environmental goals by providing observational, meteorological, hydrological and oceanographic services. Hydrological observations used to support the Bureau's water information functions, including flood forecasting and warning services, are collected from Bureau networks and from more than 200 Commonwealth, State and Territory and Local Councils across Australia (BOM, 2010).

Data and information related to the sea level height (elevation) of each Local Council, and annual rainfall over the past 100 years are accessible in BoM data sources. Relevant data for the annual mean rainfall (FC4) for the study period from 1992 to 2012, elevation (FC10), and coastal area (FC11) were collected from the BoM online database in this study (see Table 4.1).

5.5.2 Australian Bureau of Statistics (ABS)

ABS is Australia's national statistical agency and it provides key statistics on a wide range of economic, environmental and social issues, to assist and encourage informed decision-making, research and discussion within governments and the community. Most of the socio-economic data for each Local Council was obtained from the ABS online database, these include Density (person/km^2) (SE1), GRP per capita (SE2), population (SE3), age structure (SE4) and income level (SE6) (see Table 4.1).

5.5.3 Road and Maritime Services (RMS)

Roads and Maritime Services (RMS) is an agency of the NSW Government responsible for building and maintaining transport infrastructure and managing the day-to-day compliance and safety of roads and waterways. RMS is also responsible for arranging the restoration of roads and bridges after disasters, in collaboration with Local Councils. The collaboration of Local Councils with RMS is expected to influence the outcome of the research, therefore two relevant variables for measuring this effect are developed in this thesis including; **RS7:** Implementing effective coordination with other stakeholders (e.g. RMS) and **RC10:** Acquiring stakeholders' approval (e.g. RMS) on road reconstruction projects (see Table 4-1 in Section 4.2).

Five meetings were organised with the executives and managers responsible for managing infrastructure assets and natural disaster restoration projects during the data collection process. These meetings were organised to ask permission to access their databases, to obtain their feedback on the questionnaire adopted in this study, to highlight the significance of the current study, to present the theoretical framework and to explain the measurement indicators for respective constructs. The researcher was granted access to one of the RMS databases with approximately 4,000 records of post-disaster reconstruction projects from 1992 to 2012. This data was examined to extract the flood restoration projects in each Local Council, including transport infrastructure loss (FD2), local urban roads (km) (TI1), local non-urban sealed roads (km) (TI3), local non-urban unsealed roads (km) (TI4), the lengths of bridge and culverts (TI5) (see Table 4.1).

5.6 Questionnaire administration

Constructed and standardised questionnaires can increase the number of responses by providing anonymity and privacy and in comparison to face-to-face interviews, phone interviews and panel meetings, the results are easy to understand and explain (Babbie, 2012). He stated that a questionnaire is an exceptional tool for measuring attitudes and orientations in a large population.

5.6.1 Justification for using a questionnaire for data collection

This study used questionnaire for collecting primary data for the following reasons:

(i) since the pivotal focus of this study is stakeholder attributes and approaches, a questionnaire is suitable for research questions pertinent to attitudes, past behaviours and self-reported belief (Creswell, 2013).

(ii) it protects the identity of respondents (Babbie, 2012). The name of participants and Local Councils will not be identifiable in this study.

(iii) collecting FRM data is a time-consuming process and all data has not been recorded; thus, a questionnaire is a fast and economical way of collecting data pertinent to flood events.

(iv) It is an appropriate tool for empirical research and can generalise findings by testing the hypotheses (Flynn et al., 1990).

The administration process for the questionnaire consisted of (i) design and (ii) implementation as discussed below.

5.6.2 Questionnaire design

Robson (2002) stated that a questionnaire should have standardised questions so that every respondent will interpret them in the same way. In the developed questionnaire, all the questions were presented with exactly the same wording. In this case, the responses to most questions were on a Likert design, unless otherwise stated. Local Councils were asked to rate individual question on a seven point Likert scale pertinent to their flood information, FRM activities, phases and approaches over the past 20 years (1992-2012). For example, they were asked to rate the extent to which the Local Councils have adopted the mitigation activities for transport infrastructure FRM over the past 20 years (1992-2012). The seven point Likert scale was utilised in this study because: (i) it is the easiest scale to construct and administer (Zikmund, 2003); (ii) it is easy to facilitate the respondents' answering process (Bernard, 2013); and (iii) it has a higher scale reliability and validity than those with fewer scale points (Dawes, 2008). The format of seven point Liker scale in this study is 1 = Low or never and 7 = high or a lot.

There were some missing historical archive data in the three data sources, so relevant questions for collecting this missing information were included in the questionnaire. These include socio-economic flood damage cost (million A$) (SE1), the percentage of the Local Council's population at risk to the flood (SE5), the percentage of the Local Council's roads and bridges which are at risk to flood disaster (TI5), and the response time for reconstruction (TI6) (see Table 4-1).

The structured questionnaire contains 11 parts (see Appendix C). In the first part, Local Councils were required to provide general information about the Council (for example, Local Council's total capital works budget, number of staff who are involved in FRM and Local Council's priority in FRM in different types of built environment). The questionnaire ends with an optional section to determine the demographic characteristics of the respondents including the number of years they have been practicing in FRM and any potential recommendations. Part two contains four questions (Q2.1 to Q2.4, See Appendix C), related to Local Council's flood information and flood characteristics. Part three includes four questions pertinent to the socio-economic condition of Local Council in FRM (Q3.1 to Q3.4, See Appendix C), this is followed by Part four contains three questions about transport infrastructure condition of Local Council in FRM (Q4.1 to Q4.3, See Appendix C). Part five has only one question (Q5.1, See Appendix C) about FRM phases. Part six to nine covers questions related to Local Council's mitigation, preparedness, response and recovery activities, respectively.

Finally, Part ten comprises three questions (Q10.1 to Q10.3, See Appendix C) related to Local Council's proactive, reactive and overall approaches in transport infrastructure FRM.

5.6.2.1Measurement considerations

Measurement is an underlying concept in conducting a questionnaire survey (Hair, 2009) and measurement indicators can be generated using a literature review, focus groups, field survey, panel study and interviews (Churchill, 1979). In this study, the measurement indicators for each individual identified constructs were generated through a review of literature (see Chapters 4). To increase the validity of these measurement indicators, one experienced academic, two experts from FMA and one expert from a Local Council assessed the structured questionnaire before the pilot study, particularly on issues involving the contents and wording of individual measurement indicators.

Three constructs were measured by single-indicator including the proactive approach, the reactive approach and the stakeholder overall approach. Some researchers sometimes choose to use a single-indicator rather than multiple-indicators to measure constructs, because a single-indicator is easy to use, it is brief and costs less. (Hair et al., 2014a). The justification for using a single-indicator in this study is provided in Section 6.4.4.2.

5.6.2.2Pilot testing

Pilot testing is an indispensable part of constructing a questionnaire because it provides constructive feedback on how straightforward the questionnaire is and which concepts are ambiguous (Babbie, 2012). In this study, the FMA was asked to assist in a pilot testing of the questionnaire. Seven potential Local Councils were selected by the FMA to participate in the pilot study. The participants were asked to provide feedback on several issues, including (i) the clarity of the instructions, questions, and measurement indicators and (ii) the relevance of all measurement indicators to Local Councils' FRM in NSW transport infrastructure.

Only four Local Councils agreed to participate in the pilot study and they all agreed that the questionnaire was generally comprehensive. However, they mentioned that: (i) some questions would require a lot of research by a Local Council officer to complete and (ii) some questions were verbatim and probing. They suggested that some overlapping indicators could be omitted, but some unclear statements and questions should be revised in plain English. These amendments and revisions were carried out before the questionnaire was officially distributed to the 75 Local Councils across NSW.

Some measurement indicators, particularly in the construction of transport infrastructure (indicators TI1 to TI6 in Table 4-1) were discussed with experts from Local Councils in the pilot study to enhance the reliability and validity of the measurement indicators.

5.6.2.3 Ethical Considerations

Social researchers should consider the following concerns before involving humans or animals in their research (Bryman, 2012): (i) whether the participants will be harmed; (ii) whether there is a lack of informed consent; (iii) whether there is an invasion of privacy; and (iv) whether deception is involved.

This research was conducted at the University of Sydney and it abided by the University rules and regulations to protect the welfare, rights, dignity and safety of the research participants, and to protect the researchers' rights to conduct a legitimate investigation. An ethics application was submitted to the Human Ethics committee, which was subsequently approved in June, 2013, before the questionnaire was distributed to the respective local councils.

5.6.3 Questionnaire implementation

Direct contact with Local Councils to request their participation was time consuming and could not guarantee an acceptable response rate so the FMA Executive agreed to help distribute the questionnaire to its Local Councils members across NSW. Local Council staff working in NDRM were asked to complete the questionnaire. This questionnaire was designed to assess Local Councils' FRM approaches over the past 20 years (1992-2012), so their responses were supposed to reflect their stakeholder attributes and their proactive and reactive approaches in managing flood risks in transport infrastructure across NSW.

Local Council staff including floodplain engineers, planning and infrastructure engineers and emergency management officers were identified as prospective respondents for this questionnaire.

The FMA emailed the questionnaire to its 75 NSW Local Council members on 21st of September 2013, together with a link to an on-line version of the questionnaire designed using SurveyMonkey tool. The respondents were given two weeks to complete the survey questionnaire.

By mid October 2013, only 11 Local Councils had responded (15% response rate), so in an effort to improve the response rate, two attempts were made to increase the response rate via follow-up emails and calls. The follow-up emails were sent by FMA to the remaining Local Councils giving them another two weeks to complete the questionnaire. Eight more Local Councils responded, making a total of 19 (25% response rate). Eventually, 37 Local Councils completed the questionnaire, representing a response rate of 48% (see Section 8.2 for the profiles of respondents).

5.7 Summary

This study used the survey research design where data was collected through secondary data sources and a structured questionnaire as primary data. Data for flood characteristics, socio-economic and transport infrastructure was obtained from BoM, ABS, and RMS databases for the past twenty years (1982-2012). A questionnaire was then designed to collect the remaining data, particularly data pertinent to Local Councils' stakeholder attributes and approaches. Local Councils across NSW, Australia are responsible for investing, constructing, maintaining, and restoring a major portion of regional and local roads and bridges across NSW. Therefore, Local Councils were selected as stakeholders or unit of study in this research. Among 152 Local Councils in NSW, only 75 Local Council members of FMA were targeted for this study because they have been affected by flooding.

The questionnaire development phase involved design, pilot testing and ethics approval prior to the Local Council wide survey. Local Council staff including floodplain engineers, planning and infrastructure engineers and emergency management officers identified as perspective respondents for completing the structured questionnaire for this study. 37 responses were received, representing a response rate of 48%.

CHAPTER

6

Methods of Data Analysis

6.1 Introduction

This chapter explains the methods used to analyse the data. It first presents the background of the data analysis methods adopted in this study (Section 6.2), followed by details of Bootstrap-TOPSIS (Section 6.3) and PLS-SEM (Section 6.4). The last section presents the importance-performance matrix analysis for developing a stakeholder disaster response index (Section 6.5). The justification for selecting the analytical approaches used in different stages of the structural equation modelling approach is also highlighted in the corresponding sections.

6.2 Background of data analysis methods

In this study, two methods were used to address the research objectives: (i) Multi-Attribute Decision-Making (MADM) and (ii) Multivariate Data Analysis (MDA). MADM was used to analyse the exposure and vulnerability of Australian states and territories to flood risk, the second research objective, by simultaneously considering the socio-economic, coastal buildings and transport infrastructure. MDA was used to address the third to fifth research objectives by (i) testing the theoretical framework and investigating the effects of inter-relationships between stakeholder attributes, approaches and FRM in transport infrastructure; (ii) investigating the mediating effects of the socio-economic and transport infrastructure conditions on the relationship between stakeholder attributes and flood damage; and (iii) developing a stakeholder disaster response index that measures stakeholder proactive, reactive and overall approaches in FRM to transport infrastructure.

6.2.1 Multi-Attribute Decision-Making (MADM)

The use of MADM techniques dates back four decades, but since then scholars have developed the theory and applications of MADM quite extensively (Opricovic and Tzeng, 2004, Chen, 2000, Deng et al., 2000). MADM is an optimisation technique that can tackle the predicaments in conflict conditions by selecting the most desirable alternative with the highest degree of satisfaction for all the relevant attributes. In MADM, Decision-Makers (DMs) need to select or rank the alternatives that are associated with commensurate or conflicting attributes.

The main issue associated with MADM methods is determining the weights for the attributes, but fortunately, there are many methods that can be used to determine the weights of attributes in MADM. Olson (2004) compared three weighting methods; equal weights, weights generated by ordinal rank and weight generated by regression, while Deng et al. (2000) developed a task-oriented weighting approach that electively linked the criteria weights with the requirements of specific tasks for selecting the most suitable alternative, whereas Hwang and Yoon (1981) proposed the use of expert judgments and simulation methods to generate appropriate weights for criteria. It is becoming increasingly common to use regression analysis to calculate weights for attributes in MADM models, but the sample size and type of statistical distribution is imperative. Based on an assumption that the exposure and distribution of vulnerability data is unknown and the data sources are incomplete, this study applied a non-parametric resampling Bootstrap method in conjunction with the Technique for the Order Preference by Similarity to Ideal Solution (TOPSIS) method to address the second research objective by minimising the weigh factor issue in the MADM techniques.

6.2.2 Multivariate Data Analysis (MDA)

MDA methods will increasingly influence not only the analytical aspects of research but also the design and approach to collecting data for decision-making and problem solving (Hair, 2009). MDA involves the use of statistical methods that concurrently assess multiple variables (Hair et al., 2014a). Measurements collected from surveys are primary data, but from databases they are secondary data. In this study, primary and secondary data was used to address the research questions. MDA has versatile characteristics and can be quite a powerful statistical approach for data analysis (Hair, 2009). Selecting an appropriate MDA technique depends on answering the following questions (Hair, 2009): (i) can the variables be divided into independent and dependent classifications?; (ii) how many variables are treated as dependent in a single analysis?; and (iii) how are the variables measured?

In this study, a dependence technique may be suitable because there is a set of variables known as a dependent variable that must be predicted or explained by other variables called independent variables. For instance, flood damage should be predicted by flood characteristics, the socio-economic and transport infrastructure exposure and vulnerability of a Local Council, as well as their attributes. Moreover, Local Councils' proactive and reactive approaches were predicted by mitigation, preparedness, response and recovery activities and their attributes. When the research problem involves several relationships of dependent and independent variables, Structural Equation Modelling (SEM) is one of the most suitable MDA techniques (Hair, 2009). Statistical methods for analysing multivariate data are classified into two general categories (Hair et al., 2014b, Sharma, 1995): (i) first-generation techniques and (ii) second-generation techniques. Table 6-1 shows some of the major and common types of statistical techniques associated with MDA. This study used second-generation techniques

Table 6-1: Classification of MDA methods

First-generation techniques	Second-generation techniques
• Cluster analysis • Exploratory factor analysis • Multidimensional scaling • Analysis of variance • Logistic regression • Multiple regression	• Confirmatory factor analysis • CB-SEM • PLS-SEM

6.3 Bootstrap-TOPSIS: A non-parametric MADM approach

The Bootstrap technique was introduced by Efron (1979) to calculate the confidence intervals of parameters in circumstances where standard techniques cannot be applied (Efron and Gong, 1983). With a minimal set of assumptions for modelling and analysis, this technique has solved many complicated problems compared to traditional statistical analysis (Efron and Tibshirani, 1993, Hall, 1992). Unlike other resampling techniques, Bootstrapping gives more accurate results and it is more robust and popular (Sawyer, 2005). Moreover, applications of the Bootstrap technique are found in numerous subject areas such as machine learning (Reich and Barai, 1999), hydrology (Mehrotra and Sharma, 2006, Srinivas and Srinivasan, 2006, Srinivas and Srinivasan, 2005), geology (Mukul et al., 2004), model selection (Lendasse et al., 2005, Simon et al., 2003), signal processing (Zoubir and Boashash, 1998), construction risk analysis (Hashemi et al., 2011, Mojtahedi et al., 2009, Alborzi et al., 2008) and cost management (Kim et al., 2008, Sonmez, 2008).

TOPSIS was developed by Hwang and Yoon (1981) and is best MADM technique for analysing and ranking alternatives. Many researchers have used TOPSIS to solve industrial problems in construction management (Mojtahedi et al., 2010, Tan et al., 2010, Zavadskas et al., 2010, Wang and Elhag, 2006), aerospace (Wang and Chang, 2007, Feng and Wang, 2000), environmental management (Huang et al., 2011, Gumus, 2009), manufacturing (Kim et al., 2011, Yong, 2006, Chen, 2000), transportation (Önüt and Soner, 2008, Tzeng et al., 2005, Feng and Wang, 2001) and FRM in the built environment (Mojtahedi and Oo, 2014a, Almoradie et al., 2013). Ranking of alternatives by TOPSIS methods depends on the shortest distance from the Positive-Ideal Solution (PIS) and the farthest from Negative-Ideal Solution (NIS). TOPSIS concurrently takes into account the distances to PIS and NIS to calculate the Relative Closeness (RC) ratio (Chen, 2000). This notion originated from Von Neumann Morgenstern's theory and prospect theory to displace the ideal point from which a compromised solution would have the shortest distance. TOPSIS has the fewest rank reveals among the other reputable methods of MADM (e.g., Chu et al., 2007, Opricovic and Tzeng, 2004), which means it can rank alternatives quickly. TOPSIS was found to perform almost as well as multiplicative additive weights and better than Analytic Hierarchy Process (AHP) (Zanakis et al., 1998, Parkan and Wu, 1997, Saaty, 1977). Finally, a combination of the Bootstrap non-parametric re-sampling technique and TOPSIS as a MADM technique were used to rank and analyse Australian states and territories against flooding (Chapter 7).

The process of a non-parametric Bootstrap technique combined with TOPSIS is a novel approach which is described in the following sections.

6.3.1 Non-parametric Bootstrap technique

The non-parametric Bootstrap procedure is as follows (Efron, 1979):

Step 1: Let $\mathrm{X_N} = \{\mathrm{x_1}, \mathrm{x_2}, \dots, \mathrm{x_n}\}$ be an original data set.

Step 2: Select a sample $\mathrm{X_i}$ from $\mathrm{X_N}$ randomly N times with replacement.

Step 3: Compute a Bootstrap sample $\mathrm{x_i^*} = \sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{w_i} \times \mathrm{x_i}$ where $\mathrm{w_i}$ is given by:

$$w_i = \frac{\emptyset_i}{\sum_{i=1}^{N} \emptyset_i} \quad , \quad 0 \leq i \leq N$$

Equation 6-1

where $\emptyset_i$ is chosen from a uniform distribution on [0,1]. Note that $\sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{w_i}=1$

Step 4: Repeat step 1, 2, and 3, B times. B is the number of Bootstrap resampling iteration.

Step 5: Construct $\mathrm{X^*} = \{\mathrm{x_1^*}, \mathrm{x_2^*}, \dots, \mathrm{x_n^*}\}$ as the Bootstrap resample.

Note that the final result will change during each iteration of the Bootstrap procedure if a different $\emptyset_i$ is generated rather than a uniform one, but either way the result will diverge to the same outcome.

6.3.2 Proposed Bootstrap-TOPSIS method

The proposed non-parametric Bootstrap-TOPSIS procedure implemented in Microsoft Excel 2007 is an amalgamation of the Bootstrap principle (Zoubir and Boashash, 1998) and TOPSIS procedure (Hwang and Yoon, 1981) and is combined as follows:

Step 1: Construct decision-making matrix $D = [d_{ij}]$, where $\mathrm{d_{ij}}$ indicates the performance rating of i^{th} alternative with respect to j^{th} attribute.

Step 2: Construct the normalised decision matrix $R = [r_{ij}]$. The vector-normalised value r_{ij} in the decision matrix R can be calculated by Eq. 6-2:

$$r_{ij} = \frac{d_{ij}}{\sqrt{\sum_{j=1}^{n}(d_{ij})^2}}, \qquad i = 1,2,3,\dots,m$$

Equation 6-2

Step 3: Construct the weighted normalised appraisal matrix. Each appraisal criterion cannot be assumed as being of equal importance because the appraisal criteria have various meanings. The weighted normalised appraisal matrix is calculated by multiplying the normalised appraisal matrix r_{ij} by its associated weight x_j^* to obtain the result. The weighted normalised value is calculated by Eq. 6-3:

$$v_{ij} = x_j^* \times r_{ij}\,; \qquad i = 1,2,3,\dots,m \quad , \quad j = 1,2,3,\dots,n$$

Equation 6-3

x_j^* is the weight of each attribute calculated by non-parametric Bootstrap resampling technique where;

$$\sum_{j=1}^{n} x_j^* = 1,$$

Equation 6-4

Step 4: Determine the positive ideal and negative ideal solutions. The *PIS* (V^+) and *NIS* (V^-) are shown as Eqs. 6-5 and 6-6:

$$V^+ = (v_1^+, v_2^+, \dots, v_n^+) = \left\{\left(\max_i v_{ij} \,\middle|\, i = 1,2,\dots,m\right),\ \ j = 1,2,\dots,n\right\}$$

Equation 6-5

$$V^- = (v_1^-, v_2^-, \dots, v_n^-) = \left\{\left(\min_i v_{ij} \,\middle|\, i = 1,2,\dots,m\right),\ \ j = 1,2,\dots,n\right\}$$

Equation 6-6

Step 5: Calculate the separation measures. The distance of each alternative from V^+ and V^- can be calculated using Eqs. 6-7 and 6-8.

$$d_i^+ = \left\{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2\right\}^{0.5} \quad , \qquad i = 1,2,\ldots,m$$

Equation 6-7

$$d_i^- = \left\{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2\right\}^{0.5} \quad , \qquad i = 1,2,\ldots,m$$

Equation 6-8

Step 6: Calculate the relative closeness RC_i to the ideal solution. This step solves the similarities to an ideal solution by Eq. 6-9:

$$RC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad , \qquad i = 1,2,\ldots,m$$

Equation 6-9

6.4 Structural Equation Modelling (SEM)

SEM is an advanced MDA technique that combines aspects of factor analysis and regression to simultaneously examine relationships between measurement indicators and constructs (Hair et al., 2014a). SEM has been used in social science research to develop and test theories using survey data for studies in business marketing (e.g., Hair et al., 2011, Henseler et al., 2009, Fornell et al., 1996), organisational behavioural (Hair et al., 2014b), construction management (e.g., Oke et al., 2012, Aibinu and Al-Lawati, 2010, Lim et al., 2010) and disaster management (Chen et al., 2012). A hypothesised SEM model is shown in Figure 6-1 to explain its concepts..

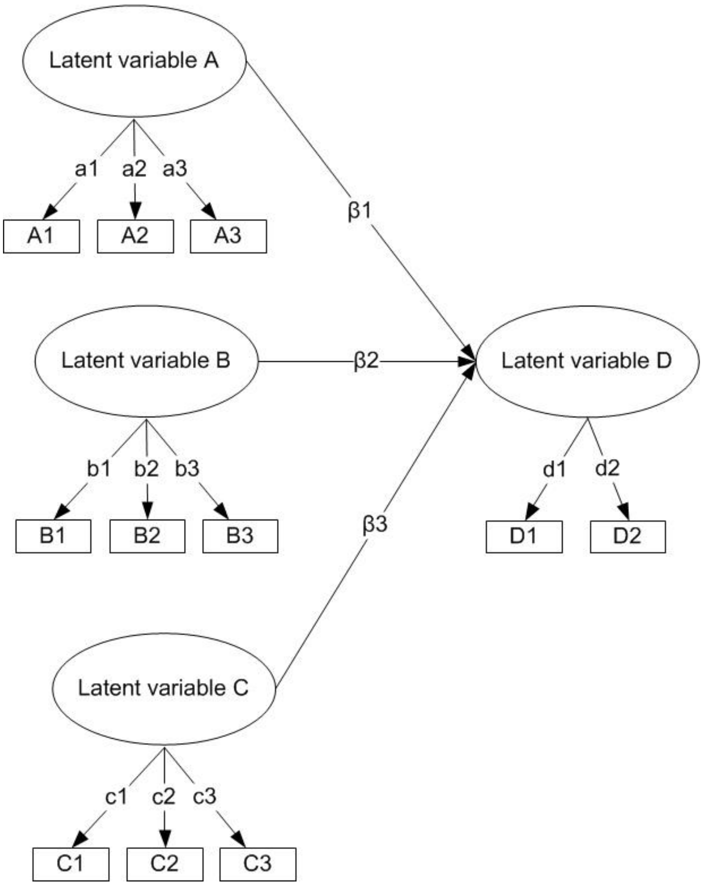


Figure 6-1: A hypothesised SEM model adopted from (Ayodeji, 2008)

The paths are hypothesised relationships between the constructs where they are represented in the path model as circles or ovals (A to D). The rectangular boxes represent observed variables or measurement indicators. For example, three indicators (A1, A2, and A3) measure construct A. The relationships between the constructs are shown in arrows and the relationships between the constructs and their assigned measurement indicators are shown as dotted-arrows. The measurement model is explained as follows:

$$y = \gamma_y \theta + \epsilon$$

Equation 6-10

$$x = \gamma_x \rho + \delta$$

where $y = (p \times 1)$ is a vector of endogenous indicators, $x = (q \times 1)$ is a vector of exogenous indicators, $\gamma_y = (q \times n)$ is a matrix of regression coefficients of ρ on x, and $\epsilon = (p \times 1)\ and\ \delta = (q \times 1)$ are vectors of measurement error for endogenous and exogenous variables, respectively.

The structural model is expressed as follows:

$$\beta\tau = \omega\varphi + \varepsilon$$ **Equation 6-11**

Where $\tau = (m \times 1)$ is a vector of latent endogenous variables, $\varphi = (n \times 1)$ is a vector of latent exogenous variables, $\beta = (m \times m)$ is a matrix of endogenous variable coefficients, $\omega = (m \times n)$ is a matrix of exogenous variable coefficients, and $\varepsilon = (m \times 1)$ is a vector of residuals (Ayodeji, 2008).

The measurement model is an element of path model that includes the measurement indicators and their relationships with the constructs, whereas the structural model is an element of a PLS path model that contains the constructs as well as the relationships between them. Endogenous constructs only serve as dependent variables, or as both independent and dependent variables, however, exogenous constructs serve only as independent variables in a structural model (Hair et al., 2014a).

SEM was used as a second-generation MDA technique in this study because an SEM approach incorporates multiple dependent constructs, recognises error indicators, and integrates theory with empirical data (Fornell, 1982). The research problems addressed by the study consist of theoretical and hypothesised relationships of constructs (see Figure 3-1, Chapter 3) which must be measured with observable measurement indicators. Multiple regression analysis was not a suitable MDA here because it deals with the relationship between single dependent variables and many independent variables and does not provide any test on validation or reliability for measuring latent variables and it cannot assess the relationships between the latent variables (Hair, 2009, Ayodeji, 2008). Moreover, the factor analysis technique cannot provide information relating to the relationship between the latent variables in the structural model. SEM has numerous advantages over multiple regression analysis and factor analysis, including (Hair, 2009): (i) it provides models among the multiple predictors and variables; (ii) it constructs unobservable latent variables; (iii) it provides ample information about any modelling errors; and (iv) it tests a priori theoretical assumptions against the empirical data.

There are two strategies for predicting the relationships in SEM by empirical data, namely: (i) Covariance-based SEM (CB-SEM) and (ii) Partial Least Square SEM (PLS-SEM) (Hair et al., 2014a, Hair et al., 2014b, Hair, 2009). Each strategy suits a different research perspective, and researchers need to grasp the discrepancies in order to apply the correct method (Hair et al., 2014a). CB-SEM was utilised to confirm (or reject) theories, whereas PLS-SEM was primarily used to develop theory in an exploratory research. Much research has been conducted to distinguish the main differences between CB-SEM and PLS-SEM (e.g., Hair et al., 2014a, Becker et al., 2012, Hair et al., 2011). In situations where theory was less developed, researchers should consider using PLS-SEM as an alternative approach to CB-SEM. PLS-SEM was thus used as an analytical technique in this study. The estimation procedure for PLS-SEM is an ordinary least squares (OLS) regression-based method rather than the maximum likelihood (ML) estimation procedure for CB-SEM (Hair et al., 2014a).

6.4.1 Justification for using PLS- SEM

In addition to the above reasoning, the following reasons were applicable for using PLS-SEM in this study:

(i) PLS-SEM works efficiently with small sample sizes and complex models and it needs no assumptions about data distributions (Henseler, 2010). This study only contains 37 samples, which is a small sample size, whereas the structural model has 12 constructs and 14 hypotheses which makes the proposed model complex.

(ii) PLS-SEM can easily manage reflective and formative measurement models, as well as single-indicator constructs (Hair et al., 2014a). The structure model proposed to investigate stakeholder attributes and approaches to FRM in the transport infrastructure consists of reflective and formative indicators. For instance, first-order constructs such as exposure and vulnerability are related to the second-order constructs (e.g., socio-economic and transport infrastructure conditions) in a formative fashion. Furthermore, because of the exploratory nature of the research, stakeholder proactive, reactive and overall approaches are single-indicator constructs. Thus, PLS-SEM is most probably one of the best techniques to handle formative-reflective and single-indicator constructs.

(iii) PLS-SEM is very efficient at estimating parameters, which results in high levels of statistical power. Greater statistical power means that PLS-SEM will probably generate a specific and significant relationship when in fact it's significant in the population (Hair et al., 2014a).

(iv) PLS-SEM is a very robust technique as long as any missing values are below a reasonable level (Roderick et al., 2002). The data collection process encountered some missing data in this study, so PLS-SEM is an appropriate tool to handle missing data with approaches such as mean value replacement (Hair et al., 2014a).

(v) The fifth objective of this research is to develop an index to measure the stakeholder overall approach to natural disasters. Undoubtedly, PLS-SEM is an effective tool when the plan is to use latent variable scores in subsequent analysis because it can generate latent variable scores by applying an impact-performance matrix analysis (Hock et al., 2010, Fornell et al., 1996).

(vi) Analyses for the mediating effects (e.g., social-economic and transport infrastructure conditions) and hierarchical component models (e.g., exposure and vulnerability) are available in the PLS-SEM technique.

There are still several limitations with PLS-SEM including: (i) it cannot handle casual loops or circular relationships between the latent variables; (ii) it does not provide ample global goodness-of-model fit measure; (iii) its use for theory testing and confirmation is limited; and (iv) its parameter estimates are not optimal regarding bias and consistency (Hair et al., 2014a, Henseler, 2010).

Several software packages have been developed for the PLS-SEM approach since the advent of the PLS-SEM technique, such as LVPLS (Lohmoller, 1988), PLS-GUI (Li, 2005), VisualPLS (Fu, 2006), PLS-Graph (Chin and Frye, 2003), and SmartPLS (Ringle et al., 2005). The SmartPLS software 2.0 was used to execute all the PLS-SEM analyses in this study because the software is free at http://www.smartpls.de and it has a graphical user interface that enables the user to effectively estimate the PLS path model.

6.4.2 Bootstrap procedure in PLS- SEM

PLS-SEM depends on a non-parametric Bootstrap procedure (Efron and Tibshirani, 1993, Efron, 1979) to test coefficients for their significance (Hair et al., 2014a). In the Bootstrapping procedure, a large number of subsamples are randomly drawn from the original sample with replacement to obtain a robust estimate of the confidence intervals of a population parameter. The resampling procedure should be iterated numerous times because the number of Bootstrap samples must be larger than the number of valid observations in the original data set, in reality, 5,000 Bootstrap samples are recommended (Hair et al., 2014a).

The Bootstrap procedure in PLS-SEM provides the standard error of an estimated coefficient that allows it to determine the empirical *t*-value. Because the *t*-distribution can be approximated by the normal distribution for sample size of more than 30, the *t*-value can be used for significance testing (Efron and Tibshirani, 1993, Efron, 1979). Theoretical t-values for a two-tailed test are 1.65 ($\alpha = 0.10$), 1.96 ($\alpha = 0.05$) , or 2.57 ($\alpha = 0.01$).

The Bootstrap procedure is a suitable technique for estimating the *t*-value in this study because the sampling distribution of a target population (i.e., Local Councils) is either indeterminate or difficult to obtain empirically; furthermore, it is an in-built procedure in the SmartPLS 2.0 software.

6.4.3 Specifying the structural model

To specify the structural model, some fundamental explications about conceptual models should be explained because the concept of NDRM (IPCC, 2012), stakeholder theory (Mitchell et al., 1997) and decision-making paradigms (Edwards, 1954) are the pillars of the proposed theoretical framework of this research. The goal of the model is to explain the effects that Local Councils' Stakeholder Attributes (SA) have on Flood Damage (FD) by considering the simultaneous effects of Flood Characteristic (FC), Socio-Economic condition (SE) and Transport Infrastructure condition (TI). At the same time, the proposed model was developed to interpret the effects of Local Councils' Stakeholder Attributes (SA) on NDRM activities such as Mitigation (MI), Preparedness (PR), Response (RS) and Recovery (RC) and, ultimately Local Council Proactive Approach (PA), Reactive Approach (RA) and Overall Approach (OA). Figure 6-2 shows the constructs and their relationships which represent the structural model for the PLS-SEM analysis by focusing on Local Council as unit of study.

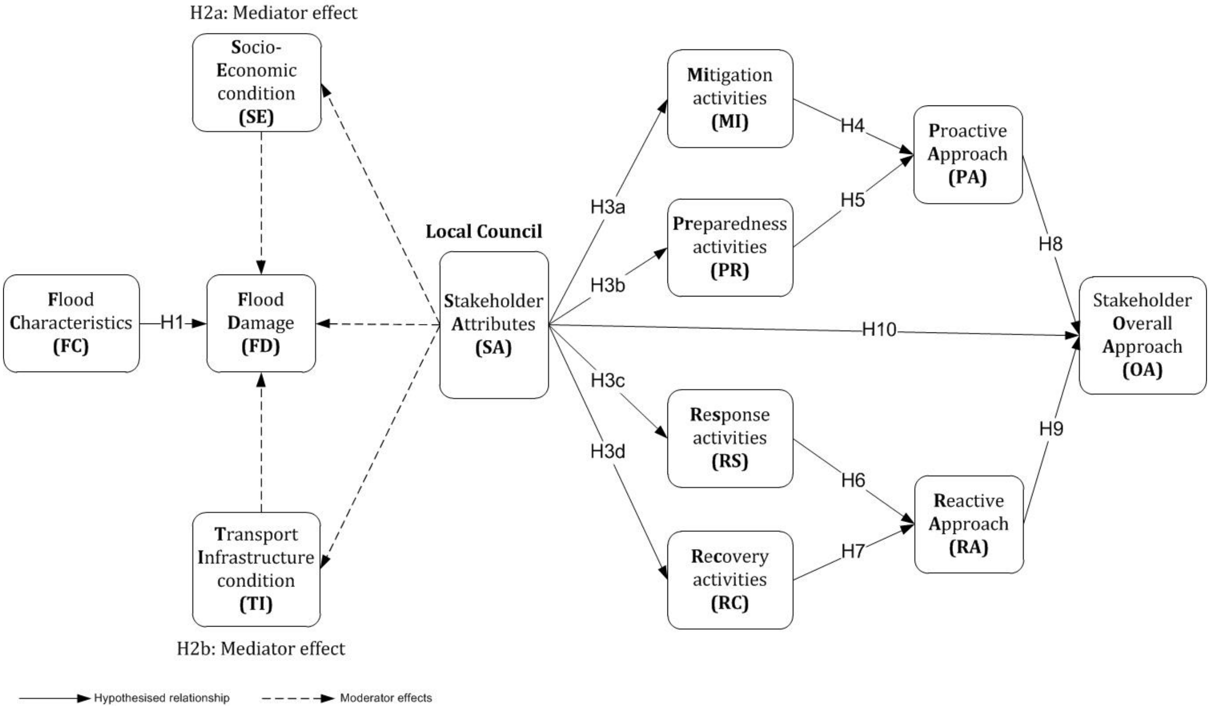


Figure 6-2: Structural model and hypotheses with Local Council as unit of study

To develop a structural model, two fundamental matters must be considered: (i) the sequence of the constructs and (ii) the relationships between them. Both issues are critical to the concept of modelling because they represent the hypotheses and their relationship to the theory being tested. The sequence of the constructs in a structural model is based on theory, logic or practical experiences observed by the researches (Hair et al., 2014a). A combination of theories and the logic of NDRM was utilised to specify the sequence of constructs in this research; constructs that only act as independent variables are generally referred to as exogenous latent variables, and exogenous latent variables only have arrows pointing out of them, never into them. For instance, in this research the flood characteristics and Local Council attributes were regarded as exogenous latent variables, whereas the construct was regarded as dependent in a structural model (i.e., those that have an arrow pointing into it) and are often called endogenous latent variables. Flood damage, mitigation, preparedness, response, recovery activities, proactive and reactive approaches, and Local Council overall approach are endogenous constructs. Determining the sequence of these constructs is not easy because opposing theoretical perspectives can result in various sequencing of latent variables. For example, some researchers assume that mitigation and preparedness tasks predict a proactive approach (Moe and Pathranarakul, 2006, Brilly and Polic, 2005), while others argue that the mitigation task is only the predictor for a proactive approach (Lyles et al., 2013, Berke and Godschalk, 2009, Godschalk, 1999, Brower and Beatley, 1989). Theory and logic should always determine the sequence of constructs in a theoretical model, but when the literature is inconsistent or unclear, researchers must specify the sequence. Undoubtedly, flood characteristics are important components with which to measure flood damage (Leroy, 2006, Merz et al., 2004) and the socio-economic and transport infrastructure conditions of a specific region directly affect the level of flood damage (e.g., Toya and Skidmore, 2007, Wilby, 2007, Haque, 2003), but increasingly, the institutional characteristics of organisations responsible for FRM will have an impact on flood damage (e.g., IPCC, 2012, Raschky, 2008, Pelling and Uitto, 2001). Therefore, the flood characteristics, socio-economic, transport infrastructure conditions, and stakeholder attributes (i.e., Local Councils' attributes) have been considered the predictors' constructs for flood damage.

Proactive and reactive approaches most probably define the stakeholder overall approach to disasters (IPCC, 2012), but based on stakeholder theory (Mitchell et al., 1997), the relationship of stakeholder attributes with NDRM tasks and approaches can be hypothesised in order to be evaluated.

Selecting the optimum sequence from several competing alternatives can be challenging, so in this study the trade-off between theoretical soundness, practical perspectives and model parsimony have been meticulously examined (Falk and Miller, 1992).

6.4.3.1 Higher-order and hierarchical component models

Higher-order Models or Hierarchical Component Models (HCM) often involve testing second-order structures that contain two layers of components (Becker et al., 2012). For instance, the socio-economic and transport infrastructure conditions can be defined at different levels of abstraction, while the socio-economic condition can be represented by numerous first-order components that capture separate attributes of society and the economy. In the context of FRM, these might include exposure and vulnerability (IPCC, 2012), as shown in Figure 6-3.

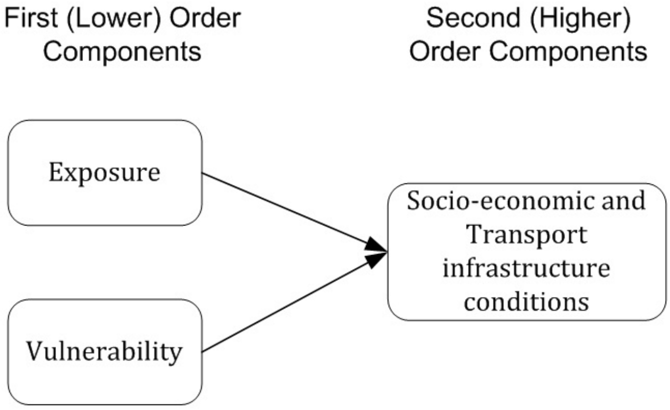


Figure 6-3: Hierarchical component model

Instead of modelling the attributes of socio-economic and transport infrastructure conditions as a single construct layer, higher-order modelling involves summarising the lower-order components (LOCs) into a single multi-dimensional higher-order construct (HOC). This approach simplifies the theory and reduces model complexity. It should be noted that theory, logic, or the body of knowledge should indicate the number of dimensions and their relationships to the higher-order construct (Becker et al., 2012). In this research, exposure and vulnerability were selected as first order components of socio-economic and transport infrastructure because IPCC (2012) argued strongly that exposure and vulnerability were key constructs of socio-economic, governance, institutional, built environment, cultural and environmental conditions in the context of NDRM. Moreover, reducing exposure and vulnerability are core common elements of NDRM (IPCC, 2012). Some scholars have shown that exposure and vulnerability are the fundamental constructs for measuring the impact of natural disaster on society, economy and the built environment (e.g., Crozier et al., 2006, Davidson and Lambert, 2001, Alexander, 2000), indeed Davidson (1997) increasingly considered both exposure and vulnerability as first order components when developing an earthquake disaster index.

6.4.3.2 Mediation effects of socio-economic and transport infrastructure conditions

A mediating effect is created when a third variable or construct intervene between two other related constructs, as shown in Figure 6-4. The socio-economic and transport infrastructure conditions were modelled as a possible mediator between Local Council stakeholder attributes and flood damage. On the basis of theory, logic and the body of NDRM knowledge, a relationship exists between institutions or stakeholder attributes and disaster damage (Raschky, 2008), but how that relationship actually works is ambiguous. Thus, an empirical investigation into how the attributes of Local Councils can affect the severity of flood damage is essential, particularly when a Local Council with high levels of stakeholder attributes experiences high levels of flood damage and some Local Councils with lower stakeholder attributes are affected less in terms of flood damage. These observations can be confusing enough to ask whether there is some other process that translates stakeholder attributes into flood damage. In Figure 6-4, the intervening process (mediating effects) was modelled as socio-economic and transport infrastructure conditions. If a Local Council has high levels of stakeholder attributes in a certain region, it may lead to lower levels of exposure and vulnerability of socio-economic and transport infrastructure conditions and ultimately to decreased flood damage. In such a case, the relationship between Local Council attributes and flood damage may be explained by their attributes → socio-economic condition → flood damage, or perhaps by both sets of relationships (Figure 6-4). After empirically testing these relationships, how Local Councils' attributes are related to flood damage could be explained, and so too could the role that socio-economic and transport infrastructure conditions might play in mediating that relationship.

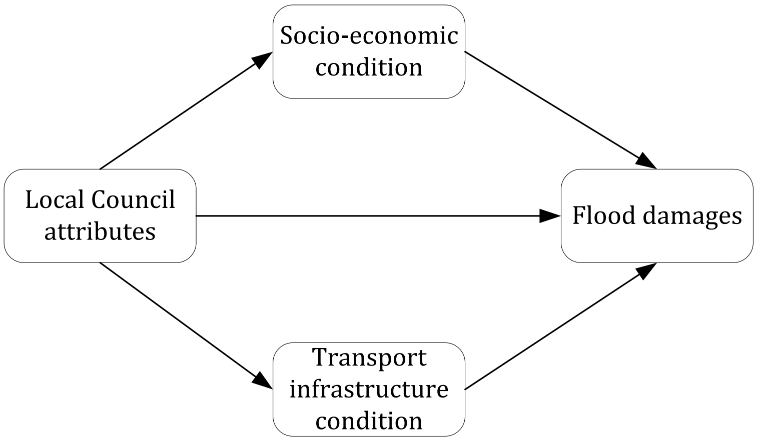


Figure 6-4: Mediating effect

6.4.4 Specifying the measurement model

Since the constructs were not measured directly, a measurement model for each individual construct should be specified. The 12 constructs in this research model were measured by multiple indicators and a single indicator. Here the measurement models represent the relationship between the constructs and their respective indicator variables, and these relationships were determined by a measurement theory that is the condition needed to acquire rewarding results from PLS-SEM. Hypothesis tests will only be as reliable and valid as the measurement models that explain how these constructs are measured (Hair et al., 2014a). All 12 constructs have reflective measurement models, as indicated by the arrows pointing from the construct to the indicators. However, two constructs (socio-economic and transport infrastructure conditions) have reflective-formative measurement models, as Figure 6-5 shows. This lower-order construct is formative to its respective second-order construct, whereas all the remaining constructs were developed as reflective, but increasingly, constructs such as the Proactive Approach (PA), the Reactive Approach (RA), and the Local Council Overall Approach (OA) were measured by single indicator.

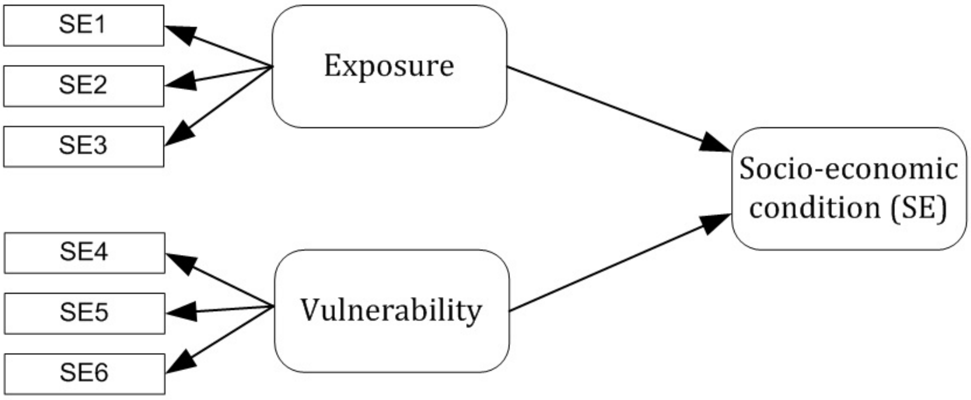


Figure 6-5: Reflective-formative measurement model

6.4.4.1 Reason for using reflective measurement model

Deciding whether a measurement model is reflective or formative is difficult, which is why the issue of selecting an appropriate measurement model has been debated among scholars in a variety of disciplines (Hair et al., 2014a). The reflective measurement model was used in this research because: (i) there is a casual priority from the construct to the indicators (Diamantopoulos and Winklhofer, 2001); (ii) the construct is a trait that explains the indicators (Fornell and Bookstein, 1982); (iii) the indicators represent the consequences of the construct (Diamantopoulos, 2005); (iv) if the assessment of the trait changes, all the indicators will change in a similar manner (Chin, 1998); and finally (v) the indicators are mutually interchangeable (Jarvis et al., 2003).

6.4.4.2 Reason for using single-indicator measures

Constructs of the Proactive Approach (PA), the Reactive Approach (RA), and the Local Council Overall Approach (OA) to flood were measured by a single indicator, as depicted in Figure 6-6. Single-indicator measures have practical advantages such as ease of application, brevity, and lower costs associated with their usage (Hair et al., 2014a), and moreover, single-indicator measures promote higher response rates because the questions can be answered quickly and easily (Fuchs and Diamantopoulos, 2009). According to guidelines proposed by Diamantopoulos et al. (2012), a single-indicator is acceptable in this research because: (i) a small sample size was used (N=37 < 50); (ii) the indicators of the originating multi-indicator scale were firmly homogenous; and (iii) the indicators were semantically redundant. Nevertheless, when setting up measurement models, this purely empirical perspective should be complemented by practical considerations (Hair et al., 2014a). In this research, the use of single-indicator measures was inevitable because the population being surveyed was small and only a limited sample size (Local Councils) was available, and moreover, the nature of this study is exploratory and the role of stakeholder approaches in the context of NDRM has not yet been investigated. Thus, the use of single-indicator measures is a pragmatic solution particularly in stakeholder approaches in the context of NDRM.

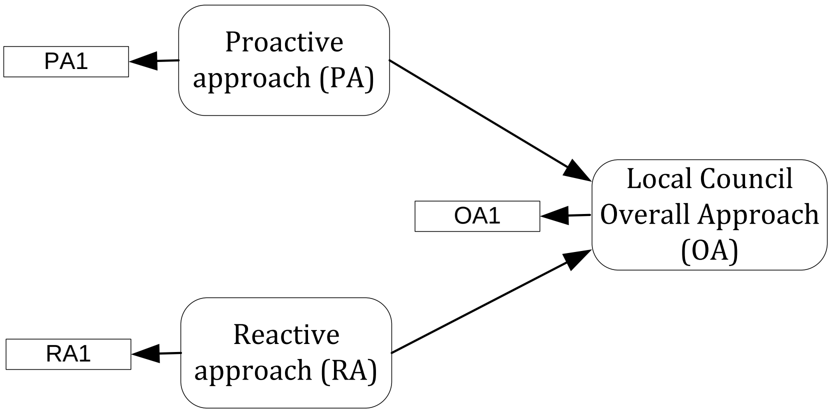


Figure 6-6: Single-indicator measures

There are some issues associated with single-indicator constructs; single-indicator measures leave researchers with fewer degrees of freedom, and from a validity perspective, it is a risky decision when it comes to predictive validity considerations (Hair et al., 2014a). However, scholars firmly suggest that the reliability and validity of single-indicator constructs should be tested (Hair et al., 2014b, Diamantopoulos et al., 2012, Fuchs and Diamantopoulos, 2009), so the blindfolding test is provided in Section 8.4.6. Finally, comprehensive research by Fuchs and Diamantopoulos (2009) showed that the use of single-indicator constructs should not be considered a fatal flaw in the context of some research.

6.4.5 Data preparation and examination

The data collection and examination stage was very important in the application of PLS-SEM because when empirical data is collected, data collection issues such as missing data, suspicious and social desirability response patterns, outliers, data distribution, and common method variance should be addressed (e.g., Hair et al., 2014a, Babbie, 2012, Flynn et al., 1990).

6.4.5.1 Missing data

A missing data process is any systematic event external to the respondent (such as data entry errors or data collection problems) or action on the part of respondent (such as a refusal to answer) that leads to missing values (Hair et al., 1986).

There were 65 missing values in the dataset, which accounted for 2.25 per cent of the total number of values. One of the most reliable tests for diagnosing the randomness of missing data is Missing at Completely Random (MCAR) (Hair et al., 1986). This test compares the actual pattern of missing data with what could be expected if the missing data was distributed randomly. Therefore, Little's MCAR test was carried out (Roderick et al., 2002) and it revealed that these values were completely missing at random, which suggested they were not based on a hidden systematic pattern and any method of imputation could be used to replace them (Klarner et al., 2013, Hair et al., 2011). The small portion of data missing in this research occurred because an online approach to collection was utilised. Collecting data online reduces missing data because respondents can be stopped from going to the next question if they do not answer a particular question (Hair et al., 2014a). The Mean Value Replacement (MVR) technique in SmartPLS 2.0 was used to treat this issue of missing values by replacing the missing values of an indicator variable with the mean of valid values of that indicator. While MVR is easy to implement, it decreases the variability in the data and probably reduces the possibility of finding meaningful relationships and therefore should only be used when there are very low levels of missing data (i.e., less than 5% missing per indicator) (Hair et al., 2014a). More precisely, SE1 had two missing values (almost 5%), and other indicators such as TI2 and TI3 had one missing value (2.7%), therefore MVR can be used. Furthermore, none of the observations had more than 15% missing values.

6.4.5.2 Suspicious response patterns

Before analysing the data, the response patterns should also be examined. The straight lining technique was used to investigate whether respondents marked the same response for a high proportion of the questions (Hair et al., 2014a, Hair et al., 1986) and if so, that respondent should be removed from the data set. There were no suspicious response patterns in this research because: (i) related personnel involved in FRM completed the questionnaire and (ii) the same questions were designed to see if respondents would give different answers to the same question or not.

6.4.5.3 Outliers

An outlier is an extreme response to a specific question, or extreme responses to all questions, which is why data should be examined for the presence of outliers to ascertain their type of influence owing to their distorting role in statistical tests (Hair et al., 2014a). Box-plots and stem-and-leaf plots techniques were used to help identify outliers by respondents in IBM SPSS (Mooi and Sarstedt, 2011). As Figure 6-7 shows, one case (response) was identified as an outlier and then removed from the data set. This action reduced the data from 37 to 36 cases in this study (48% response rate).

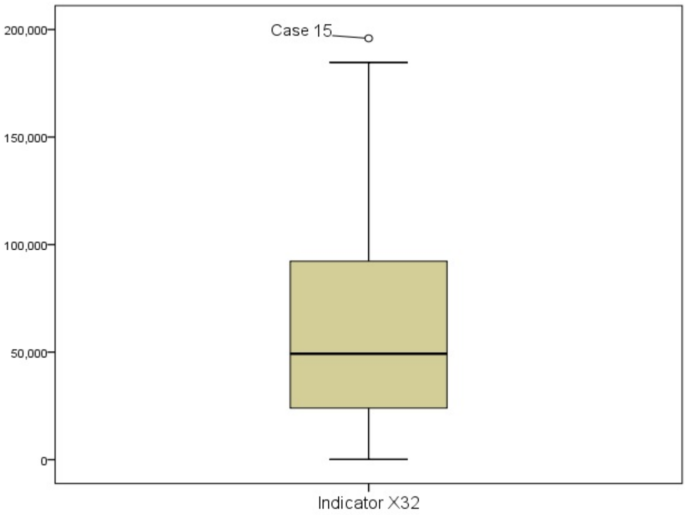


Figure 6-7: Single-indicator measures

6.4.5.4 Data distribution

It is important to verify that the data is not too far from normal because non-normal data can prove problematic in assessing the significance of parameters (Henseler et al., 2009). When both skewness and kurtosis are close to zero, the response pattern is considered to be a normal distribution (Hair et al., 1986).

The non-normality of data regarding skewness and kurtosis was not an issue because their indicators were within the -1 and +1 acceptable range. The only exceptions were FC5, SE6, RC3 and RS5, which had a skewness of -1.3, -1.2, +1.4 and -1.1, respectively, which indicated a slight degree of non-normality. However, because the degree of skewness was not severe, and those indicators were not the only indicator measuring their respective constructs, this deviation from normality was not considered an issue, so the indicators were retained. Finally, PLS-SEM is a non-parametric statistical tool that does not require the data to be normally distributed contrary to CB-SEM (Hair et al., 2014a).

6.4.5.5 Common method variance

To address the issue of self-report data in the questionnaire, Harman's one-factor test was used to assess the common method variance (Schriesheim, 1979). If this method was a significant issue in the study, a single factor would have emerged from a factor analysis or one general factor would have accounted for most of the covariance in the independent variables (Podsakoff and Organ, 1986). Thus, prior to data analysis all the measures were imported into IBM SPSS Statistics version 21 and a principle component factor analysis was performed on the subjective indicators to measure the stakeholder attributes, mitigation, preparedness, response and recovery activities, proactive approach, reactive approach and the stakeholder's overall response. The results showed that no one general factor accounted for the majority of covariance in the measurement indicators, so the common method variance was not an issue in this study.

Finally, Podsakoff and Organ (1986) mentioned that despite the disadvantages involved in the usage of self-report measures, their practical functionality makes them integral in many research contexts.

6.4.6 Evaluation of measurement models

Having examined how to create and specify measurement models, an assessment of the measurement model is discussed in this section. Model estimation delivers empirical measures of the relationships between the indicators and the constructs. The adequacy of reflective measurement models in PLS-SEM was evaluated as follows: (i) individual indicator reliability; (ii) convergent validity of the measures associated with individual constructs (Cook et al., 1979); and (iii) discriminant validity (Campbell and Fiske, 1959). An assessment of reflective measurement models includes composite reliability to evaluate internal consistency, individual indicator reliability and average variance extracted (AVE) to evaluate convergent validity. In addition, Fornell-Larcker criterion and cross loadings were used to assess discriminant validity (Hair et al., 2014a). In the following sections, each criterion used to assess the reflective measurement models is explained.

6.4.6.1 Individual indicator reliability

Individual indicator reliability is an interpretation of the extent to which measurements of the constructs taken with multiple-indicator scale manifests the true score of the constructs relative to any errors (Hulland, 1999). It is the correlations of the indicators with their respective constructs. This correlation is called factor loading (Hair, 2009). Higher loadings on a construct indicate that the associated indicators have much in common and they are captured by the construct (Carmines and Zeller, 1979). All the indicators' outer loadings should be statistically significant. As a rule of thumb, and as used by many researchers, the outer loadings should be 0.708 or higher (e.g., Hulland, 1999, Chin, 1998, Fornell and Larcker, 1981), but if the objective of the research is exploratory, 0.4 or higher is also acceptable (Hulland, 1999). Nunnally et al. (1967) suggested that indicators with low loadings (between 0.4 and 0.7) should only be removed from the scale when deleting the results of the indicator result in an increase in composite reliability or the average variance extracted is more than the suggested threshold value. Indicators with weaker outer loadings are sometimes retained on the basis of their contribution to content validity (Hair et al., 2011). Barclay et al. (1995) also claimed that where the instruments is designed under a specific context and applied to a different context, the loadings threshold value could be lower.

In this study, the scales were adapted from studies on stakeholder attributes in organisational settings. they were not tested beforehand in the context of NDRM in the built environment, which means that some indicators were not applicable across all contexts and or settings. Moreover, some of the indicators were newly developed (see for example, TI2, TI3 and TI6 in Table 4-1 of Chapter 4) based on an exploratory review of reports related to flood disaster reconstruction projects and discussion with experts in NSW Local Councils and RMS. Thus, in order to minimise the errors in measurement models and enhance the precision and validity of the scales and exploratory power of the developed model, a conservative value of 0.70 was used as the threshold value. Nonetheless, prior to removal, the potential practical significance of indicators with loadings lower than 0.70 was meticulously investigated.

6.4.6.2 Convergent validity

Convergent validity is the extent to which a measure correlates positively with alternative measures of the same construct (Hair et al., 2014a). Indicators of a specific measure should converge or share a high portion of variance. Convergent validity is estimated to ensure that the indicators are assumed to measure each respective construct and not another construct (Hulland, 1999). In PLS-SEM, two tests can be used to determine the convergent validity of the measured constructs (Fornell and Larcker, 1981): (i) a composite reliability score and Cronbach's Alpha for the constructs; and (ii) the average variance extracted (AVE).

Composite reliability scores and Cronbach's alpha

The traditional criterion for convergent validity is Cronbach's alpha, which provides an estimate of the reliability based on the inter-correlations of the observed indicator variables (Hair, 2009). Cronbach's alpha has the following limitations to estimate the internal consistency reliability: (i) it assumes that all the indicators are equally reliable (Hair et al., 2014a); (ii) it is sensitive to the number of indicators in the scale and generally tends to underestimate the internal consistency reliability; and (iii) it is low when data has a multi-dimensional structure. Cronbach's alpha can be estimated using the following formula (Cronbach, 1951):

$$\alpha = \frac{N \times \bar{r}}{1 + (N - 1) \times \bar{r}} \qquad \textbf{Equation 6-12}$$

where N is equal to the number of indicators and $\bar{r}$ is the average inter-correlation among indicators. Due to Cronbach alpha's limitations in the population, it would better to apply a different measure of internal consistency reliability, which is referred to as composite reliability (ρ_c). This type of reliability considers the different outer loadings of the indicator variables and is calculated with the following formula (Hair et al., 2014a):

$$\rho_c = \frac{(\sum_i l_i)^2}{(\sum_i l_i)^2 + \sum_i var(e_i)} \qquad \textbf{Equation 6-13}$$

where l_i is the standardised outer loading of the indicator variable i of a specific construct, e_i is the measurement error of indicator variable i, and $var(e_i)$ shows the variance of the measurement error, which is defined as $1 - l_i^2$.

Composite reliability is superior to Cronbach's alpha because it uses the indicator loadings obtained within the theoretical model (Fornell and Larcker, 1981). Cornbach's alpha and composite reliability both vary between 0 and 1, with higher values indicating higher levels of reliability. Churchill (1979) suggested that a Cronbach's alpha value of 0.6 would be acceptable, whereas Nunnally et al. (1967) proposed 0.7 as a benchmark for modest composite reliability. In some exploratory research, composite reliability values of 0.6 to 0.7 were acceptable and values between 0.70 and 0.9 are satisfactory. It is important to note that values above 0.95 are not desirable because they indicate that the indicator variables are measuring the same phenomenon and are hence unlikely to be a valid measure of the construct (Hair et al., 2014a, Rossiter, 2002). Finally, composite reliability values less than 0.6 depict a lack of internal consistency reliability.

Average variance extracted (AVE)

A common measure to establish convergent validity at the construct level is the average variance extracted (AVE) (Hair et al., 2014a). AVE measures the amount of variance that a construct obtains from its indicators relative to the amount due to measurement errors (Fornell and Larcker, 1981). They stated that the AVE should be higher than 0.5, which indicates that on average, the construct explains more than half of the variance of its indicators. Conversely, an AVE of less than 0.5 means that on average, more errors remain in the indicators than the variance explained by the construct (Hair et al., 2014a). The AVE can be calculated as follows:

$$AVE = \frac{\sum \lambda_i^2}{\sum \lambda_i^2 + \sum_i var(\epsilon_i)}$$ **Equation 6-14**

where λ_i is the component loading of each indicator to a latent construct and $var(\epsilon_i) = (1 - \lambda_i^2)$.

6.4.6.3 Discriminant validity

Discriminant validity is the extent to which a construct is truly distinct from other constructs (Hulland, 1999); therefore, establishing a valid discriminant implies that a construct is unique and absorbs phenomena not represented by other constructs in the measurement models (Hair et al., 2014a). Two assessment tools are proposed (Chin, 1998): (i) an analysis of cross-loadings and (ii) an analysis of average variance extracted (AVE).

Analysis of cross-loadings

Cross loadings is an indicator's correlation with other constructs in the model and an analysis of cross-loadings indicates that an indicator's outer loading on the associated construct should be greater than all of its loadings on the other constructs (Chin, 1998). The presence of cross loadings that exceed the indicator's outer loadings represents a discriminant validity problem (Hair et al., 2014a).

Analysis of average variance extracted (AVE)

An analysis of AVE or the Fornell-Larcker criterion (Fornell and Larcker, 1981) is a second and more conservative approach to analysing the discriminant validity because it compares the square root of the AVE values with the latent variable correlations. The square root of each construct's AVE should be greater than its highest correlation with any other construct (Hair et al., 2014a) because this indicates that more variance is shared between the construct and its indicators than with another construct representing different sets of indicators (Hulland, 1999).

6.4.7 Evaluation of structural model

Section 6.4.6 provided insights into the evaluation of the reflective measurement models, while this section continues the analysis and focuses on the structural model that represents the underlying theory or concept of the path model. The structural model was assessed to determine how well the empirical data supported the theory or concept, and hence decide whether the theory or concept had been empirically confirmed. Figure 6-8 shows the systematic approach used to assess the results of the structural model in order to examine its predictive capabilities and the relationships between the constructs (Hair et al., 2014a).

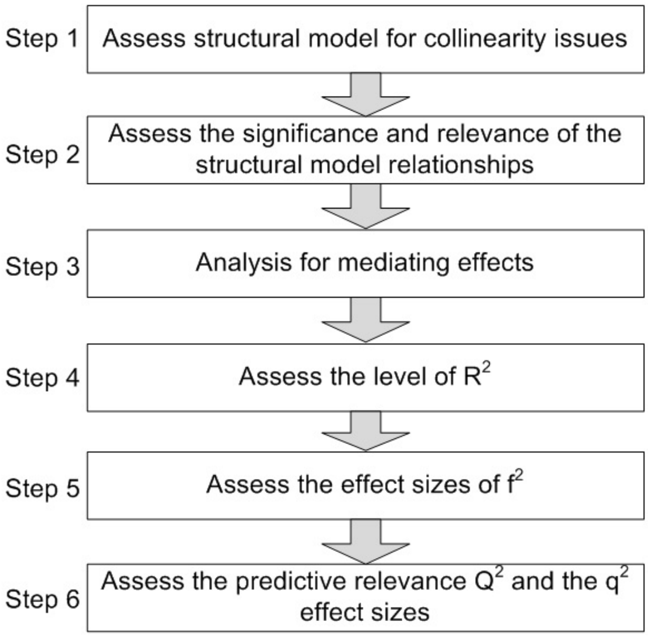


Figure 6-8: Structural assessment procedure

6.4.7.1 Step 1: Collinearity assessment

The structural model for collinearity should be examined because the estimated path coefficients in the structural model were based on the OLS regressions of each endogenous latent variable on its corresponding predecessor constructs (Hair et al., 2014a). To assess collinearity, the tolerance should be computed first because it represents the amount of variance of one construct not predicted properly by the other constructs. Thus, each set of predictor constructs should be examined separately for each subpart of the structural model.

With regard to testing for the presence of collinearity among predictor constructs, a formal test suggested by Neter et al. (1990) was conducted to obtain the variance inflation factors (VIF) values for all the predictor constructs and respective mean VIF values. Each predictor construct's tolerance (VIF) should be higher than 0.2 and lower than five, and if not they should be eliminated, merged with other constructs, or considered to be a higher-order construct to treat collinearity issues (Hair et al., 2014a).

6.4.7.2 Step 2: Structural model path coefficients

The path coefficients represent the hypothesized relationships between the constructs, and have standardised values between -1 and +1. The estimated path coefficients close to +1 indicate strong positive relationships and vice versa for negative values that are always statistically significant (Hair et al., 2014a). Path coefficients (β_{ij}) indicate the strength of the relationship between the two constructs (Wixom and Watson, 2001). The standard error obtained by Bootstrapping specifies whether a coefficient is significant or not and the Bootstrap standard error enables the empirical *t*-value to be computed. The *t*-value between the predictor and predicted constructs can be calculated as follows:

$$t_{ij} = \frac{\beta_{ij}}{se_{ij}}$$ **Equation 6-15**

where β_{ij} is the coefficient of the path between the predictor *i* and predicted construct j. se_{ij} is the Bootstrap error of the path between the predictor *i* and predicted construct *j*. When the empirical *t*-value is larger than the critical value, the coefficient is significant as a certain error probability (i.e., the significant level) (Hair et al., 2014a). Commonly used critical values for two tailed tests are 1.65 (significant level = 10%), 1.96 (significant level = 5%), and 2.57 (significant level = 1%) (e.g., Churchill and Iacobucci, 2009, Hair, 2009, Sharma, 1995). When a study is exploratory in nature, researchers often assume a significant level of 10% (Hair et al., 2014a).

The hypotheses in this study were tested by a statistical validation of the structural model; this was achieved by looking at the sign, size, and statistical significant of the path coefficients between constructs in the structural model.

6.4.7.3 Step 3: Analysis for mediating effects

Mediation focuses on a theoretically established direct path relationship (i.e., path p_{13} in Figure 6-9) between Local Councils' Stakeholder Attributes (SA) and Flood Damage (FD), as well as on additional theoretically relevant constructs - Socio-economic (SE) and Transport Infrastructure (TI) conditions, all of which indirectly provide information on the direct effect via its indirect effect (i.e., $p_{12} \times p_{23}$) from LA to FD via SE and TI (Figure 6-9). Therefore, the indirect relationship via the SE and TI mediators affected the direct relationship from SA to FD in the mediator model.

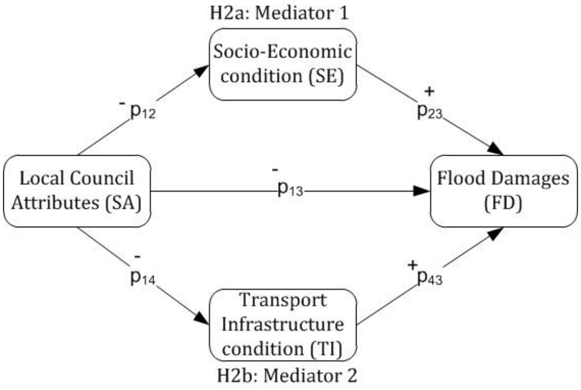


Figure 6-9: Single-indicator measures

Technically, a variable functions as a mediator when it meets the following conditions (Baron and Kenny, 1986): (i) variations in the levels of the independent variable account significantly for variations in the presumed mediator (i.e., path p_{12} in Figure 6-9); (ii) variations in the mediator account significantly for variations in the dependent variable (i.e., path p_{23}in Figure 6-9); and (iii) when paths p_{12} and p_{23} were controlled, a previously significant relationship between the independent and dependent variables (i.e., path p_{13}in Figure 6-9) changed its value significantly.

The direct effect (i.e., path p_{13}) should be significant if the mediator is not included in the model, and although this is not a necessary condition (Mathieu and Taylor, 2006), when the mediator is included the indirect effect (i.e., $p_{12} \times p_{23}$) must be significant (Hair et al., 2014a). A significance test was conducted by carrying out the Bootstrapping procedure with 36 cases and 2,000 samples (Preacher and Hayes, 2008, Preacher and Hayes, 2004). The significance of each individual path p_{12} and p_{23} is also a requirement for this condition, although the main aim was to determine the extent to which the dependent variable could be explained directly by the independent variable and how much of the target construct's variance was explained by the indirect relationship via the mediator variable (Hair et al., 2014a). In this, the variance accounted for (VAF) determines the size of the indirect effect in relation to the total effect.

VAF was achieved by using the following formula (Preacher and Hayes, 2008):

$$VAF = \frac{p_{12} \times p_{23}}{(p_{12} \times p_{23}) + p_{13}}$$

Equation 6-16

where $p_{12} \times p_{23}$ is the indirect effect and p_{13} is the direct effect.

6.4.7.4 Step 4: Coefficient of determination (R^2 value)

The coefficient of determination (R^2 value) measures the structural model's predictive accuracy and it was computed as the squared correlation between a specific endogenous construct's actual and predictive values. The R^2 value ranged from 0 to 1 with higher levels indicating higher levels of predictive accuracy. It is not possible to provide rules of thumb for acceptable R^2 values because it depends on the complexity of the model and research discipline (Hair et al., 2011, Henseler et al., 2009). Note that models with low R^2 values and/or low factor loadings can still lead to acceptable goodness of fit. Smart-PLS 2.0 provided the R^2 values for each endogenous construct in the model, and the F-test of significance for all the R^2 values was achieved using the following formula (Falk and Miller, 1992):

$$F = \frac{R^2/m}{(1-R^2)/(N-m-1)}$$

Equation 6-17

Where N is the total number of the sample size, m is the number of predictors of the construct and F was distributed as a distribution with degrees of freedom (m) and$(N-m-1)$.

6.4.7.5 Step 5: Effect size f^2

Further to evaluating the R^2 values of all endogenous constructs, the change in the R^2 value when a specified exogenous construct was eliminated from the model can be used to assess whether the deleted construct had an actual impact on the endogenous constructs. This measure is called the f^2 effect size, and it can be calculated as:

$$f^2 = \frac{R^2_{included} - R^2_{excluded}}{1 - R^2_{included}}$$ **Equation 6-18**

Where $R^2_{included}$ and $R^2_{excluded}$ are the R^2 values of the endogenous latent variable when a selected exogenous latent variable is included or excluded from the model. Guidelines for assessing f^2 are that values of 0.02, 0.15, and 0.35, respectively represent small, medium, and large effects (Cohen, 1988) of the exogenous latent variables. The significance of f^2 statistic was also estimated by using F test as follows (Chin, 2010):

$$F = (f^2) \times (N - m - 1)$$ **Equation 6-19**

Where N is the total number of the sample size, m is the number of predictors of the construct, and F was distributed as a distribution with degrees of freedom 1 and $(N - m)$.

6.4.7.6 Step 6: Blindfolding and predictive relevance Q^2

In addition to evaluating the degree of R^2 values as a criterion for predictive accuracy, Stone-Geisser's Q^2 value (Geisser, 1974, Stone, 1974) should also be examined, particularly for single-indicator constructs (Hair et al., 2014a) because this measure is an indicator of the model's predictive relevance. This measure accurately predicts the data points of indicators in reflective measurement models of endogenous constructs and endogenous single-indicator constructs (Hair et al., 2014a). Q^2 values greater than zero for a certain reflective endogenous variable indicate the path model's predictive relevance for this particular construct (Geisser, 1974, Stone, 1974). The Q^2 value was obtained by applying a blindfolding procedure to eliminate every d^{th} data point in the endogenous construct's indicators and estimate the parameters with the remaining data points (Hair et al., 2014a, Chin, 2010). The Q^2 value can be calculated using a blindfolding procedure to measure how perfectly the path model can predict the originally observed values. Like the q^2 effect size approach (Section 6.6.4) for assessing R^2 values, the relative impact of predictive relevance can be compared by means of the measure to the q^2 effect size, formally defined as follows (Hair et al., 2014a):

$$q^2 = \frac{Q^2_{included} - Q^2_{excluded}}{1 - Q^2_{included}} \qquad \textbf{Equation 6-20}$$

Values of 0.02, 0.15, and 0.35 indicate that an endogenous construct has a small, medium, or large predictive relevance for a certain endogenous construct. It is important to highlight that a blindfolding procedure and the f^2 effect size are the best tools to predict the accuracy of endogenous single-indicator constructs (Hair et al., 2014b).

6.5 Stakeholder disaster response index (SDRI)

NDRM efforts to date have generally taken one of two forms of indices – social vulnerability indices (e.g., Ahsan and Warner, 2014, Lee, 2014, Balica et al., 2012) and disaster preparedness indices (e.g., Carreño et al., 2007, Peduzzi, 2006, Davidson and Lambert, 2001). The Stakeholder Disaster Response Index (SDRI) was fundamentally different from all of them because it measures stakeholder approaches in managing a particular natural disaster but the previous indices measure vulnerability of a specific region to natural disasters (Davidson, 1997) or level of preparedness against a natural disaster in emergency situations (Peduzzi, 2006).

A key characteristic of the PLS-SEM method is the extraction of latent variable scores (Hair et al., 2014a). Importance-performance matrix analysis (IPMA) is an instrumental technique that extends the findings of the basic PLS-SEM outcomes using the latent variable scores (e.g., Hair et al., 2014a, Hock et al., 2010, Fornell et al., 1996). The extension builds on the PLS-SEM estimates of the path model relationships and includes a supplementary dimension to the assessment that considers the latent variables' average values. For a key target endogenous construct in the analysis, IPMA contrasts the structural model total effects (importance) and the average values of the latent variable scores (performance) to shed light on significant areas for improving management activities (Hair et al., 2014a). Executing an IPMA first requires identifying a target construct as well as the total effects and performance values of the target construct.

The concept of IPMA technique in PLS-SEM was used in this study to develop an index to measure the stakeholder's overall approach (OA, the target construct) to flood disasters. Therefore, the general form of SDRI is as follows:

$$SDRI = \frac{E[\emptyset] - min[\emptyset]}{max[\emptyset] - min[\emptyset]} \times 100 \qquad \textbf{Equation 6-21}$$

Where $\emptyset$ is the latent variable for SDRI and $E[\emptyset]$, $min[\emptyset]$ and $max[\emptyset]$ denote the expected, and the minimum and maximum value of the variable, respectively. The corresponding manifest variables determine the minimum and the maximum values as follows:

$$min[\emptyset] = \sum_{i=1}^{n} w_i \ min[x_i] \ \ and \ max[\emptyset] = \sum_{i=1}^{n} w_i \ max[x_i] \qquad \textbf{Equation 6-22}$$

Where x_i is the i^{th} measurement variable of the Local Council Overall Approach (OA), and w_i is the weight and n is the number of measurement variables.

6.6 Summary

Taking into consideration the nature of research objectives and sample data of this study, a Bootstrap-TOPSIS and a PLS-SEM was chosen over other MADM and MDA techniques, and justifications for applying these two techniques were provided. Microsoft Excel 2007 (VBA coding) and SmartPLS 2.0 software packages were used for Bootstrap-TOPSIS and PLS-SEM techniques, respectively. The combination of the Bootstrap non-parametric re-sampling technique and TOPSIS as a MADM technique were used to rank and analyse Australian states and territories against flooding (Chapter 7). The PLS approach is a second-generation multivariate technique that combines both econometric and psychometric perspectives in statistical modelling attempts. PLS-SEM model (Figure 6.1) on flood risk management was specified corresponding to the third to fifth research objectives of the study. Details of the modelling approach were covered in separate sections including: the estimation process, the required construct validation processes and the model evaluation process, and the moderating process in examining the moderating effects of socio-economic and transport infrastructure conditions on the relationships between the Local Council stakeholder attributes and flood damage. Finally, the IPMA technique was introduced to develop Stakeholder Disaster Risk Response (SDRI). The subsequent chapter sets out the results of flood risk analysis using Bootstrap-TOPSIS and the construct validation processes, of the specified PLS model.

CHAPTER

7

Flood Risk Analysis using Bootstrap-TOPSIS

7.1 Introduction

Although several natural disaster risk management policies and techniques that provide resilience to the built environment in Australian communities exist, only a few empirical studies have been conducted to develop tools that measure the exposure and vulnerability of states and territories to flood disasters (e.g., Mojtahedi and Oo, 2014a, Blong, 2004, Dwyer et al., 2004).

This chapter presents the research results that will help address the second research objective by analysing the exposure and vulnerability of Australian states and territories to flood risk by simultaneously considering the socio-economic and built environment conditions simultaneously, using a multi-attribute decision-making tool. This chapter begins by applying Bootstrap-TOPSIS for flood risk analysis (Section 7.2) and ends with a discussion of the results (Section 7.3). The main objective here is to: (i) assess the exposure and vulnerability of Australian states and territories to flooding and (ii) investigate whether the socio-economic and built environment conditions can be considered in one integrated framework.

Although natural disasters associated with climate change and their relationships with the socio-economic and built environment exposure and vulnerability are considered to be important areas for contemporary research, only a few studies have considered these two exposures together (Mojtahedi and Oo, 2014a). Moreover, there has been little empirical study on applying the Multi-Attribute Decision-Making approach for analysing and ranking areas against flood disasters. For example in Australia, Blong (2004) explored the impact of natural disasters on Australian residential buildings, and claimed that land-use planning regulations are strong in some states, but the regulations for buildings in flood-prone areas are limited. Crompton and McAneney (2008) used two surrogate factors such as the number and average nominal values of dwellings over time to normalise the insured losses from meteorological hazards, while more recently, Australian flood management authorities began using computer and communication technologies to develop a Decision Support System (DSS) that can control flood emergency operations more effectively (Mirfenderesk, 2009).

7.2 Bootstrap-TOPSIS approach for flood risk analysis

A comprehensive approach is proposed here to consider multiple-attribute analysis based on the Bootstrap-TOPSIS technique to assess the exposure and vulnerability of states and territories in Australia to flood disasters. Figure 7-1 shows the proposed Bootstrap-TOPSIS technique in three phases for Australian buildings and transport infrastructure.

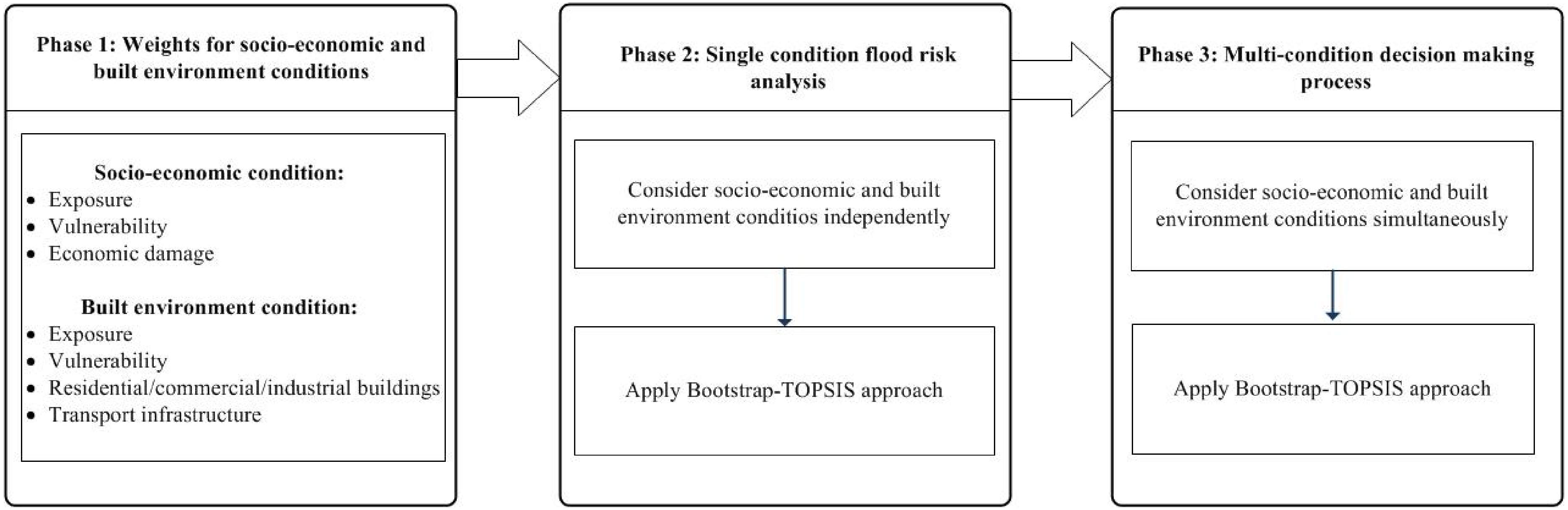


Figure 7-1: Bootstrap-TOPSIS approach for flood risk analysis

The main objective here is to use MADM to analyse the exposure and vulnerability of Australian states and territories to flood risk by considering the socio-economic, coastal buildings and transport infrastructure simultaneously and by following the notion that the exposure and vulnerability of each state and territory against flood risk is a MADM problem. Because natural disaster exposure and vulnerability data distribution is unknown and the data sources may be incomplete due to difficulties experienced during collection (Deloitte, 2014), a new technique which is a combination of the non-parametric resampling Bootstrap method and a MADM tool –TOPSIS – is introduced.

The core of this section illustrates the use of the Bootstrap-TOPSIS technique in buildings and transport infrastructure flood risk analysis by applying the socio-economic and built environment exposures and vulnerability independently (single condition analysis) and then simultaneously (multi-condition analysis). In addressing the research question, both single condition and multi-condition analysis were executed to investigate whether remarkable changes occurred in ranking the states and territories when the socio-economic and built environment exposures and vulnerability were considered simultaneously.

7.2.1 Phase 1: Weights for socio-economic and built environment conditions

To apply the TOPIS method, appropriate weights for attributes must be generated so here the impact of flooding on the Australian socio-economic condition from three of the above mentioned data sources were collected (see Section 5.5). Table 7-1 is a summary of the data sources analysis and the weights of the respective socio-economic condition obtained from the data sources.

The Bootstrap technique was executed with a different resampling repetition of B (B = 50, 100, 200, 500, 1000) and the weights were converged after five hundred resamples (B = 500). This means that the standard deviation (SD) does not change when B is 500. Table 7-1 shows the Bootstrap results for the attributes' weights that were used in the Bootstrap-TOPSIS procedure in Phase 2. Note that SD for the attributes was calculated based on the formula below:

$$\boldsymbol{SD} = \sqrt{\frac{\boldsymbol{1}}{\boldsymbol{B}}\sum_{\boldsymbol{b=1}}^{\boldsymbol{B}}\left(\boldsymbol{x_i^*} - \boldsymbol{B^{-1}}\sum_{\boldsymbol{b=1}}^{\boldsymbol{B}}\boldsymbol{x_i^*}\right)^{\boldsymbol{2}}} \qquad \text{Equation 7-1}$$

Table 7-1: Socio-economic conditions' weights based on the Bootstrap method

Bootstrap (B=500)	Exposure	Vulnerability	Economic damage
Average	0.03657	0.0761	0.88836
Standard Deviation	0.00028	0.00084	0.00163

It should be noted that the same weight factors were applied to the attributes of the built environment condition because access was only gained to one unique data source for the exposure and vulnerability of the Australian buildings and transport infrastructure to floods.

7.2.2 Phase 2: Single condition flood analysis

In Phase 2, the Bootstrap-TOPSIS method was applied (see Section 6.3 for details) using Microsoft Excel for the socio-economic and built environment conditions separately, the Australian Capital Territory (ACT) was excluded from the analysis because it is not located in a coastal area. Having considered the Bootstrap-TOPSIS procedure, Table 7-2 shows RC and final ranking for each alternative (state and territory).

Table 7-2: Bootstrap-TOPSIS outcome for socio-economic condition

State and territories	PIS	NIS	RC	Rank
New South Wales (NSW)	0.224	0.152	0.405	3
Queensland (QLD)	0.035	0.336	0.905	1
Victoria (VIC)	0.340	0.032	0.085	4
South Australia (SA)	0.371	0.000	0.001	7
Western Australia (WA)	0.081	0.362	0.817	2
Tasmania (TAS)	0.368	0.003	0.007	6
Northern Territory (NT)	0.364	0.007	0.019	5

Likewise, Table 7-3 shows the respective final scores (*RC*) obtained from the Bootstrap-TOPSIS procedure using equal weight factors for the built environment condition attributes.

Table 7-3: Bootstrap-TOPSIS outcome for built environment condition

State and territories	PIS	NIS	RC	Rank
New South Wales (NSW)	0.116	0.073	0.387	4
Queensland (QLD)	0.092	0.115	0.555	2
Victoria (VIC)	0.119	0.071	0.373	5
South Australia (SA)	0.098	0.073	0.427	3
Western Australia (WA)	0.085	0.118	0.583	1
Tasmania (TAS)	0.157	0.011	0.067	7
Northern Territory (NT)	0.149	0.069	0.316	6

7.2.3 Phase 3: Multiple-condition decision-making process

In this phase of the proposed approach, the socio-economic and built environment conditions were simultaneously included in the analysis. Table 7-4 shows the respective final scores (*RC*) and ranking obtained from the Bootstrap-TOPSIS procedure.

Table 7-4: Bootstrap-TOPSIS outcomes for socio-economic and built environment conditions

State and territories	PIS	NIS	RC	Rank
New South Wales (NSW)	0.128	0.084	0.396	3
Queensland (QLD)	0.044	0.182	0.805	1
Victoria (VIC)	0.184	0.034	0.154	4
South Australia (SA)	0.195	0.031	0.138	5
Western Australia (WA)	0.074	0.188	0.717	2
Tasmania (TAS)	0.202	0.006	0.029	7
Northern Territory (NT)	0.199	0.029	0.127	6

Figure 7-2 shows the Australian states and territories' flood RC when the socio-economic and built environment conditions were considered independently; it also depicts the multiple-condition analysis for a better comparison. Here the results from the multiple-condition analysis are between the respective single socio-economic and built environment condition analysis. Based on this socio-economic condition analysis, QLD is the most vulnerable state for flood disasters, but based on the built environment condition (exposure and vulnerability of coastal buildings and transport infrastructure), it ranks second followed by WA. As another example, the RC for NSW was 0.405 and 0.387 based on the socio-economic and built environment conditions respectively, but when both conditions were considered concurrently the RC increased to 0.396. Therefore, the exposure and vulnerability of Australian coastal buildings and transport infrastructure in different states and territories changed when a multiple condition analysis was executed rather than a single condition flood risk analysis.

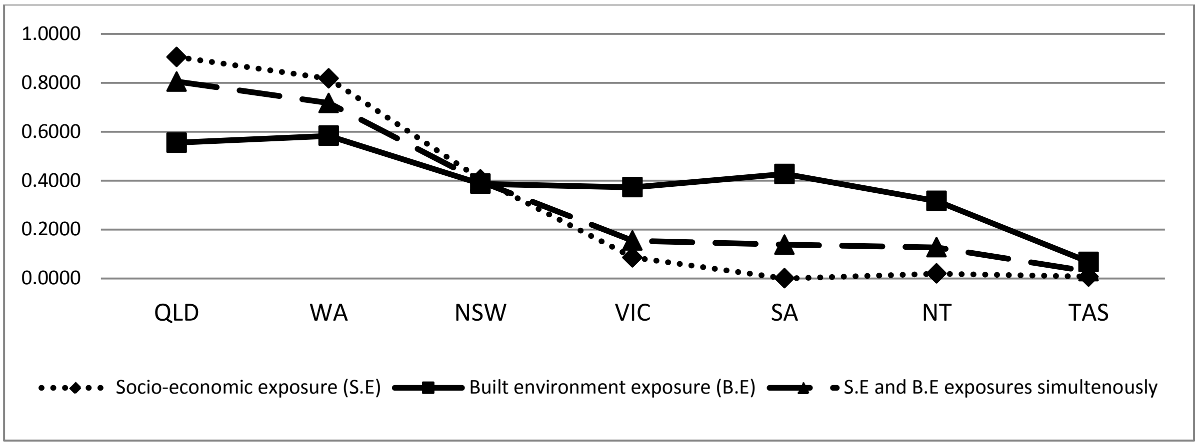


Figure 7-2: Bootstrap-TOPSIS approach for multi-condition flood risk analysis

It is essential to consider the socio-economic and built environment conditions in FRM studies, and therefore including both conditions in the proposed theoretical framework in this study was rational.

7.3 Discussion

The results show that QLD, WA, and NSW are the three top-ranked states in Australia in terms of exposure and vulnerability of buildings and transport infrastructure to flooding, but there is a significant difference between the ranking of Australian states and territories when the socio-economic and built environment conditions are considered concurrently. This finding provides evidence that the exposure and vulnerability analysis is a MADM problem in the context of NDRM.

In fact, the degree to which a state or a territory is vulnerable to flood disaster depends on considering multi attributes and exposures because socio-economic condition such as exposure, vulnerability, and economic damage are not the only factors to define the vulnerability of a specific location. Thus, state and regional entities should not only focus on the societal exposure of floods, but they should also include the built environment exposure and vulnerability as well. The exposure and vulnerability of buildings and transport infrastructure to a rise in sea level associated with climate change is prevalent and flooding will increase into the future.

The analysis clearly showed that buildings and transport infrastructure in NSW would likely be exposed to flood disasters in a sea level rise scenario of 1.1 metres (high-end scenario for 2100), the RC for NSW is 0.396 when the socio-economic and built environment conditions were considered simultaneously. For instance, the intrusion of salt water may be of particular concern for numerous old dumpsites, and potential changes in wind speed and extreme storm events could cause damage or failure to structures.

The empirical findings of multi-condition flood risk analysis have implications for flood risk management, as well as policy makers and stakeholders who are involved in resource allocation for NDRM. For example, policy makers would be able to assign resources to the most exposed and vulnerable states and territories. However, one of the limitations of a multi-condition flood risk analysis is its sensitivity to the attributes' weights because multiple exposure flood risk analysis in the built environment seems to be a point of conflict in decision-making. Conflict conditions complicate the decision-making process when the alternatives conflict and therefore more options should be explored to find the best solution.

7.4 Summary

This proposed approach analysed and ranked Australian states and territories in terms of the vulnerability of their buildings and infrastructure to flood disasters, by simultaneously considering the socio-economic and built environment parameters as well as a multi exposure analysis based on a MADM technique – Bootstrap-TOPISIS – by applying the Bootstrap resampling technique to generate weights for socio-economic condition in the decision-making process. Most scholars used regression models to generate weights for attributes in MADM problems whereas conventional statistical models are applicable when the data size is large enough or the data distribution is known statistically. The proposed Bootstrap-TOPSIS method does not depend on regression models, so it can work with a small data sample and unknown data distribution; in other words, the uncertainty factor in decision-making is much lower and the precision is much higher in this approach.

For a single exposure analysis of a disaster, conventional techniques such as statistical methods, macroeconomic models and decision-making approaches are preferable, but MADM can be used to solve any conflict situation between the attributes. By applying the Bootstrap-TOPSIS technique, QLD was determined as being the state most susceptible to flood disasters when the socio-economic and built environment conditions were considered simultaneously.

The results show that QLD, WA, and NSW are the three top-ranked states in Australia in terms of exposure and vulnerability of buildings and transport infrastructure to flooding, but there is a significant difference between the ranking of Australian states and territories when the socio-economic and built environment conditions are considered concurrently. This finding provides evidence that the exposure and vulnerability analysis is a MADM problem in the context of NDRM. Interestingly, WA was ranked first among Australian states and territories only when the built environment condition against flood disasters was considered.

CHAPTER

8

Empirical Data Analysis using PLS-SEM

8.1 Introduction

This chapter presents the results that help to address the third to fifth research objectives by testing a theoretical framework for stakeholder attributes and approaches through flood risk management in transport infrastructure. This chapter begins with an evaluation of the response rate and profile of the respondents (Section 8.2). It continues with an evaluation of the measurement models (Section 8.3), followed by an evaluation of the structural model for testing the research hypotheses (Section 8.4). After this, the Stakeholder Disaster Response Index (SDRI) is developed (Section 8.5), followed by interpretations and discussions of the findings (Section 8.6). The main objective of this chapter is (i) to establish the reliability and validity of the measurement model; (ii) to assess the structural model; and (iii) to measure the overall approach of stakeholders to flood disasters in flood risk management.

8.2 Response rate and the profile of respondents

Although only 37 responded to follow up emails, this was still a response rate of 48%, which was reasonable considering the normal rate of response in the construction industry (Lim, 2010, Kumaraswamy et al., 2005) and NDRM studies (Bharosa et al., 2010). Albeit the number of responses was relatively low, a statistical analysis could still be performed based on the central limit theorem that holds true if the sample size is more than 30 (Field, 2013).

Local Council staff such as floodplain engineers, planning and infrastructure engineers and emergency management officers completed the questionnaires. It is important to note that the questions were designed to investigate Local Councils' experiences in FRM, not staff experiences, so a team might have completed a single questionnaire.

Table 8-1 shows the FRM staff of Local Councils and Council's average capital works budget. Council priority in FRM had an average of $51 million capital works budget for 2012-13.

Table 8-1: Characteristics of the Local Councils

Flood risk management staff	Number of councils (%)	Average capital budget for 2012-13 (A$ million)
1-2	21 (58.3%)	16
3-4	7 (19.4%)	25
5-6	5 (13.9%)	31
7-8	1 (2.8%)	42
9-10	2 (5.6%)	51

Table 8-2 shows the budget allocations of the Local Councils to different facilities in FRM and indicate that private residential buildings and transport infrastructure were high priority in their assignment of annual works budgets for FRM.

Table 8-2: Local Councils' priority in flood risk management

Facility	Number of councils (%)	Rank
Private residential buildings	8 (18.55%)	1
Public roads and bridges	7 (18.31%)	2
Public buildings	7 (18.07%)	3
Utilities (water, sewerage, telecommunication, electricity etc.)	6 (16.88%)	4
Private commercial/industrial buildings	6 (16.65%)	5
Rural industries	4 (11.53%)	6

8.3 Evaluation of measurement models

In the following sections an evaluation of the measurement models are addressed based on the procedure provided in Chapter 6 (see Section 6.4.6).

8.3.1 Individual indicator reliability

In this study, the scales were adapted from studies on Local Councils' stakeholder attributes in organisational settings. The scales were not tested beforehand in the context of NDRM in the built environment and on transport infrastructure, which means that some measurement indicators were not applicable across all the contexts and or settings. Moreover, some of the measurement indicators were newly developed (see for example, TI2, TI3 and TI6 in Table 4-1 of Chapter 4) based on an exploratory review of reports related to flood disaster reconstruction projects and discussions with experts in Local Councils and RMS. Thus, to minimise the errors in measurement models and enhance the precision and validity of the scales and exploratory power of the developed model, a conservative value of 0.70 was used as the threshold value. Nonetheless, prior to removal, the potential practical significance of indicators with loadings lower than 0.70 was meticulously investigated (see Section 6.4.6.1).

Based on the 0.70 rule of thumb for the removal of reflective indicators, an iterative evaluation of outer loadings was conducted using SmartPLS 2.0 software, and those indicators with a loading of less than 0.70 were removed in sequence after each run. Thereafter the remaining indicators were entered again and the same procedure was applied. This process was carried out iteratively until no indicator with a loading below 0.7 was found. The indicators (30 indicators) removed are listed in Table 8-3 while Table 8-4 shows the indicators used to assess the measurement models (40 indicators).

Table 8-3: Eliminated indicators during exploratory analysis

Construct	Ind.	Indicator description
Flood Characteristics **(FC)**	FC2	Moderate flooding
	FC3	Minor flooding
	FC7	Ocean flooding
	FC8	Flash flooding
	FC9	Human cause of flooding
	FC10	Elevation (m)
	FC11	Coastal area (m^2)
Socio-economic **(SE)** Vulnerability	SE3	Population
	SE4	Age structure
Transport Infrastructure **(TI)** Exposure	TI1	Local urban roads (km)
Mitigation **(MI)**	MI1	Training and education on FRM
	MI2	Analysing risks to measure the potential areas for floods
	MI3	Prevent building of roads in flood prone areas
	MI8	Providing timely and effective information related to FRM
	MI9	Constructing flood retarding basins, barriers, culverts, levees, and drainage
Preparedness **(PR)**	PR1	Recruiting personnel for flood emergency services
	PR2	Developing flood emergency management systems
	PR5	Maintaining flood emergency supplies
	PR6	Locating places for flood emergency operation centres
	PR7	Developing prediction and warning communications system
	PR8	Conducting FRM exercises to train personnel and test capabilities
Response **(RS)**	RS2	Evacuating threatened populations and vehicles
	RS3	Operating shelters and provision of mass care
	RS6	Documenting lessons learned and best practices
	RS9	Implementing effective mobilisation and disbursement of resources
	RS10	Providing information on flooded areas to public
Recovery **(RC)**	RC1	Cleaning flood disaster debris
	RC7	Documenting lessons learned and best practices in recovery phase
	RC9	Realigning roads and relocating bridges to lower flood hazard locations
	RC10	Acquiring stakeholders' approval (e.g., RMS) on road reconstruction projects

Table 8-4: Indicators used in model estimation

Construct	Code	Indicator
Flood Characteristics **(FC)**	FC1	Major flooding
	FC4	Rainfall annual mean
	FC5	Frequency of major flooding
	FC6	River flooding
Flood Damage **(FD)**	FD1	Socio-economic loss
	FD2	Transport infrastructure loss
Socio-economic **(SE)** Exposure	SE1	Density (Person/km^2)
	SE2	GRP per capita
	SE5	Population at risk to the flood disaster
	SE6	Income level
Transport Infrastructure **(TI)** Exposure	TI2	Local non-urban sealed roads (km)
	TI3	Local non-urban unsealed roads (km)
	TI4	Total bridge and culverts length on local roads
TI Vulnerability	TI5	Roads and bridges at risk to the flood disaster
	TI6	Average response time for road reconstruction
Local Council Stakeholder Attributes **(SA)**	SA1	Power
	SA2	Legitimacy
	SA3	Urgency
Mitigation **(MI)**	MI4	Insuring roads and bridges to reduce the financial impacts of floods
	MI5	Developing a master plan for FRM
	MI6	Developing FRM information system among stakeholders
	MI7	Developing engineering design standards for resilient roads and bridges
Preparedness **(PR)**	PR3	Developing strategies for public education
	PR4	Budgeting for and acquiring flood emergency vehicles and equipment
	PR9	Using technology to identify and assess floods, and damaged roads
	PR10	Developing coordination procedures with other stakeholders
Response **(RS)**	RS1	Activating the flood emergency operations plans and operations centres
	RS4	Estimating economic damage
	RS5	Establishing procedures to prevent and suppress secondary hazards
	RS7	Implementing effective coordination with other stakeholders (e.g., RMS)
	RS8	Implementing effective logistics management (e.g., supply of equipment and services to flooded areas)
Recovery **(RC)**	RC2	Considering sustainability in post-disaster reconstruction
	RC3	Shortening reconstruction time by applying quick mobilisation
	RC4	Selecting reconstruction contractors from a predetermined list of
	RC5	Constructing temporary roads and bridges
	RC6	Implementing execution plan for post-disaster reconstruction
	RC8	Applying lean construction in post-flood reconstruction (e.g. waste minimisation, get it right first time)
Proactive Approach **(PA)**	PA1	Proactive approach in FRM
Reactive Approach **(RA)**	RA1	Reactive approach in FRM
Overall Approach **(OA)**	OA1	Overall level of approach in FRM

The outer loadings and statistical significance of all the indicators used in the final model are shown in Table 8-5. They all have loadings above 0.70, which implies that less than 50 per cent of an indicator's variance was owing to error. All the indicators presented a satisfactory level of individual reliability, and Table 8-3 shows that the outer loadings were all statistically significant.

8.3.2 Convergent validity

The convergent validity of measurement models is assessed based on (i) a composite reliability score and Cronbach's Alpha for the constructs and (ii) the average variance extracted (AVE) (see Section 6.4.6.2).

8.3.2.1 Composite reliability scores and Cronbach's alpha

In this study, Cronbach' alpha and composite reliability generated by SmartPLS 2.0 software and results are shown in Table 8-5. Craonbach's alpha and composite reliability threshold values, based on Churchill (1979) and Nunnally et al. (1967) suggestions, indicated that all the constructs have high levels of internal consistency reliability and the measurement indicators were appropriate for their respective constructs. Note that the composite reliability values of the single-indicator constructs (PA, RA and OA) are 1.00. However, this cannot be interpreted as evidence that the constructs exhibit perfect reliability (Hair et al., 2014a).

8.3.2.2 Average variance extracted (AVE)

The AVE values generated by SmartPls 2.0 software are well above the required minimum level of 0.5 (Table 8-5). Hence, the measures of reflective constructs have high levels of convergent validity. Note that AVE is not an appropriate measure because the indicator's outer loading was fixed at 1.00 (Hair et al., 2014a).

The results in Table 8-5 indicate there was convergent validity and good internal consistency in the measurement model which implies that the measurement indicators of each construct measured them well and were not measuring another construct. It is important to note that the single-indicator constructs (PA, RA and OA) are not illustrated in Table 8-5, because internal consistency reliability and convergent validity are not applicable to single-indicator constructs (Hair et al., 2014a). However, blindfolding procedure was used to assess the validity of single-indicator constructs in this study (See section 8.4.6).

Table 8-5: Measurement models evaluation result

Construct	Indicator	Loading	Cronbach's alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Flood Characteristics (FC)	FC1	0.767	0.862	0.906	0.708
	FC4	0.894			
	FC5	0.866			
	FC6	0.832			
Flood Damage (FD)	FD1	0.892	0.630	0.705	0.557
	FD2	0.704			
Socio-economic (SE)			0.660	0.795	0.507
Exposure	SE1	0.969	0.879	0.940	0.886
	SE2	0.931			
Vulnerability	SE5	0.954	0.788	0.897	0.815
	SE6	0.848			
Transport Infrastructure (TI)			0.647	0.766	0.563
Exposure	TI2	0.910	0.839	0.887	0.757
	TI3	0.837			
	TI4	0.862			
Vulnerability	TI5	0.750	0.542	0.781	0.650
	TI6	0.980			
Local Council Attributes (SA)	SA1	0.950	0.927	0.954	0.873
	SA2	0.939			
	SA3	0.914			
Mitigation (MI)	MI4	0.943	0.943	0.959	0.854
	MI5	0.914			
	MI6	0.902			
	MI7	0.937			
Preparedness (PR)	PR3	0.961	0.947	0.962	0.863
	PR4	0.913			
	PR9	0.931			
	PR10	0.910			
Response (RS)	RS1	0.950	0.963	0.972	0.873
	RS4	0.924			
	RS5	0.943			
	RS7	0.925			
	RS8	0.928			
Recovery (RC)	RC2	0.940	0.965	0.902	0.852
	RC3	0.941			
	RC4	0.911			
	RC5	0.877			
	RC6	0.940			
	RC8	0.919			

8.3.3 Discriminant validity

In this study, two assessment tools are proposed (Chin, 1998): (i) an analysis of cross-loadings and (ii) an analysis of average variance extracted (AVE) (see Section 6.4.6.3).

8.3.3.1 Analysis of cross-loadings

A cross-loading assessment was carried out using Smart-PLS 2.0 software; the results are illustrated in Table 8-6 and show that all the indicators loaded higher on the construct and they were theoretically specified to measure any other construct in the measurement models. This result indicates that all 40 indicators loaded distinctly on the specified construct they measured, and therefore demonstrate a discriminant validity of the constructs (see Section 6.4.6.4).

Table 8-6: Cross-loading analysis

Code	FC	FD	SE	TI	SA	MI	PR	RS	RC	PA	RA	OR
FC1	**0.767**	0.265	0.018	0.095	0.286	0.401	0.416	0.603	0.561	0.370	0.588	0.484
FC4	**0.894**	0.372	0.150	0.170	-0.002	0.386	0.311	0.419	0.396	0.365	0.387	0.235
FC5	**0.866**	0.300	0.175	0.201	0.026	0.204	0.110	0.220	0.200	0.149	0.174	0.093
FC6	**0.832**	0.419	0.150	0.350	0.405	0.377	0.376	0.448	0.462	0.373	0.476	0.476
FD1	0.116	**0.892**	0.799	0.156	0.064	0.134	0.087	0.028	0.038	0.117	-0.016	0.038
FD2	0.564	**0.679**	0.077	0.411	0.170	0.151	0.114	0.354	0.319	0.178	0.322	0.356
SE1	0.065	-0.071	**0.555**	-0.216	-0.050	0.550	0.484	0.219	0.285	0.514	0.270	0.149
SE2	-0.152	-0.073	**0.244**	-0.292	-0.096	0.094	0.215	-0.110	-0.062	0.205	-0.086	-0.171
SE5	0.157	0.700	**0.992**	0.041	0.099	0.130	0.080	-0.056	-0.068	0.076	-0.091	-0.160
SE6	0.147	0.697	**0.995**	0.049	0.115	0.131	0.078	-0.060	-0.073	0.077	-0.095	-0.153
TI2	0.276	0.355	0.173	**0.894**	-0.057	0.097	0.015	0.013	0.000	0.042	-0.075	0.100
TI3	0.140	0.116	-0.094	**0.821**	0.085	-0.067	-0.028	0.050	0.044	-0.084	-0.023	0.164
TI4	0.258	0.282	0.058	**0.856**	0.098	0.083	0.059	-0.096	0.014	0.073	-0.111	0.008
TI5	0.095	0.191	0.146	**0.076**	0.124	0.115	0.136	0.043	0.077	0.124	0.081	0.150
TI6	0.008	0.162	0.057	**0.318**	0.057	0.007	0.102	-0.205	-0.197	0.060	-0.104	0.120
SA1	0.204	0.225	0.115	0.141	**0.950**	0.278	0.395	0.432	0.471	0.294	0.422	0.520
SA2	0.085	0.019	0.008	0.011	**0.939**	0.140	0.221	0.435	0.483	0.141	0.414	0.420
SA3	0.310	0.100	0.179	-0.003	**0.914**	0.366	0.447	0.438	0.449	0.320	0.407	0.395
MI4	0.292	0.056	0.065	-0.058	0.292	**0.943**	0.868	0.427	0.413	0.900	0.437	0.426
MI5	0.483	0.356	0.106	0.070	0.133	**0.914**	0.800	0.483	0.500	0.889	0.505	0.456
MI6	0.367	0.168	0.103	0.079	0.325	**0.902**	0.844	0.591	0.613	0.838	0.604	0.538
MI7	0.379	0.102	0.026	0.107	0.308	**0.937**	0.881	0.384	0.388	0.910	0.428	0.471
PR3	0.424	0.125	0.024	-0.051	0.323	0.883	**0.913**	0.597	0.628	0.875	0.644	0.586
PR4	0.231	0.066	-0.021	-0.069	0.294	0.873	**0.931**	0.431	0.427	0.925	0.512	0.544
PR9	0.275	0.076	0.059	0.146	0.418	0.791	**0.910**	0.485	0.493	0.806	0.464	0.514
PR10	0.420	0.192	0.067	0.122	0.408	0.863	**0.961**	0.549	0.535	0.907	0.577	0.613
RS1	0.462	0.141	-0.092	0.005	0.447	0.523	0.580	**0.950**	0.913	0.555	0.916	0.731
RS4	0.412	0.046	-0.092	-0.220	0.429	0.453	0.476	**0.924**	0.879	0.472	0.880	0.613
RS5	0.470	0.150	-0.077	-0.060	0.437	0.380	0.426	**0.943**	0.895	0.398	0.917	0.665
RS7	0.578	0.256	-0.005	0.055	0.432	0.525	0.566	**0.925**	0.914	0.534	0.887	0.728
RS8	0.402	0.271	-0.047	0.025	0.427	0.491	0.542	**0.928**	0.907	0.499	0.880	0.781
RC2	0.434	0.131	-0.129	-0.041	0.503	0.403	0.455	0.924	**0.940**	0.423	0.902	0.681
RC3	0.445	0.139	-0.035	0.015	0.456	0.544	0.585	0.918	**0.941**	0.548	0.902	0.668
RC4	0.447	0.074	-0.145	-0.051	0.311	0.417	0.471	0.873	**0.911**	0.440	0.850	0.624
RC5	0.397	0.354	0.054	0.102	0.486	0.458	0.445	0.823	**0.887**	0.453	0.793	0.664
RC6	0.490	0.148	-0.054	0.044	0.538	0.514	0.600	0.890	**0.940**	0.549	0.908	0.730
RC8	0.444	0.143	-0.165	-0.093	0.460	0.509	0.534	0.913	**0.919**	0.535	0.922	0.703
PA1	0.380	0.178	0.031	0.030	0.277	0.957	0.947	0.526	0.534	**1.000**	0.572	0.574
RA1	0.482	0.133	-0.107	-0.090	0.444	0.532	0.592	0.959	0.954	0.572	**1.000**	0.798
OA1	0.387	0.194	-0.157	0.123	0.479	0.511	0.608	0.753	0.736	0.574	0.798	**1.000**

8.3.3.2 Analysis of average variance extracted (AVE)

Table 8-7 presents the correlation matrix for the constructs. There was no correlation identified between any two latent constructs that were larger than or even equal to the square root of these two constructs. This shows that the discriminant validity test did not display any serious predicament and indicated that all the constructs differed from each other (see Section 6.4.6.5).

Table 8-7: Fornell-Larcker criterion

Constructs	AVE	FC	FD	SE	TI	LA	MI	PR	RS	RC
FC	0.708	**0.841**								
FD	0.557	0.414	**0.746**							
SE	0.507	0.154	0.701	**0.712**						
TI	0.563	0.258	0.317	0.073	**0.750**					
SA	0.873	0.221	0.131	0.114	0.057	**0.934**				
MI	0.854	0.410	0.181	0.080	0.053	0.287	**0.924**			
PR	0.863	0.364	0.124	0.035	0.040	0.388	0.918	**0.929**		
RS	0.873	0.498	0.185	-0.067	-0.041	0.465	0.507	0.555	**0.934**	
RC	0.852	0.480	0.177	-0.086	-0.005	0.500	0.515	0.560	0.965	**0.923**

Note: The diagonal elements (in bold) are the square root of the AVEs; non-diagonal elements are latent variable correlations.

8.3.4 Final measurement model

Based on the results in sections 8.3.1 to 8.3.3, the measurement model presents acceptable indicator reliability, convergent validity, and discriminant validity. Figure 8-1 depicts the measurement model with a loading of the individual indicator on its respective construct, while the results show that the constructs are within an acceptable level of error. Thus, the measurement model demonstrates the ample robustness needed to test the relationship between the constructs (a structural model assessment).

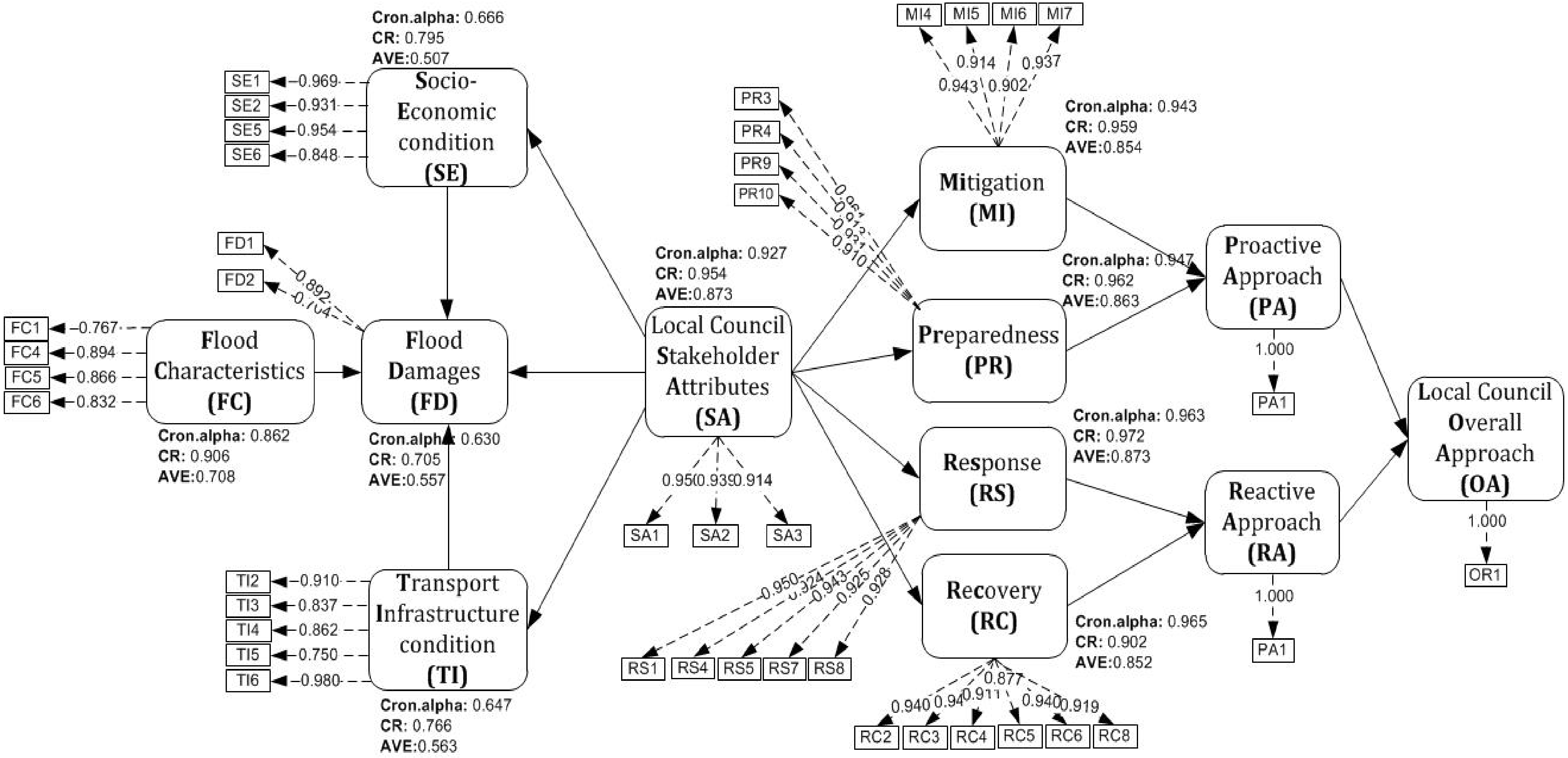


Figure 8-1: Measurement models showing loadings

8.4 Evaluation of structural model

Section 8.3 provided insights into an evaluation of the measurement models. This section continuous the analysis and focuses on the results of the structural model evaluation in six steps that represents the underlying concept of the path model (see Section 6.4.7).

8.4.1 Step 1: Collinearity assessment

Data was imported to IBM SPSS Statistics software to run multiple regressions with a set of predictor constructs as independent variables and any other latent variable as the dependent variable. The results of the regression analysis do not matter and were not analysed any more, the only result that was important for assessing collinearity issues was the tolerance (VIF) values. The following sets of predictor constructs for collinearity were assessed: (i) FC, SE, TI, and LA as predictors of FD; (ii) MI and PR as predictors of PA; (iii) RS and RC as predictors of RA; and (iv) PA and RA as predictors of OA. The results of this test shown in Table 8-8 representing all the VIF values and mean VIF values were below the suggested threshold levels (lower than 5), and therefore collinearity among the predictor constructs was not an issue in the structural model.

Table 8-8: Collinearity assessment

First set (FD)		**Second set (PA)**		**Third set (RA)**		**Fourth set (OR)**	
Predictor constructs	**VIF**	**Predictor constructs**	**VIF**	**Predictor constructs**	**VIF**	**Predictor constructs**	**VIF**
FC	1.139	MI	2.383	RS	3.637	PA	1.486
SE	1.033	PR	2.203	RC	3.514	RA	1.425
TI	1.073						
LA	1.058						

8.4.2 Step 2: Structural model path coefficients

The significance of *t*-values associated with each path was tested using the Bootstrap procedure of the SmartPLS 2.0 software with 36 cases and 500 resamples. Table 8-9 summarises the path results and the corresponding t-values. Due to the exploratory nature of this study, hypotheses were considered to be supported based on a significant level of 10% (1.65) (Hair et al., 2014a). Table 8-9 illustrates that 11 out of 12 hypotheses were fully supported, but one was not supported (*t*-value = 1.204-H10). These results are discussed in Section 8.6.

Table 8-9: Results of hypotheses testing

Relation (hypothesis)	Path Coefficient	*t*-Value	Inference
H1: Flood Characteristics → Flood Damage	+ 0.608	4.451	Supported
H3a: Local Council Attributes → Mitigation Activity	+ 0.287	1.767	Supported
H3b: Local Council Attributes → Preparedness Activity	+ 0.388	2.984	Supported
H3c: Local Council Attributes → Response Activity	+ 0.465	2.959	Supported
H3d: Local Council Attributes → Recovery Activity	+ 0.500	3.747	Supported
H4: Mitigation Activity → Proactive Approach	+ 0.559	5.795	Supported
H5: Preparedness Activity → Proactive Approach	+ 0.433	4.469	Supported
H6: Response Activity → Reactive Approach	+ 0.560	2.521	Supported
H7: Recovery Activity → Reactive Approach	+ 0.413	1.800	Supported
H8: Proactive Approach → Local Council Overall Approach	+ 0.170	1.759	Supported
H9: Reactive Approach → Local Council Overall Approach	+ 0.634	5.543	Supported
H10: Local Council Attributes → Local Council Overall Approach	+ 0.151	1.204	Not Supported

8.4.3 Step 3: Analysis for mediating effects

The extent to which the variance of the dependent variable (flood damage) was directly explained by the independent variable (Local Council stakeholder attributes) and how much of the target construct's variance (flood damage) was explained by the indirect relationship via the mediator variables (socio-economic and transport infrastructure conditions) could be determined. Table 8-10 shows that Local Council attributes had a high and significant effect on the socio-economic and transport infrastructure condition, which in turn had a strong and significant relationship with flood damage. The indirect effect of stakeholder attributes (i.e., 0.724, p < 0.01) via the mediator construct – socio-economic– was significant, whereas the direct relationship between stakeholder attributes and flood damage remained significant (path coefficient of 0.104, p < 0. 10). Thus, the socio-economic condition fully mediated the relationship between stakeholder attributes and flood damage, which provided empirical evidence for Hypothesis 2a.

Similarly, the indirect effect of stakeholder attributes (i.e., 0.433, p < 0.01) via the mediator construct – transport infrastructure– was also significant because the direct relationship between stakeholder attributes and flood damage also remained significant (path coefficient of 0.372, p < 0. 10). Thus, the transport infrastructure condition partially mediated the relationship between stakeholder attributes and flood damage and provided empirical evidence for Hypothesis 2b.

Table 8-10: Separate analysis for mediating effects

Constructs/indicators	**Direct effect**	**Indirect effect**	**Total effect**	**Bootstrap t-statistic**	**VAF**
H2a: Local Council Attributes → Flood Damage (via socio-economic condition)	0.104	0.724***	0.828***	3.07	87.44% (full mediation)
H2b: Local Council Attributes → Flood Damage (via transport infrastructure condition)	0.372*	0.433***	0.805***	2.25	53.78% (partial mediation)

(*p < 0.10, **p < 0.05, ***p < 0.01)

8.4.4 Step 4: Coefficient of determination (R^2 value)

The results of the F-test are shown in Table 8-11, and indicate that the R^2 values for all endogenous constructs were significant ($p \leq 0.05$). The significance of the F-test

(Table 8-11) indicated that the exploratory power of the structural model was statistically significant. Falk and Miller (1992) recommended that the R^2 value should be more than 0.1 as a rule of thumb. All the R^2 values in this structural model were above 10% indicating that 10% or more of variance in endogenous variables was accounted for by the exogenous variables. This results suggests that all the hypothesised relationships in the model were informative, with only being marginally above 10% (R^2 for Mitigation construct is 0.083); nevertheless, the construct Mitigation was predicted by only one independent construct (Local council Attributes), and therefore the impact of Local Council Stakeholder Attributes (SA) on Mitigation Activities (MI) was also pertinent and instrumental in the model.

It is imperative to note that selecting a model based on the R^2 value is not a safe approach (Hair et al., 2014a) because adding or omitting non-significant constructs to explain an endogenous latent variable in the structural model would probably fluctuate its R^2 value. In the next section, the structural model was assessed by exploring the change in R^2 values to see if the influence of a particular independent (exogenous) construct on a dependent (endogenous) construct had a large impact (Chin, 1998).

Table 8-11: Results of F-test for significance of R^2

Endogenous constructs	R^2 value	F-test	Significance Level
Flood Damage (FD)	0.626	12.972	0.01
Mitigation Activity (MI)	0.108	4.117	0.05
Preparedness Activity (PR)	0.151	6.047	0.05
Response Activity (RS)	0.216	9.367	0.01
Recovery Activity (RC)	0.250	11.333	0.01
Proactive Approach (PA)	0.745	31.163	0.000
Reactive Approach (RA)	0.702	25.128	0.000
Local Council Overall Approach (OA)	0.676	22.255	0.000

8.4.5 Step 5: Effect size f^2

The summary and inference on the f^2 estimate for independent (exogenous) constructs across the model is shown in Table 8-12. The results of F-test for the significance of f^2 are also shown in Table 8-12.

Table 8-12: Results of effective size (f^2) analysis

Dependent constructs	Independent construct	R^2 Included	R^2 Excluded	Effect size (f^2)	F-test	Inference
FD	FC	0.672	0.564	0.329	10.207	Large Effect
	SE	0.672	0.221	1.375	42.625	Large Effect
	TI	0.672	0.587	0.259	8.034	Large Effect
	SA	0.672	0.625	0.143	4.442	Medium Effect
MI	SA	0.083	0.000	0.091	3.077	Medium Effect
PR	SA	0.151	0.000	0.178	6.047	Medium Effect
RS	SA	0.216	0.000	0.276	9.367	Large Effect
RC	SA	0.250	0.000	0.333	11.333	Large Effect
PA	MI	0.745	0.706	0.153	5.047	Medium Effect
	PR	0.745	0.726	0.075	2.459	Medium Effect
RA	RS	0.702	0.680	0.074	2.436	Medium Effect
	RC	0.702	0.620	0.275	9.081	Large Effect
OA	PA	0.676	0.656	0.062	2.037	Medium Effect
	RA	0.676	0.440	0.728	24.037	Large Effect

The result of the F-test for the significance of f^2 shows that of the 4 predictors of flood damage (FD), the effect size of the socio-economic condition was much higher than the other predictors. The effect size of Local Council stakeholder attributes (SA) on reactive approaches such as response (RS) and recovery (RC) was high and significant. It is interesting to note that the effect size of the reactive approach (RA) to predict the Local Council overall approach (OA) was much higher that the effect size for the proactive approach (PA).

Although some of the exploratory variables individually had a little effect on predicting the dependent constructs, the results of the F-test for all the R^2 indicated that the model explained the variance in the dependent variables quite well.

8.4.6 Step 6: Blindfolding and predictive relevance Q^2

Table 8-13 provides the Q^2 values (along with the R^2 values) of all the endogenous constructs. All the Q^2 values were above zero and therefore supported the model's predictive relevance regarding the endogenous latent variables. Finally, there was no issue associated with a single-indicator construct as a predictor construct in this study.

Table 8-13: Results of predictive relevance (Q2) and q2 effect size

Dependent constructs	Independent construct	Q^2 Included	Q^2 Excluded	Effect size (q^2)	F-test	Inference
FD	FC	0.412	0.382	0.051	1.582	Medium Effect
	SE	0.412	0.057	0.604	18.716	Large Effect
	TI	0.412	0.488	0.017	0.527	Small Effect
	SA	0.412	0.365	0.080	2.478	Medium Effect
MI	SA	0.029	0.000	0.030	1.015	Medium Effect
PR	SA	0.136	0.000	0.157	5.352	Large Effect
RS	SA	0.184	0.000	0.225	7.667	Large Effect
RC	SA	0.226	0.000	0.292	9.928	Large Effect
PA	MI	0.929	0.887	0.246	8.105	Large Effect
	PR	0.929	0.901	0.164	5.404	Large Effect
RA	RS	0.914	0.903	0.158	5.219	Large Effect
	RC	0.914	0.908	0.235	7.745	Large Effect
OR	PA	0.626	0.603	0.061	2.029	Medium Effect
	RA	0.626	0.392	0.626	20.647	Large Effect

In the path model, the predictive relevance of $Q^2$of single-indicator constructs such as PA, RA and OA were 0.929, 0.914, and 0.626, respectively, which implied that the model has predictive relevance for single-indicator constructs (Hair et al., 2014a). The results of the structural model and hypotheses tests generated by SmartPLS 2.0 are depicted in Figure 8-2.

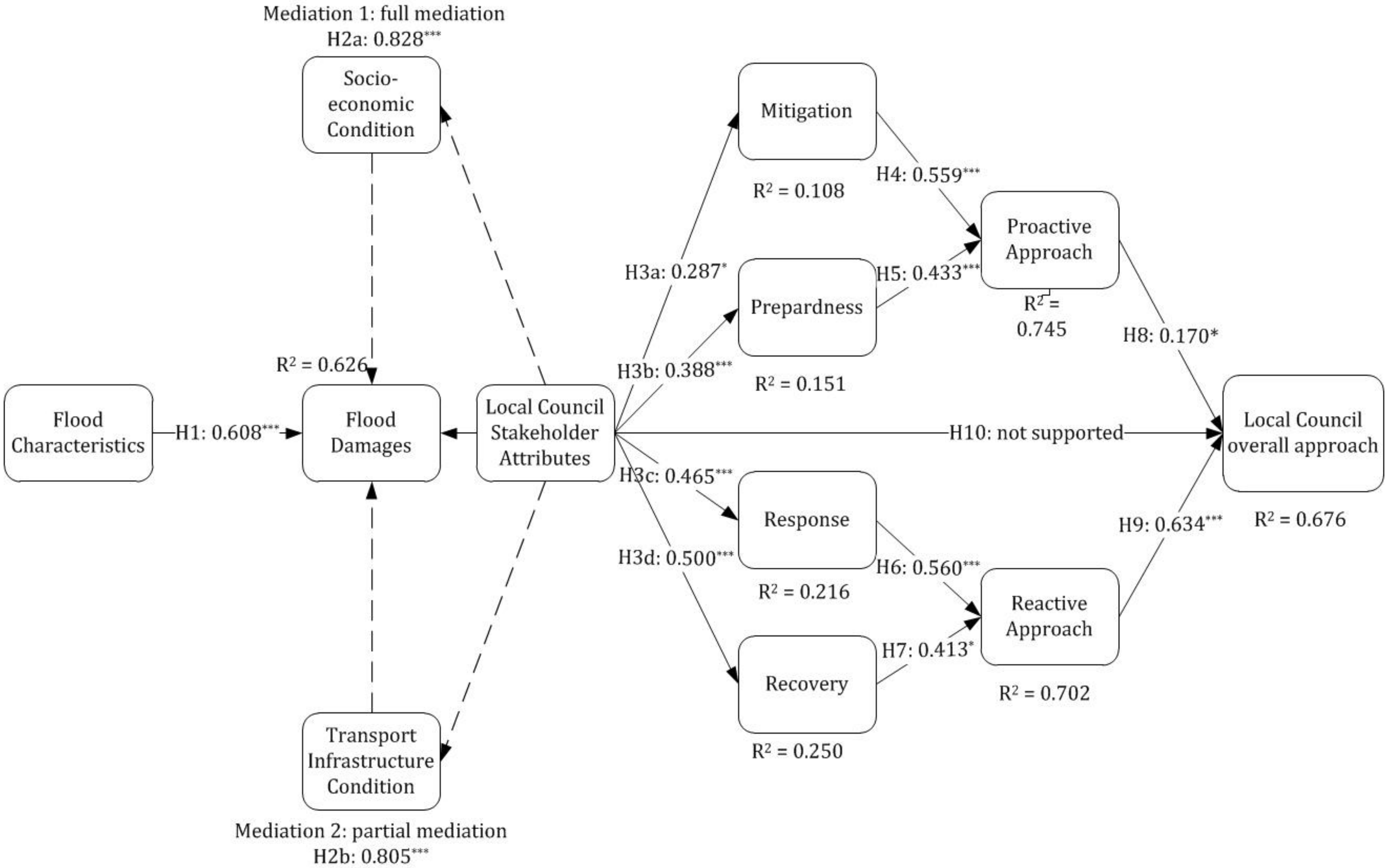


Figure 8-2: Results of research model and hypotheses testing

8.5 Stakeholder disaster response index (SDRI)

Table 8-14 presents the results of the total effects (importance) and index value of SDRI (performance) used for IPMA of the key target construct Local Council Overall Approach (OA) in the PLS path method (see Section 6.5). Table 8-14 represents the major factors in predicting SDRI. For example, the Reactive Approach (RA) had the highest performance (68.889) among other factors and Proactive Approach (PA) with highest effects (0.634) on defining SDRI.

Table 8-14: Results of IPMA analysis for SDRI

Main constructs to define SDRI	Total effects (Importance)	SDRI (Performance)
Mitigation (MI)	0.095	45.271
Preparedness (PR)	0.073	53.964
Response (RS)	0.355	61.555
Recovery (RC)	0.262	60.682
Proactive approach (PA)	0.634	47.777
Reactive approach (RA)	0.551	68.889

8.6 Discussion

This section focuses on interpreting and discussing the interaction effects between Local Councils' stakeholder attributes, exposure and vulnerability of socio-economic and transport infrastructure, flood characteristics, and how these effects collectively influence flood damage and Local Councils' approaches. All the observed predictive relationships are explained in relation to the measurement indicators of the respective predictor and predicted constructs reported in Table 8-9.

8.6.1 The effect of flood characteristics on flood damage

As depicted in Table 8-9, the test results generally support the relationship between flood characteristics and flood damage, which validated hypothesis 1 reasonably well (H1: flood characteristics have a direct effect on the magnitude of flood damage). The findings indicate that a region (Local Council area) with a higher degree of flood characteristics is more likely to have more flood damage. These findings are consistent with those of Ho et al. (2008) who found that flood characteristics have a significant and direct impact on flood damage. Transport infrastructure and socio-economic damage due to flooding in Australia is mainly associated with major and river flooding and higher annual rain fall exacerbates these damages. McKenzie et al. (2005) showed that river flooding is likely to be more problematic than other types of flooding and fatalities and economic losses have mostly been from river flooding. More interestingly, the findings of this study indicate that Australian coastal areas are not as vulnerable as riverine areas against flood. Finally, this study found that major flooding (FC1, factor loading = 0.767), rainfall annul mean (FC4, factor loading = 0.894), frequency of major flooding (FC5, factor loading = 0.866), and river flooding (FC6, factor loading = 0.832) are the most significant measurement indicators for flood characteristics. Although reducing rainfall and frequency of major flooding are inevitable, Local Councils could probably reduce the impact of socio-economic and transport infrastructure damage by not constructing roads and bridges close to river banks.

8.6.2 Local Councils' stakeholder attributes and mediating roles of socio-economic and transport infrastructure conditions

It is found that socio-economic exposure and vulnerability (SE), as measured by population density (SE1), GRP per capita (SE2), population at risk due to floods (SE5), and the income level (SE6) play mediating effects on the direct relationship between Local Council attributes (LA)-power (LA1), legitimacy (LA2), urgency (LA3), and flood damage (FD). The indirect effect of stakeholder attributes (i.e., 0.724, $p < 0.01$) via socio-economic condition (mediator) was significant while simultaneously, the direct relationship between stakeholder attributes and flood damage remained significant as well (path coefficient of 0.104, $p < 0.\ 10$; see Section 8.4.3 and Table 8-10). Thus, the socio-economic condition fully mediated the relationship between stakeholder attributes and flood damage, and provided empirical evidence for Hypothesis 2a (H2a: the socio-economic condition mediates the relationship between stakeholder attributes and flood damage).

Similarly, the exposure and vulnerability of transport infrastructure (TI) which is measured by local non-urban sealed roads (TI2), local non-urban unsealed roads (TI3), the total length of bridges and culverts on local roads (TI4), the roads and bridges at risk of flood (TI5), and the average response time for road reconstruction (TI6) of a Local Council, have mediating effects on the direct relationship between Local Council attributes (LA) and flood damage (FD). The indirect effect of stakeholder attributes (i.e., 0.433, $p < 0.01$) via the mediator construct – transport infrastructure– was also significant, as was the direct relationship between stakeholder attributes and flood damage (path coefficient of 0.372, $p < 0.\ 10$; see Section 8.4.3 and Table 8-10). Thus, the condition of transport infrastructure partially mediated the relationship between stakeholder attributes and flood damage and provided empirical evidence for Hypothesis 2b (H2b: the transport infrastructure condition mediates the relationship between stakeholder attributes and flood damage). In other words, the low transport infrastructure condition (TI) (high exposure and vulnerability) exacerbated the negative relationship between Local Councils' stakeholder attributes (SA) and flood damage (FD).

These findings agree with some previous research findings (e.g., IPCC, 2012, Nicholls and Tol, 2006, O' Brien and Leichenko, 2000) which showed that increases in exposure and vulnerability of the socio-economic and transport infrastructure conditions resulted in higher direct economic losses from natural disasters. Furthermore, the findings indicate that a region with higher Local Council's stakeholder attributes (powerful, legitimate, and urgent Local Council) is more likely to have less flood damage, although the socio-economic and transport infrastructure conditions of a region would change the strength of this relationship. In other words, increasing Local Councils' stakeholder attributes and decreasing exposure and vulnerability of socio-economic and transport infrastructure conditions of a region should be practiced at the same time as reducing the impact of flood damage. This claim is also consistent with Olander (2007) findings indicated that stakeholder attributes are not the only factors to predict the overall performance of an organisation, the external environmental factors should also be considered.

8.6.3 The effect of Local Councils' stakeholder attributes on FRM activities

The findings indicate that Local Councils with more power, legitimacy and urgency have practised more mitigation, preparedness, response and recovery activities (see Table 8-9). Interestingly, the positive coefficient of 0.287, 0.388, 0.465, and 0.500 between Local Councils' stakeholder attributes and mitigation, preparedness, response, and recovery activities respectively, imply that increasing Local Councils' stakeholder attributes (power, legitimacy and urgency) is highly justified in improving FRM activities before, during and after flooding. Finally, enhancing stakeholder attributes not only reduces the flood damage, but also enriches the FRM activities conducted by Local Councils.

The highest path coefficient is between stakeholder attributes and the response and recovery activities (see Table 8-9). It is obvious that stakeholder attributes do not guarantee more mitigation and preparedness activities, it occurs because power and legitimacy do not necessarily lead to noticeable decisions by stakeholders (Mitchell et al., 1997). The power and legitimacy of stakeholders results in a mitigation and preparedness activities if Local Councils consider a value maximisation paradigm in their decision-making process. Although the power and legitimacy attributes of stakeholders help them to take mitigation and preparedness activities against natural disasters, they might practice more response and recovery activities by making irrational decisions in their strategies based on intuitive reasoning paradigms, which is another role player in their decision-making process which assumes that decisions by humans are influenced by complicated factors (Ariely, 2009, Levy, 1992). Furthermore, the results indicate that Local Councils are more urgent rather than being more powerful and legitimate, because urgent stakeholders react to problems when they happen (Mitchell et al., 1997), the results also indicate that time sensitivity and criticality are two criteria that arise from urgency. Therefore, the results are consistent with some of previous studies which argued that stakeholder attributes - power, legitimacy and urgency – have been playing essential role in firm's performance (e.g., Olander, 2007, Phillips et al., 2003, Freeman, 1984) and stakeholder theory has supported this claim (Mitchell et al., 1997).

8.6.4 The effect of Local Councils' stakeholder attributes on stakeholder approaches

The findings indicate that Local Councils with higher mitigation and preparedness activities are more proactive (H4 and H5 supported) and vice versa, whereas Local Councils with higher response and recovery activities are more reactive in FRM, particularly in transport infrastructure (H6 and H7 supported) (see Section 8.4.2 and Table 8-9). This claim agrees with Moe and Pathranarakul (2006) findings which showed that on one hand mitigation and preparedness activities form a stakeholder proactive approach and on the other hand response and recovery activities constitute a reactive approach in NDRM

The findings also indicate that both proactive and reactive approaches would most likely lead to an overall approach by stakeholders in managing natural disasters (H8 and H9 supported). These findings are consistent with previous studies that contributed to the view that proactive and reactive approaches are essentially different, if not complementary (e.g., IPCC, 2012, Lavell, 2011, Mercer, 2010).

The findings indicate there is a positive and significant effect between proactive and reactive approaches in predicting Local Councils' overall approaches in FRM (see Table 8-9), wheras Olander (2007) claimed that stakeholder institutional attributes are essential factors in defining their overall performance. He empirically discovered that power, legitimacy, and urgency are the three main attributes based on stakeholder theory (Mitchell et al., 1997, Freeman, 1984), which could enhance their overall response and performance.

Previous studies mentioned that to reduce the overall cost of natural disasters, investment in mitigation and preparedness or proactive approaches are firmly encouraged by governments, the insurance sector, and the donor community (Linnerooth-Bayer et al., 2005, Gurenko, 2004, Kreimer and Arnold, 2000), indeed shifting from reactive approaches to proactive approaches depends on strengthening mitigation and preparedness (IPCC, 2012). However, they did not explain how stakeholders can shift from a reactive approach to a proactive approach, but this study found that enhancing stakeholder attributes in NDRM would enable them to practice more mitigation and preparedness activities; consequently, they are more proactive rather than being reactive.

8.6.5 Stakeholder disaster risk index (SDRI)

The fifth objective in this research was to design an index to measure stakeholder overall approach to natural disasters in the built environment, so to this end the concept of an IPMA technique in PLS-SEM was used to develop the SDRI in this study (see Section 8.5). The findings from the IPMA analysis are shown in Figure 8-3, and indicate that the proactive approach is extremely important when establishing SDRI. However, its performance is slightly low compared to the other constructs, and the reactive approach is high in performance and importance when defining SDRI compared to the proactive approach and other constructs. Mitigation, preparedness, and response and recovery activities are not relevant because they are not important, even though they performed very well. Finally, the reactive approach is the pivotal construct in defining SDRI because it is high in importance and performance compared to the other constructs. Thus, SDRI shows that Local Councils have been more reactive rather than been proactive in managing flood in transport infrastructure.

The aim of the SDRI is to recognise the correct actions for specific Local Councils to take in order to best deal with future flood risk exposure and vulnerability specific to the related built environment particularly transport infrastructure. SDRI is a powerful tool for policy and operational decision-makers to prioritise the allocation of resources and make decision-making more transparent.

The performance of each Local Council can be benchmarked in more specific FRM and monitored over time. Benchmarking SDRI would enable Local Councils and other key stakeholders to measure the individual balance of resource allocation, overall priorities and the effectiveness of alternative resourcing strategies. Such measures could then be used to inform related considerations including: maintenance regimes, state-wide funding priorities, insurance premiums, allied NDRM strategies, urban planning and evacuation planning (Davidson, 1997).

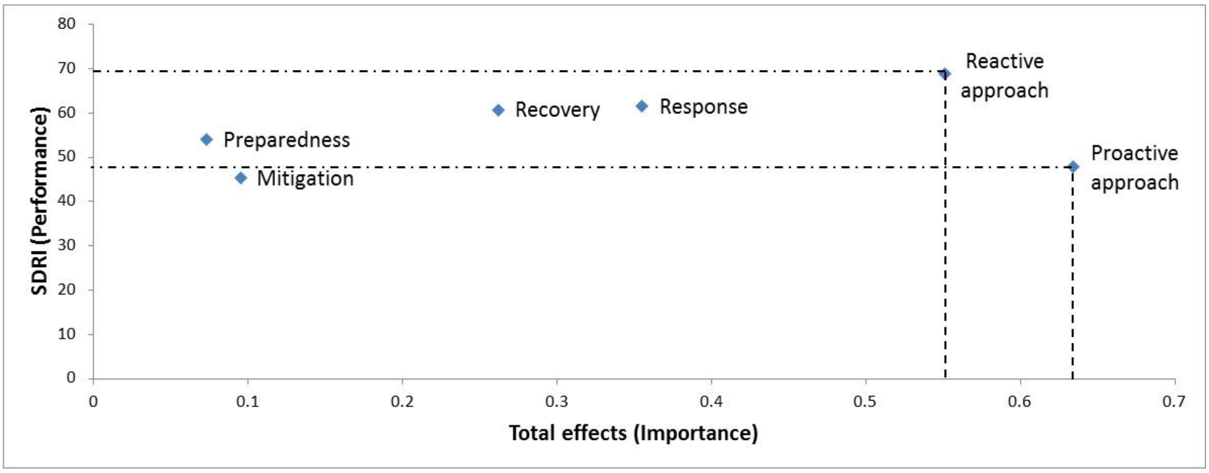


Figure 8-3: IPMA representation of SDRI

8.7 Summary

This chapter has presented the results for validating the theoretical framework for FRM in transport infrastructure by focusing on Local Councils' stakeholder attributes and approaches. The measurement of the model has acceptable individual indicator reliability, convergent validity, and discriminant validity, so the measurement models have demonstrated the robustness needed to test the relationship between constructs.

Goodness-of-fit measures are not applicable in a PLS-SEM context, so rather than applying measures of goodness-of-fit, the structural model is assessed on the basis of heuristic criteria determined by the model's predictive capabilities, and which can be explained by the level of R^2 values. The average R^2 for the model is 0.44, which indicates reasonably satisfactory predictive power, while the R^2 for all endogenous variables in the model are statistically significant, thus demonstrating the predictive relevance of the model.

It is found that flood damage (FD) are positively influenced by: (i) the flood characteristics; (ii) the socio-economic condition (SE) (exposure and vulnerability); and (iii) the transport infrastructure condition (TI) (exposure and vulnerability). However, Local Council stakeholder attributes (SA) have significant negative influences on flood damage (FD). It is imperative to note that the relationship between Local Council stakeholder attributes (SA) and flood damage (FD) is mediated by both socio-economic (SE) and transport infrastructure (TI) conditions. Furthermore, Local Council stakeholder attributes (SA) have a positive influence on NDRM activities including: (i) mitigation (MI); (ii) preparedness (PR); (iii) response (RS); and (iv) recovery (RC). Increasingly, mitigation (MI) and preparedness (PR) tasks have a positive impact on the Local Council proactive approach (PA) and response (RS) and recovery (RC) have a positive impact on Local Council reactive approach (RA). Consequently, the proactive approach (PA) and reactive approach (RA) define Local Council Overall Approach (OA) to floods.

14 hypotheses are tested based on the inter-relationships developed within PLS-SEM, of which thirteen are supported, but the relationship between Local Council Attributes (LA) and Local Council Overall Approach (OA) (H10) is not supported. Based

on the empirical results obtained, the mediating effects of socio-economic (SE) and transport infrastructure (TI) conditions on the relationship between Local Council stakeholder attributes (SA) and flood damage (FD) are statistically significant.

Finally, an index (SDRI) is developed to measure the Local Council overall approach against flood, and reveals that the reactive approach is the pivotal construct that defines SDRI because it has high importance and performance compared to the proactive approach. SDRI shows that Local Councils have been more reactive rather than been proactive in managing flood in transport infrastructure. The next chapter presents a validation of the results.

CHAPTER

9

Validation of Results

9.1 Introduction

The focus of this chapter is on the validation of results reported in Chapters 7 and 8. The validation and comparison of results for flood risk analysis using Bootstrap-TOPSIS (Section 9.2) is discussed first, followed by the process for validating the structural model (Section 9.3), and then the stakeholders' perspective on the results concerning the practicality and comprehensiveness of the structural model (Section 9.4). Finally, the robustness of the structural model results was also tested, particularly the SDRI (Section 9.5), in order to fulfil the fifth research objective of this study.

9.2 Validation and comparison of Bootstrap-TOPSIS results

In the proposed Bootstrap-TOPSIS technique (see Chapter 6), normality checking is an essential procedure for validating the results. Indeed, for the confidence intervals around an estimated parameter to be accurate, that estimate must come from a normal distribution; and for significance tests of models to be accurate, the sampling distribution of what is being tested must be normal; or, based on the central limit theorem, our sample size should be large enough (Efron, 1979). The distribution of original flood data for buildings and transport infrastructure did not conform with normal distribution, and the sample size for generating weights for the attributes of natural disasters was not large enough, however, an assumption of normal distribution or a large sample size do not matter for the non-parametric Bootstrap-TOPSIS technique (Mojtahedi and Oo, 2014a). The results of the combined Bootstrap-TOPSIS technique proposed in this study followed the rough normality shown in Table 9-1. It can be seen that, the *p*-value from a one-sample Kolmogorov-Smirnov test for all three attributes of socio-economic condition are greater than 0.05 indicating a robust validation for the normality test (Field, 2013).

Table 9-1: Normality check for socio-economic condition after executing the Bootstrap-TOPSIS

	Normality test - Kolmogorov-Smirnov			Shape descriptors	
Attribute	**Statistic**	**df**	**Significance**	**Skewness**	**Kurtosis**
Exposure	0.115	500	0.105	0.271	-0.502
Vulnerability	0.133	500	0.192	-0.175	-0.375
Economic damage	0.062	500	0.251	-0.369	-0.547

9.3 Process for validating structural model

After completing of the PLS-SEM analysis, a validation exercise was carried out via face-to-face interviews in order to examine the practicality and comprehensiveness of the structural model and to test the feasibility of the SDRI. An interviewing approach was selected because it is an effective way of collecting information from experts on the subject matter at hand (Lim, 2010, Robson, 2002).

Two experts from two different Local Councils and one from RMS agreed to participate in the validation exercise. They were from the Infrastructure Asset Management Departments of Local Councils and RMS in NSW Australia. In order to maintain anonymity and facilitate further discussion, they were assigned a code starting with the letter 'S' followed by numbering from one to three (i.e., S1, S2, and S3). These experts have broad practical experience in NDRM in the Australian built environment, particularly transport infrastructure asset management that ranges from 15 to 28 years, with an average of 21 years.

The experts were asked to provide feedback on the practicality and comprehensiveness of the resultant models, and complete a questionnaire. The questionnaire used to develop the structural models was modified based on the findings reported in Chapter 8 (see Sections 8.4 and 8.5) where inconsistent measurement indicators of respective constructs were eliminated from the structured questionnaire appended in Appendix C. The questionnaire was shortened so the interviews could be conducted efficiently. Moreover, the structural model developed in this study was presented to the experts to validate the results. They were asked to provide feedback to the following items: (i) the relationship between constructs; (ii) the mediating effect of the socio-economic and transport infrastructure conditions on the relationship between Local Council stakeholder attributes and flood damage; (iii) the feasibility of the mitigation and preparedness activities in forming a proactive approach; (iv) the feasibility of the response and recovery activities in constituting a reactive approach; and (v) the effects of proactive and reactive approaches in determining the overall approach of Local Council to FRM in transport infrastructure.

9.4 Stakeholders' perspectives about the structural model

This section focuses on the external validity of the resultant PLS-SEM model by examining the extent to which the models were comprehensive and applicable to FRM. A consensus was obtained from the experts that the 12 constructs and 14 hypotheses developed in this study were relevant to the context of FRM in the transport infrastructure, and the inter-relationships were logically shaped. In view of the definitions attached to stakeholder attributes – power, legitimacy, and urgency – they mentioned that these attributes are pertinent to the Local Council's institutional characteristics and capabilities in flood risk identification, assessment, flood risk reduction, and flood management. They also shared that powerful and legitimate Local Councils are able to act more proactively in FRM. They stated that power and legitimacy helped them to practice more proactive approaches rather than reactive approaches. They explained that power and legitimacy deal with mitigation and preparedness activities, while urgency deals with response and recovery tasks in FRM. They also categorised FRM processes into: (i) flood identification; (ii) flood risk reduction (mitigation); and (iii) flood management (preparedness, response, and recovery). This classification is very consistent with the NDRM definition provided by IPCC (2012) and Moe and Pathranarakul (2006) in Section 2.4.1.

In the second part of the interview, they were asked about the mediating effect of socio-economic and transport infrastructure conditions on the relationship between Local Council stakeholder attributes and flood damage. Prior to this, the definition of the mediating effect was clearly spelled out. Three veins of perspectives were collected: (i) it is useful to have more conditions such as resilience, sustainability, and rural and urban conditions; (ii) it is useful to consider the relationship between the socio-economic and transport infrastructure conditions; and (iii) it is instrumental to combine two conditions into a single construct. Their suggestions were consistent with previous NDRM studies, but those viewpoints were considered promising for future studies (see Section 10.6). However, they concluded that the mediating roles of socio-economic and transport infrastructure were logical due to their potential to lessen the impact of flood damage.

In the final section of the interview, they were asked to shed light on Local Council's overall approach to FRM and important factors in determining this overall approach. They agreed that proactive and reactive approaches could construct Local Councils overall approaches, but they were not quite sure whether they have been proactive or reactive over the past twenty years, because tools to measure proactive and reactive approaches have been non-existent for Local Councils. Finally, they were asked to complete the questionnaire, which was then assessed for testing the SDRI.

9.5 Testing stakeholder disaster response index (SDRI)

A new dataset collected from the three experts were used to test the SDRI. Using Equations 9-1 to 9-3, the anticipated errors for the SDRI was calculated. These were compared to actual SDRI (see results of IPMA analysis in Section 8.5). The following equations were adopted to assess the robustness of anticipated model (Upton and Cook, 2014, Hair et al., 1986):

(i) Equation 9-1 is used to measure the percentage errors between the actual and anticipated SDRI of Local Council overall approach.

$$\text{Percentage Error (PE)} = \frac{\text{Actual SDRI} - \text{Anticipated SDRI}}{\text{Actual SDRI}} \times 100$$

Equation 9-1

(ii) Equation 9-2 is used to calculate the mean percentage error by summing up all percentage error (PE) found in Equation 9-1, and then dividing the sum by the number of observations (n)

$$\text{Mean Percentage Error (MPE)} = \frac{\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{PE_i}}{\mathrm{n}}$$

Equation 9-2

(iii) Equation 9-3 was used to estimate the mean absolute percentage error by adding all percentage errors (PE) discovered in Equation 9-1.

$$\text{Mean Absolute Percentage Error (MAPE)} = \frac{\sum_{i=1}^{n} |PE_i|}{n}$$ **Equation 9-3**

The actual importance and performance results for SDRI was derived from the IPMA results in Chapter 8 (see Section 8.5), but the anticipated importance and performance were analysed after receiving completed post-questionnaires from experts during the interviews. The actual and anticipated results and pertinent analysis (PE, MPE, and MAPE) are shown in Table 9-2 and 9-3 for the importance of SDRI and the performance of SDRI, respectively.

Table 9-2: Comparison of actual and anticipated of IPMA analysis for SDRI (Importance)

Main constructs for SDRI	Exp.	Actual importance	Anticipated importance	Percentage error (PE%)	Mean percentage error (MPE%)	Mean absolute percentage error (MAPE%)
Proactive approach (PA)	S1	0.634	0.752	-18.61%	-33.07%	33.07%
	S2	0.634	0.950	-49.84%		
	S3	0.634	0.829	-30.76%		
Reactive approach (RA)	S1	0.551	0.351	36.30%	15.25%	21.17%
	S2	0.551	0.500	18.33%		
	S3	0.551	0.650	-8.89%		

Table 9-3: Comparison of actual and anticipated of IPMA analysis for SDRI (Performance)

Main constructs for SDRI	Exp.	Actual performance	Anticipated performance	Percentage error (PE%)	Mean percentage error (MPE%)	Mean absolute percentage error (MAPE%)
Proactive approach (PA)	S1	47.777	35.51	25.68%	6.68%	13.27%
	S2	47.777	52.50	-9.89%		
	S3	47.777	45.75	4.24%		
Reactive approach (RA)	S1	68.889	75.28	-9.28%	-11.53%	11.53%
	S2	68.889	85.14	-23.59%		
	S3	68.889	70.08	-1.73%		

The results in Table 9-2 show that the percentage of errors for the two main predictors of SDRI (proactive and reactive approaches) ranged from -18.61% to 49.84%. Since the percentage of errors registered for the importance of the proactive approach in defining Local Councils' overall approach were all negative, the mean percentage errors and mean absolute percentage errors were the same at an absolute figure of 33.07%. This indicates that the model developed in this study underestimated the importance of the proactive approach for the three stakeholders' organisations, that is, they showed that the proactive approach was more important than the reactive approach in predicting Local Councils' overall approach in FRM. Another possible explanation is that proactive approach is a remarkably significant factor in defining stakeholder overall approach in FRM in transport infrastructure. On the other hand, the corresponding mean percentage errors and mean absolute percentage errors registered for the importance of the reactive approach at 15.25% and 21.17% suggest that the importance of the reactive approach was relatively robust at predicting Local Councils' overall approach to FRM in transport infrastructure.

The results in Table 9-3 show that the mean percentage errors and mean absolute percentage errors are 6.68% and 13.27%, respectively. These relatively small error percentages suggest that the performance of the proactive approach was robust enough to predict Local Councils' overall approach to floods, but the corresponding mean percentage errors and mean absolute percentage errors registered for the performance of the reactive approach at -11.53% and 11.53% indicate that the performance of reactive approach in predicting Local Councils' overall approach in the developed model overestimated the overall approach of the experts' organisation. Another possible explanation for this is that the high level of stakeholder overall approach in FRM occurs because the stakeholders' reactive approaches are much higher than their proactive approaches.

The above shows that the importance of the proactive approach is much higher than the reactive approach in explaining the SDRI, but all the stakeholders (e.g., Local Councils) performed more reactively than proactively over the past two decades. A possible explanation for this might be that Local Councils have practised reactive approaches in FRM, despite their belief that a proactive approach is fundamentally important in FRM for reducing the adverse impacts of flooding in society and the built environment. The validation of SDRI is compatible with the results of this study (see Section 8.6.5). Thus, SDRI is an applicable tool to measure stakeholders' proactive, reactive and overall approaches in NDRM in the built environment.

9.6 Summary

The results of the proposed Bootstrap-TOPSIS for flood risk analysis were validated by performing a normality check. The results show that all the attributes of socio-economic condition are more than 0.05, indicating a robust validation for the normality test. This indicates that Bootstrap-TOPSIS is an extremely attractive tool because it requires few assumptions for flood risk analysis and an assumption of normal distribution or a large sample size does not matter for the non-parametric Bootstrap-TOPSIS.

The mathematical model based on IPMA for estimating SDRI (see Section 8.5) was validated in this chapter. To determine the robustness of SDRI, three equations were developed: (i) percentage error (PE); (ii) mean percentage error (MPE); and (iii) mean absolute percentage error (MAPE). New datasets were also collected from three experts from two Local Councils and one from RMS who were not involved in this study, by face-to-face interviews.

The results show that the SDRI (MAPE=33.07% for proactive approach and 22.17% for reactive approach) is relatively robust for measuring stakeholder proactive and reactive approaches in flood risk management in transport infrastructure. The results show that Local Councils have performed more reactive approaches than proactive approaches in flood risk management (MAPE=11.53%), but the importance of the proactive approach is more greater than the reactive approach in explaining the SDRI and predicting the stakeholder overall approach to disasters. Also, the interviews revealed that the results derived from PLS-SEM were comprehensive and provided rewarding insights into flood risk management in transport infrastructure. A summary that includes the applications and conclusions of this study are presented in the next chapter.

CHAPTER

10

Summary and Conclusion

10.1 Summary

Both natural and technological disasters have jeopardised society, the performance of the economy, and the built environment, but natural disasters have been the most costly type of disaster. While natural disasters cannot be eliminated, a resilient built environment means disasters are effectively managed by stakeholders. However, natural disaster risk management has often been viewed by stakeholders as a reactive practice or profession rather than proactive. No research has been found that investigated the role of stakeholder attributes in reducing natural disaster damage and in defining stakeholder proactive and reactive approaches. Finally, an index to measure stakeholder overall approach has not been developed in previous studies.

Based on the identified research problems (see Section 1.2), the aim of this study was to investigate stakeholder attributes and approaches of Local Councils to flood risk management in transport infrastructure across New South Wales in Australia. A theoretical framework of the relationship between natural disaster characteristics, stakeholder attributes (power, legitimacy and urgency), and the socio-economic and built environment conditions (exposure and vulnerability) was developed. At the same time, the relationship between stakeholder attributes and mitigation, preparedness, response and recovery activities and stakeholder approaches (proactive and reactive approaches) was considered in the proposed theoretical framework (see Figure 3-1). The developed theoretical framework was operationalised into flood risk management in transport infrastructure by selecting Local Councils as stakeholders (see Chapter 4).

This study research design collected data from secondary data sources and through a structured questionnaire. Data for flood characteristics, socio-economic conditions and transport infrastructure was obtained from the Bureau of Meteorology, Australian Bureau of Statistics and NSW Roads and Maritime Services for the past 20 years (1992-2012). A questionnaire was then designed to collect the remaining data, particularly data on Local Councils' stakeholder attributes and approaches. Taking into consideration the nature of the research objectives and the data available for this study, Bootstrap-Technique for the Order Preference by Similarity to Ideal Solution (Bootstrap-TOPSIS) and Partial Least Square Structural Equation Modelling (PLS-SEM) analytical methods were used in the analysis phase (see Chapter 6).

Exposure and vulnerability of coastal buildings and transport infrastructure to flood disasters in Australian states and territories were assessed by considering the socio-economic and built environment conditions simultaneously, by using Bootstrap-TOPSIS technique (see Chapter 7). The hypothesised inter-relationships were analysed using data obtained from secondary historical databases and a structured questionnaire by using PLS-SEM. A stakeholder disaster response index (SDRI) was then developed (see Chapter 8). Finally, the results of the data analysis were validated to investigate the robustness of the structural model results, particularly the stakeholder disaster response index (see Chapter 9).

10.2 Summary of research findings and hypotheses testing

This section summarises the findings of this study by stating the results corresponding to the research objectives and research hypotheses.

10.2.1 Theoretical framework for natural disaster risk management in the built environment

The first objective of this research was to develop a theoretical framework for stakeholder attributes and approaches to natural disaster risk management in the built environment context. This theoretical framework was underpinned by integrating the natural disaster risk management discipline, stakeholder theory and decision-making paradigms. This study adds knowledge to disaster risk reduction and management by applying a new theoretical framework developed from the natural disaster risk management concept to investigate and empirically demonstrate the influence of stakeholder attributes on natural disaster damage and stakeholder proactive and/or reactive approaches to the built environment. It offers a new and logical explanation for the factors influencing flood damage and Local Councils' overall approaches to transport infrastructure.

This is the first known quantitative study in built environment research to investigate the concept of stakeholder attributes in flood risk management. It has provided empirical evidence that flood risk analysis is a multi-attribute decision-making process and Local Councils' attributes of power, legitimacy and urgency affect flood damage and determine Local Councils' overall approaches such as proactive and reactive approaches. The study has also empirically demonstrated an index to measure the effect and importance of factors predicting Local Councils' overall approach to flood risk management in transport infrastructure.

10.2.2 Flood risk analysis using Bootstrap-TOPSIS

The results in Chapter 7 addressed the second research objective and provided evidence that the vulnerability of Australian coastal buildings and transport infrastructure in different states and territories against flood disasters depended on the socio-economic and built environment conditions. There is a significant difference between exposure and vulnerability of states and territories to flood in Australia when the socio-economic and built environment conditions were considered concurrently. Furthermore, the findings provided evidence that the exposure and vulnerability analysis is a multi-attribute decision-making problem in the context of natural disaster risk management, which means the socio-economic and built environment conditions must be considered when analysing the exposure and vulnerability of Australian states and territories to flood risks in order to achieve a precise ranking of states and territories in flood risk management.

Queensland was identified as the state most susceptible to flood disasters when the socio-economic and built environment conditions were considered simultaneously. When only the built environment condition was considered, Western Australia was ranked as the most susceptible of the Australian states and territories. The analysis clearly showed that coastal buildings and transport infrastructure in NSW would likely be exposed to flood disasters in a sea level rise scenario of 1.1 metres, the high-end scenario for 2100. The relative closeness (RC) of vulnerability for NSW is 0.396 when the socio-economic and built environment conditions were considered simultaneously, indicating the exposure and vulnerability to flood disasters of the state's coastal buildings and transport infrastructure.

10.2.3 The effect of flood characteristics on flood damage

Hypothesis 1 states "flood characteristics have a direct effect on the magnitude of flood damage". It is found that flood characteristics (FC) have a significant direct impact on flood damage (FD) (path coefficient = +0.608, $p < 0.01$; see Section 8.4.2), therefore

Hypothesis 1 is fully supported. The flood characteristics were measured by major flooding (FC1), rainfall annual mean (FC4), frequency of major flooding (FC5) and river flooding (FC6), whereas flood damage was characterised by socio-economic loss (FD1) and transport infrastructure loss (FD2). The findings indicated that Local Councils that are susceptible to major flooding and high levels of annual rainfall, are frequently affected by flooding and, most importantly, are located in areas close to major rivers, and therefore are more likely to have higher socio-economic and transport infrastructure economic losses from flooding. It is important to note that flood characteristics are not the only indicators to predict the flood damage so further investigation into more predictors is suggested.

10.2.4 Mediating roles of socio-economic and transport infrastructure conditions

Many studies showed that increases in exposure and vulnerability of the socio-economic and built environment conditions will result in higher direct economic losses from natural disasters (e.g., IPCC, 2012, Nicholls and Tol, 2006, O' Brien and Leichenko, 2000).

Hypothesis 2a states that “the socio-economic condition mediates the relationship between stakeholder attributes and flood damage” and

Hypothesis 2b states that “the transport infrastructure condition mediates the relationship between stakeholder attributes and flood damage”.

It is found that socio-economic exposure and vulnerability (SE), which were measured by population density (SE1), GRP per capita (SE2), population at risk due to floods (SE5), and the income level (SE6), play mediating effects on the direct relationship between the Local Council attributes of power (SA1), legitimacy (SA2) and urgency (SA3), and flood damage (FD).

Similarly, the exposure and vulnerability of transport infrastructure (TI) which were measured by local non-urban sealed roads (TI2), local non-urban unsealed roads (TI3), the total length of bridges and culverts on local roads (TI4), the roads and bridges at risk to flood (TI5), and the average response time for road reconstruction (TI6) of a Local Council, have mediating effects on the direct relationship between Local Council attributes (SA) and flood damage (FD).

The indirect effect of stakeholder attributes (path coefficient of 0.724, $p < 0.01$) via the mediator construct – socio-economic – is significant. The direct relationship between stakeholder attributes and flood damage is significant as well (path coefficient of 0.104, $p < 0.10$; see Section 8.4.3). Thus, the socio-economic condition fully mediates the relationship between stakeholder attributes and flood damage. **Hypothesis 2a** is supported.

The indirect effect of stakeholder attributes (path coefficient of 0.433, $p < 0.01$) via the mediator construct – transport infrastructure – is significant and the direct relationship between stakeholder attributes and flood damage is significant (path coefficient of 0.372, $p < 0.10$; see Section 8.4.3). Thus, the condition of transport infrastructure partially mediates the relationship between stakeholder attributes and flood damage. **Hypothesis 2b** is supported. The low transport infrastructure condition (TI) (high exposure and vulnerability) exacerbates the negative relationship between Local Council attributes (SA) and flood damage (FD).

Finally, hypotheses 2a and 2b indicate that powerful, legitimate and urgent Local Councils most probably face less economic flood damage as long as their regions have less exposure and vulnerability to flooding in terms of the socio-economic and transport infrastructure conditions.

10.2.5 The effect of Local Councils' attributes on their overall approach in FRM

Apart from the effect of stakeholder attributes on natural disaster economic damage, the effect of stakeholder attributes on natural disaster risk management activities has been investigated empirically in this study. **Hypothesis 3** states that "Stakeholder attributes have a direct effect on stakeholder (a) mitigation, (b) preparedness, (c) response and (d) recovery activities in flood risk management".

It is found that Local Council attributes (SA) have a statistically significant impact on (a) mitigation activities (MI) (path coefficient = +0.287, $p < 0.05$); (b) preparedness tasks (PR) (path coefficient = +0.388, $p < 0.01$); (c) response tasks (RS) (path coefficient = +0.465, $p < 0.01$); and (d) recovery tasks (RC) (path coefficient = +0.500, $p < 0.01$; see Section 8.4.2). **Hypothesis 3** is fully supported. The findings indicate that by increasing Local Councils' stakeholder attributes such as power, legitimacy and urgency, their natural disaster risk activities in mitigation, preparedness, response and recovery will increase accordingly.

The measurement indicators for the mitigation activities construct in this study included training and education on flood risk management (MI1), analysing risks to measure the potential areas for floods (MI2), zoning and land use controls to prevent building of roads in flood prone areas (MI3), providing timely and effective information related to flood disasters (MI8) and constructing flood retarding basins, barriers, culverts, levees and drainage (MI9).

The measurement indicators for the preparedness activities construct in this study covered recruiting personnel for flood emergency services (PR1), developing flood emergency management systems (PR2), maintaining flood emergency supplies, locating places for flood emergency operation centres (PR6), developing prediction and warning communications systems (PR7), and conducting flood risk management exercises to train personnel and test capabilities (PR8).

The measurement indicators for the response activities construct in this study were evacuating threatened populations and vehicles (RS2), operating shelters and providing mass care (RS3), documenting the lessons learnt and best practices in the response phase (RS5), implementing effective mobilisation and disbursement of resources (RS9), and providing information on flooded areas to the public (RS10).

The measurement indicators for the recovery activities construct in this study covered cleaning flood disaster debris (RC1), documenting the lessons learnt and best practices in the recovery phase (RC7), realigning roads and relocating bridges to lower flood hazard locations (RC9), and requiring RMS approval on road reconstruction projects (RC10).

Mitigation and preparedness activities were used to define a proactive approach, while response and recovery activities defined stakeholders' reactive approaches.

Hypothesis 4 states "mitigation activities have a direct effect on stakeholder proactive approach in flood risk management". It is found that Local Councils' mitigation activities (MI) have a statistically significant positive impact on their proactive approaches (PR) to flood risk management in the specific region (path coefficient = +0.559, $p < 0.01$; see Section 8.4.2). **Hypothesis 4** is fully supported.

Hypothesis 5 states "preparedness activities have a direct effect on stakeholder proactive approach in flood risk management". It is found that Local Councils' preparedness activities (PR) have a statistically significant positive impact on their proactive approaches (PR) to flood risk management in the specific region (path coefficient = +0.443, $p < 0.01$; see Section 8.4.2). **Hypothesis 5** is fully supported.

These findings indicate that increasing Local Councils' mitigation and preparedness activities means they most likely take a proactive approach to managing flood risks in transport infrastructure. The results indicate that the effect of mitigation activities (MI) is higher than the preparedness activities (PR) in predicting a proactive approach.

Hypothesis 6 states "response activities have a direct effect on stakeholder reactive approach in flood risk management". It is found that Local Councils' response activities (RS) have a statistically significant positive impact on their reactive approaches (RA) to flood risk management in a specific region (path coefficient = +0.560 , $p < 0.05$; see Section 8.4.2). **Hypothesis 6** is fully supported.

Hypothesis 7 states "recovery activities have a direct effect on stakeholder reactive approach in flood risk management". It is found that Local Councils' recovery activities (RC) have a statistically significant positive impact on their reactive approaches (RA) to flood risk management in transport infrastructure in a specific region (path coefficient = +0.413, $p < 0.10$; see Section 8.4.2). **Hypothesis 7** is only partially supported.

These findings indicate that response and recovery activities in natural disaster risk management are important factors in predicting a stakeholder's reactive approach.

Increasing Local Councils' response and recovery activities means they take a reactive approach to flood risk management in transport infrastructure. The results also indicate that the effect of response activities (RS) is higher than recovery activities (RC) in predicting a reactive approach.

The fifth objective in this research is to investigate the main factors predicting stakeholders' overall approach to natural disaster risk management in the built environment.

Hypothesis 8 states "a proactive approach has a direct effect on overall stakeholder approach in flood risk management". It is found that Local Councils' proactive approaches have a statistically significant positive effect on their overall approach to flood risk management in transport infrastructure across NSW (path coefficient = +0.170, $p < 0.10$; see Section 8.4.2). **Hypothesis 8** is partially supported.

Similarly, **Hypothesis 9** states "a reactive approach has a direct effect on stakeholder overall approach in flood risk management". It is found that Local Councils' reactive approaches have a statistically significant positive effect on their overall approach to flood risk management in transport infrastructure across NSW (path coefficient = +0.634, $p < 0.01$; see Section 8.4.2). **Hypothesis 9** is fully supported.

These findings indicate that proactive and reactive approaches to natural disaster risk management are important factors in predicting stakeholder overall approach, although it is interesting to note that a reactive approach is more important than a proactive approach at predicting the overall approach of a Local Council.

Finally, **Hypothesis 10** states "stakeholder attributes have a direct effect on stakeholder overall approach in flood risk management". It is found that Local Councils' attributes do not have a direct effect on their overall approach (path coefficient = +0.151, $p > 0.10$; see Section 8.4.2). Therefore, **Hypothesis 10** is not supported in this study because the indirect relationship between Local Councils' attributes and their overall approach is investigated through natural disaster risk management activities of mitigation, preparedness, response and recovery. For instance, Local Councils with greater stakeholder attributes have implemented more mitigation and preparedness activities, which means they have been more proactive and consequently they have had an effective overall approach in FRM.

10.3 Contribution to theory

The study provides three contributions to the theory in the context of natural disaster risk management. Firstly, the study provides empirical evidence to support the claim that stakeholder attributes to natural disaster damage and stakeholder proactive and reactive approaches are important because stakeholder theory amalgamates power, legitimacy and urgency to propose dynamism in a systematic identification of stakeholders' approaches (Olander, 2007).

Secondly, this study also contributes to knowledge by discovering the mediating role played by the socio-economic and transport infrastructure conditions on the relationship between Local Councils' stakeholder attributes and flood damage (see Section 8.4.3). These findings may suggest that stakeholder theory can no longer explain why Local Council areas have faced devastating flood damage despite the Local Councils having a high level of power, legitimacy and urgency in flood risk management. This phenomenon may be partly explained in relation to the socio-economic and transport infrastructure of a specific Local Council area in terms of its exposure and vulnerability to floods.

Finally, this study examined the role of stakeholder theory in explaining stakeholder proactive and reactive approaches. Powerful, legitimate and urgent stakeholders usually practise mitigation and preparedness activities in a proactive approach, but this study showed that Local Councils with a low level of power, legitimacy and urgency in their decision-making process practise more response and recovery tasks in a reactive approach. Olander (2007) argued that powerful and legitimate stakeholders have an obligation to proactively manage the decisions they have made. Moe and Pathranarakul (2006) proposed that mitigation and preparedness activities form a proactive approach, while response and recovery activities constitute a reactive approach. This study tested the Moe and Pathranarakul (2006) proposal by conducting an empirical study. This action could help contribute to the development of theory in future studies.

10.4 Contribution to flood risk management practice

The empirical findings of this study have implications for policy makers and stakeholders who are involved in natural disaster risk management in the built environment, particularly in flood risk management of transport infrastructure.

First, flood characteristics have a substantial impact on flood damage in Australian society, the economy and transport infrastructure, such that the severity, frequency and type of flood are the main contributing factors in determining flood losses. Australian transport infrastructure is very susceptible to major flooding and river floods, therefore stakeholders, in particular Local Councils, should take necessary measures in flood risk management for (i) controlling the zoning and use of land to prevent construction of roads and bridges in areas prone to river flooding; (ii) developing engineering design standards for resilient roads and bridges; and (iii) designing comprehensive proactive flood risk management procedures and mandates.

Second, it is very important to note that areas with better socio-economic conditions are not necessarily less vulnerable to floods; even wealthy locations can be severely impacted by floods, socially as well as economically. In general, the observed or modelled relationship between socio-economic exposure and vulnerability and flood damage indicated that a wealthier Local Council is better equipped to manage the consequences of floods because it can reduce the risk of impacts and manage them better when they occur. This is due to higher GRP per capita, higher income levels and lower population density. Furthermore, the findings indicate that Local Councils need to upgrade non-urban unsealed roads and bridges to become resilient sealed roads and bridges.

Third, stakeholders and policy makers who seek to manage flood risks should understand that careful management of stakeholder attributes, such as strengthening power, legitimacy and urgency, is essential for reducing floods' devastating impacts while also improving the stakeholder overall approach to floods. Power enables stakeholders to use social and political forces and benefit from flood risk management resources from their respective organisations. Legitimacy enables Local Councils to abide by beneficial or harmful risks pertinent to flood risk management because legitimacy is a generalised assumption that a Local Council will behave properly within socially constructed systems of norms, mandates and procedures. Finally, urgency enables Local Councils to coordinate immediate response and recovery activities in a reactive approach in flood risk management.

A fourth insight is that the relationship between stakeholder attributes and flood losses is mediated by socio-economic conditions. While prior research has examined the direct relationship of socio-economic conditions on natural disaster losses by focusing on exposure and vulnerability, it was found that the socio-economic condition mediates the relationship between Local Councils' attributes and flood damage. Local Councils' attributes enhance the socio-economic condition: their power, legitimacy and urgency help to reduce the exposure and vulnerability of a region to flood disasters. Thus, Local Councils' attributes have a direct role in reducing the impact of flood damage and an indirect impact via socio-economic conditions in mitigating the devastating consequences of floods. This finding will help policy makers, local government, and flood risk management organisations strengthen stakeholders' power, legitimacy and urgency in flood risk management.

Fifth, this study further demonstrates that the condition of transport infrastructure mediates the relationship between Local Councils' attributes and flood damage. This means that roads and bridges with a higher exposure and vulnerability exacerbate the negative relationship between Local Councils' attributes and flood damage because more non-urban unsealed roads and bridges are located in some local areas, which makes those regions more vulnerable to flood damage. It was found that some Local Councils did not respond to floods quickly, particularly in recovery activities such as post-flood reconstruction. Hence, Local Councils need to implement lean post-disaster reconstruction practices to reduce the reconstruction time. Finally, Local Councils' attributes help to reduce the impact of flooding providing that transport infrastructure is not exposed to floods and is less vulnerable.

Sixth, it was found that Local Councils' attributes have direct positive impacts on mitigation, preparedness, response and recovery practices. By increasing the power, legitimacy and urgency attributes of Local Councils, Local Councils would be better able to initiate mitigation activities in natural disaster risk reduction and preparedness, and implement response and recovery practices in natural disaster management more effectively. Local councils with stronger levels of stakeholder attributes had more proactive and less reactive approaches.

Finally, the new stakeholder disaster response index (SDRI) developed in this study was used to measure stakeholders' overall approach to flood disasters, such as the overall approach taken by Local Councils in managing flood impacts on transport infrastructure in NSW. Although Local Councils showed high level of overall approach to flood risk management, this was attributed to the high level of reactiveness but not proactiveness. Thus, Local Councils should practise more proactive approaches instead of reactive approaches to flood risk management. The proposed SDRI allows for a direct comparison of the different stakeholders such as Local Councils who were involved in the built environment planning, construction and maintenance tasks. The SDRI conveyed information about the various factors that comprised the overall approach of different stakeholders. It is a tool for high level natural disaster risk management and planning, and could help local government and policy makers in resource planning before, during and after flood disasters.

10.5 Limitations of this study

This study presented empirical evidence that contributes to knowledge about natural disaster risk management in the built environment, but these research findings must be interpreted within the limitations of this study, which is exploratory in nature. In particular, most of the measurement indicators for the constructs were borrowed from cross-discipline studies and then re-contextualised into natural disaster risk management in the built environment context. The limitations of this study are as follows.

First, some limitations were inevitable because the objects studied were Local Councils and government areas located in NSW, particularly Local Councils that have been exposed to flood disasters over the past 20 years. Hence, the scope of this study was limited to 75 out of 152 Local Councils in NSW. The restrictions on data collection were imposed not only to maintain their privacy and sensitivity, but also because not enough flood disaster data has been recorded over the past 20 years. Nevertheless, 36 usable survey responses, representing a 48% response rate, were collected, which was very rewarding considering the lack of such data in natural disaster risk management.

Second, in the primary data collection using the questionnaire, every question relating to the independent and dependent variables was assessed by a team of experts from each Local Council. It follows that the strength of the reported relationships between predictor and predicted constructs may be inflated by the common method variance, and the results may also be susceptible to social desirability bias such as informant bias and distorted self-reporting error. Some measures were taken to minimise any social desirability bias and common method variance problems: (i) questions relating to independent and dependent variables were structured such that the respondents were not aware of the proposed relationships; (ii) an assurance of anonymity for Local Councils in this study was provided; and (iii) Harman's one-factor test was used to assess the existence of a common method variance (see Section 6.4.5.5).

Third, the study developed and tested the structural models based on 12 key constructs to investigate the pivotal role of stakeholder attributes in determining (i) flood damage; (ii) stakeholder proactive and/or reactive approaches; and (iii) stakeholder overall approach. It was acknowledged that the models could be further refined by: (i) considering other natural disaster risk management constructs such as socio-political conditions and resilience, and (ii) exploring other possible relationships between the 12 constructs and the measurement indicators.

Fourth, the socio-economic and transport infrastructure conditions were measured by two other constructs in second level orders: exposure and vulnerability. Most previous studies have shown that the severity of the impact of disasters depends mainly on the level of vulnerability and exposure to these events (IPCC, 2012). However, based on a new perspective of natural disaster risk management, the role of resilience is important, and therefore considering resilience in this study could change the results. However, measuring the many aspects of the socio-economic and transport infrastructure conditions, particularly resilience, was problematic because it has been subjected to a wide range of interpretations (Bosher, 2008, Cutter et al., 2003).

Fifth, the measurement models developed in this study considered complex constructs that are intangible such as stakeholders' attributes and dynamic such as exposure and vulnerability and soft natural disaster risk management activities such as mitigation, preparedness, and response and recovery activities. Although the results showed an acceptable level of constructs that were reliable and valid, measurement indicators for the constructs should be updated continuously to improve our understanding of how to accomplish proactive approaches for the respective stakeholders in flood risk management in transport infrastructure.

Sixth, the form and strength of the proposed relationships between constructs were likely to differ in different states and territories and different countries. Although the findings of this study provided valuable insights into flood risk management in transport infrastructure, its application could have limitations in developing countries with socio-economic and transport infrastructure conditions that differ from Australia. The model developed was tested on the time horizon of 1992-2012, due to the difficulties encountered in collecting data on flood damage to transport infrastructure before 1992. Finally, this study did not consider other built environment types such as residential and commercial buildings, railways, airports and harbours.

10.6 Suggestions for future research

While this study provides important insights into research on flood risk management in transport infrastructure in general, and stakeholder attributes and approaches in particular, it also offers several promising avenues for further research.

First, power, legitimacy and urgency are changing variables and most likely vary among different stakeholders. By reviewing previous studies, it was found that the classification of stakeholders introduced by Freeman (1984) and later developed by Mitchell et al. (1997) has a significant role in determining why stakeholders have different approaches to natural disasters. Stakeholder theory could help policy makers classify stakeholders based on three distinct attributes of power, legitimacy and urgency. Mitchell et al. (1997) classified and defined stakeholders into seven main groups as: (i) dormant stakeholders; (ii) discretionary stakeholders; (iii) demanding stakeholders; (iv) dominant stakeholders; (v) dangerous stakeholders; (vi) dependent stakeholders; and (vii) definitive stakeholders. Although dormant stakeholders have little or no interaction with an organisation, they still possess the power to impose their wills on an organisation. Discretionary stakeholders hold the attributes of legitimacy, but they do not have enough power to affect an organisation's decisions. Demanding stakeholders possess urgent claims but have neither power nor legitimacy. Dominant stakeholders have enough power and legitimacy to direct an organisation's decision-making process, and coercive behaviours among dangerous stakeholders make them dangerous to an organisation. Dependent stakeholders depend upon others for the power necessary to conduct their decisions. Finally, definitive stakeholders have enough power and legitimacy to mandate their claims in an organisation (Mitchell et al., 1997). Hence, classifying stakeholders and studying the influence of the classification on stakeholders' proactive and reactive approaches to natural disaster risk management in the context of the built environment would be a rewarding research stream.

Second, this study was based on recorded data and perceptions from 36 Local Councils in NSW. Future research could replicate the principle features of this study with a larger sample of different stakeholders in different states, regions or countries. This study could also be applied to different types of built environments such as energy infrastructure, ports and airports, and residential and commercial buildings. Such comparative studies would be useful to test and refine the developed models, and to identify the differences in the constituents of natural disaster risk management in the built environment. This may offer a new insight for researchers and practitioners into the effects of natural disaster risk management and other specific factors on stakeholders' approaches to managing natural disasters.

Third, given that this study focused on the 1991-2012 period, another direction for future research would be to validate and extend the empirical findings by collecting and analysing longitudinal data over a longer timeframe. It is strongly believed that longitudinal studies may provide a better understanding of changes in stakeholders' approaches over time and influences on their overall approach to natural disasters. Indeed, the importance of longitudinal studies is supported by the increasing level of exposure and vulnerability. To analyse the longitudinal data in structured models, it is suggested that the Longitudinal-SEM technique could be used because it is novel and instrumental in the case of changing measures over time (McArdle, 2009).

Fourth, although this study has provided a useful insight into stakeholder attributes in natural disaster risk management, it would be useful to explore stakeholder attributes in more detail, such as how to identify and increase power, legitimacy and urgency in stakeholders with limited or minimum resources in order to realise the full potential advantages of stakeholder proactive and/or reactive approaches to natural disaster risks in the built environment context.

Fifth, considering the exploratory nature of this study, another possible direction for future research would be to explore how mitigation, preparedness, response and recovery activities interact between each other, and in turn determine stakeholders' proactive and/or reactive approaches and overall natural disaster approach in particular. For example, future studies could explore which constructs are indispensable to proactive natural disaster risk management, while considering different categories of stakeholders that in turn affect the overall approach to natural disasters. Furthermore, studies may explore the ratio between mitigation, preparedness, response and recovery activities that defines stakeholder proactive and/or reactive approaches.

Sixth, this study developed a structural model based on stakeholder attributes as the pivotal construct identified from the literature. Future studies could explore the effect of stakeholders' other organisational capabilities, such as management leadership and governance, and an organisation's capabilities in natural disaster risk management. Considering other constructs such as resilience, sustainability and adapting to climate change would also be a practical and rewarding avenue for researchers and practitioners.

Finally, refining and developing variations of the stakeholder disaster response index could be progressed in future work. The theoretical framework could be expanded to address fully the interactions between constructs and measurement indicators. The indicator selection process could be improved by exploring more indicator options. Federal, state and local governments might be interested in a country-specific SDRI, one that is evaluated only for cities within a specific state. An index that uses a country as the unit of study might be useful for some international organisations, and it would have the advantage of improved data availability compared to an index associated with cities or regions. Furthermore, insurance companies, reinsurance companies or financial institutions might be interested in developing an index to use as a means to determine a precise premium for natural disaster insurance. For instance, Australian transport infrastructure is not currently insured because of the difficulties in estimating the premium for each individual road and bridge.

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Appendix

A

Publications

Refereed Journal Articles

- **Mojtahedi, S.M.H.,** Oo, B.L. (2014). Stakeholders' Approaches to Disaster Risk Reduction in Built Environment. *Journal of Disaster Prevention and Management*, *23 (4), 356-369*.

- **Mojtahedi, S.M.H.,** Oo, B.L. (2014). Coastal Buildings and Infrastructure Flood Risk Analysis using Multi-Attribute Decision-Making. *Journal of Flood Risk Management*, (DOI: 10.1111/jfr3.12120).

- **Mojtahedi, S.M.H.,** Oo, B.L. (2014). Development of an Index to Measure Stakeholder Approaches toward Disasters in the Built Environment. *Procedia Economics and Finance*, 18, 95-102.

Conference Presentations and Publications

- **Mojtahedi, S.M.H.,** Oo, B.L., Flood Disaster Risk Management in NSW Transport Infrastructure: Councils' Approaches, *54th Floodplain Management Association Conference*, Deniliquin, Australia, May 2014

- **Mojtahedi, S.M.H.,** Oo, B.L., Theoretical Framework for Stakeholders' Disaster Response Index in the Built Environment, *CIB World Building Congress 2013*, Brisbane, Australia, May 2013

- **Mojtahedi, S.M.H.,** Oo, B.L., Stakeholders' approaches towards natural disasters in built environment: A theoretical framework, *28th Annual ARCOM Conference*, Edinburgh, Scotland, September 2012

- **Mojtahedi, S.M.H.,** Oo, B.L., Possibility of applying lean in post-disaster reconstruction: An evaluation analysis, *20th International Group for Lean Construction (IGLC)*, San Diego, USA, July 2012

- **Mojtahedi, S.M.H., Oo, B.L.,** Vulnerability of Australian Coastal Buildings and Infrastructure to Flood Disasters: socio-economic and built-environment approach, *AUBEA*, Sydney, Australia, 2012

- **Mojtahedi, S.M.H.,** Oo, B.L., Climate change disaster analysis: socio-economic and built-environment approach, *International Conference on Construction and Real Estate Management*, Guangzhou, China, 2011

Appendix

B

NSW Local Councils

#	Local Council
1	Albury City Council
2	Armidale Dumaresq Council
3	Ashfield Council
4	Auburn City Council
5	Ballina Shire Council
6	Balranald Shire Council
7	Bankstown City Council
8	Bathurst Regional Council
9	The Hills Shire Council (Baulkham Hills Shire)
10	Bega Valley Shire Council
11	Bellingen Shire Council
12	Berrigan Shire Council
13	Blacktown City Council
14	Bland Shire Council
15	Blayney Shire Council
16	Blue Mountains City Council
17	Bogan Shire Council
18	Bombala Council
19	Boorowa Council
20	The Council of the City of Botany Bay
21	Bourke Shire Council
22	Brewarrina Shire Council
23	Broken Hill City Council
24	Burwood Council
25	Byron Shire Council
26	Cabonne Council
27	Camden Council
28	Campbelltown City Council
29	City of Canada Bay Council
30	Canterbury City Council
31	Carrathool Shire Council
32	Central Darling Shire Council
33	Cessnock City Council
34	Clarence Valley Council
35	Cobar Shire Council
36	Coffs Harbour City Council
37	Conargo Shire Council
38	Coolamon Shire Council
39	Cooma-Monaro Shire Council

#	Local Council
40	Coonamble Shire Council
41	Cootamundra Shire Council
42	Corowa Shire Council
43	Cowra Shire Council
44	Deniliquin Council
45	Dubbo City Council
46	Dungog Shire Council
47	Eurobodalla Shire Council
48	Fairfield City Council
49	Forbes Shire Council
50	Gilgandra Shire Council
51	Glen Innes Severn Council
52	Gloucester Shire Council
53	Gosford City Council
54	Goulburn Mulwaree Council
55	Greater Taree City Council
56	Greater Hume Shire Council
57	Great Lakes Council
58	Griffith City Council
59	Gundagai Shire Council
60	Gunnedah Shire Council
61	Guyra Shire Council
62	Gwydir Shire Council
63	Harden Shire Council
64	Port Macquarie-Hastings Council
65	Hawkesbury City Council
66	Hay Shire Council
67	Holroyd City Council
68	The Council of the Shire of Hornsby
69	The Council of the Municipality of Hunters Hill
70	Hurstville City Council
71	Inverell Shire Council
72	Jerilderie Shire Council
73	Junee Shire Council
74	Kempsey Shire Council
75	The Council of the Municipality of Kiama
76	Kogarah City Council
77	Ku-ring-gai Council
78	Kyogle Council

#	Local Council
79	Lachlan Shire Council
80	Lake Macquarie City Council
81	Lane Cove Municipal Council
82	Leeton Shire Council
83	Leichhardt Municipal Council
84	Lismore City Council
85	City of Lithgow Council
86	Liverpool City Council
87	Liverpool Plains Shire Council
88	Lockhart Shire Council
89	Maitland City Council
90	Manly Council
91	Marrickville Council
92	Mid-Western Regional Council
93	Moree Plains Shire Council
94	Mosman Municipal Council
95	Murray Shire Council
96	Murrumbidgee Shire Council
97	Muswellbrook Shire Council
98	Nambucca Shire Council
99	Narrabri Shire Council
100	Narrandera Shire Council
101	Narromine Shire Council
102	Newcastle City Council
103	North Sydney Council
104	Oberon Council
105	Orange City Council
106	Palerang Council
107	Parkes Shire Council
108	Parramatta City Council
109	Penrith City Council
110	Pittwater Council
111	Port Stephens Council
112	Queanbeyan City Council
113	Randwick City Council
114	Richmond Valley Council
115	Rockdale City Council
116	Ryde City Council
117	Shellharbour City Council

#	Local Council
118	Shoalhaven City Council
119	Singleton Council
120	Snowy River Shire Council
121	Strathfield Municipal Council
122	Sutherland Shire Council
123	Council of the City of Sydney
124	Tamworth Regional Council
125	Temora Shire Council
126	Tenterfield Shire Council
127	Tumbarumba Shire Council
128	Tumut Shire Council
129	Tweed Shire Council
130	Upper Hunter Shire Council
131	Upper Lachlan Shire Council
132	Uralla Shire Council
133	Urana Shire Council
134	Wagga Wagga City Council
135	The Council of the Shire of Wakool
136	Walcha Council
137	Walgett Shire Council
138	Warren Shire Council
139	Warringah Council
140	Warrumbungle Shire Council
141	Waverley Council
142	Weddin Shire Council
143	Wellington Council
144	Wentworth Shire Council
145	Willoughby City Council
146	Wingecarribee Shire Council
147	Wollondilly Shire Council
148	Wollongong City Council
149	Woollahra Municipal Council
150	Wyong Shire Council
151	Yass Valley Council
152	Young Shire Council

Appendix

C

Survey Questionnaire

Part 1: General Information about Your Council

1.1 **Name of your council?** …………………………………………

1.2 **What was your council's total capital works budget for 2012-2013?** A$ ……………………………………

1.3 **How many staff are currently involved in floodplain management in your council?**

0 ☐ 1-2 ☐ 3-4 ☐ 5-6 ☐ 7-8 ☐ 9-10 ☐ ☐ Other, pls specify …………………

1.4 **How would you rate your council's priorities for floodplain risk and disaster management for the following facilities?**

	Low	⟷					*High*
Facility	1	2	3	4	5	6	7
Private residential buildings	☐	☐	☐	☐	☐	☐	☐
Private commercial/industrial buildings	☐	☐	☐	☐	☐	☐	☐
Public buildings	☐	☐	☐	☐	☐	☐	☐
Rural industries	☐	☐	☐	☐	☐	☐	☐
Public roads and bridges	☐	☐	☐	☐	☐	☐	☐
Utilities (water, sewerage, telecommunication, electricity etc.)	☐	☐	☐	☐	☐	☐	☐

1.5 **To what extent does your council allocate its budget to reflect above priorities to the following facilities?**

	Not at all		⟷			*To a great extent*	
Facility	1	2	3	4	5	6	7
Private residential buildings	☐	☐	☐	☐	☐	☐	☐
Private commercial/industrial buildings	☐	☐	☐	☐	☐	☐	☐
Public buildings	☐	☐	☐	☐	☐	☐	☐
Rural industries	☐	☐	☐	☐	☐	☐	☐
Public roads and bridges	☐	☐	☐	☐	☐	☐	☐
Utilities (water, sewerage, telecommunication, electricity etc.)	☐	☐	☐	☐	☐	☐	☐

Comment:

Part 2: Your council's Flood Information

2.1 **How often does your council encounter the following flood severity?**

	Never	⟷					*A lot*
Flood severity	1	2	3	4	5	6	7
Minor flooding	☐	☐	☐	☐	☐	☐	☐
Moderate flooding	☐	☐	☐	☐	☐	☐	☐
Major flooding	☐	☐	☐	☐	☐	☐	☐

Minor flooding: Causes inconvenience. Low-lying areas next to watercourses are inundated, which may require the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged.

Moderate flooding: The evacuation of some houses may be required. Main traffic routes may be covered. The area of inundation is substantial in rural areas requiring the removal of stock.

Major flooding: Extensive rural areas and/or urban areas are inundated. Properties are likely to be isolated and major traffic routes likely to be closed. Evacuation of people from flood affected areas may be required.

2.2 **How many major floods have occurred over the past twenty years (1992-2012) in your council?**

0 ☐ 1-4 ☐ 5-8 ☐ 9-12 ☐ 13-16 ☐ 17-20 ☐ 21-25 ☐ ☐ Other, pls specify …………………

2.3 **What is the average major flooding duration, in terms of days, in your council?**

1-2 ☐ 3-4 ☐ 5-7 ☐ 8-10 ☐ 11-13 ☐ 14-16 ☐ 17-20 ☐ ☐ Other, pls specify …………………

2.4 **How often does your council encounter the following flood types?**

	Never	←				→	*A lot*
Flood type	1	2	3	4	5	6	7
River flooding	☐	☐	☐	☐	☐	☐	☐
Ocean flooding	☐	☐	☐	☐	☐	☐	☐
Flash flooding	☐	☐	☐	☐	☐	☐	☐
Human cause of flooding (e.g., dam and pipeline failure)	☐	☐	☐	☐	☐	☐	☐

Part 3: Socio-economic Exposure of Flood in Your Council

3.1 **Has a floodplain risk management study been undertaken in your council?** YES ☐ NO ☐

(If your answer is YES, please answer questions 3.2 to 3.4)

3.2 **What percentage of your council' population is at risk to the flood disaster?**

<1% ☐ 1-10% ☐ 11-20% ☐ 21-30% ☐ 31-40% ☐ 41-50% ☐ >50% ☐ ☐ Other, pls specify ……………

3.3 **What percentage of your council's residential buildings are at risk to the flood disaster?**

<1% ☐ 1-10% ☐ 11-20% ☐ 21-30% ☐ 31-40% ☐ 41-50% ☐ >50% ☐ ☐ Other, pls specify ……………

3.4 **What is the estimated average annual damage cost (million A$) of flood disaster in your council?**

<1 ☐ 1-5 ☐ 6-10 ☐ 11-15 ☐ 16-20 ☐ 21-25 ☐ >25 ☐ ☐ Other, pls specify ……………

Part 4: Transport Infrastructure Exposure to Flood in Your Council

4.1 **How many kilometres of roads and bridges have been reconstructed over the past 20 years (1992-2012) due to flood disaster(s) in your council?**

<1 ☐ 1-10 ☐ 11-20 ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ ☐ Other, pls specify ……………

4.2 **What percentage of your council's roads and bridges are at risk to flood disaster?**

<1% ☐ 1-10% ☐ 11-20% ☐ 21-30% ☐ 31-40% ☐ 41-50% ☐ >50% ☐ ☐ Other, pls specify ……………

4.3 **What is the average response time (weeks) for road and bridge reconstruction after a flood disaster in your council?**

<1 ☐ 1-2 ☐ 2-3 ☐ 3-4 ☐ 4-5 ☐ 5-6 ☐ 6-7 ☐ ☐ Other, pls specify ……………

Part 5: Flood Disaster Management Phases

5.1 **What is the extent of your council's involvement in the following flood disaster management phases?**

	Low	←				→	*High*
Flood disaster management phases	*1*	*2*	*3*	*4*	*5*	*6*	*7*
P1: Prediction/warning	☐	☐	☐	☐	☐	☐	☐
P2: Emergency response (e.g. closure, clearing debris, etc)	☐	☐	☐	☐	☐	☐	☐
P3: Repair (short-term)	☐	☐	☐	☐	☐	☐	☐
P4: Reconstruction/rehabilitation (long-term)	☐	☐	☐	☐	☐	☐	☐

Part 6: Typical Transport Infrastructure Mitigation Activities against Flood

6.1 **To what extent does your council adopt the following mitigation activities?**

	Low	↔				*High*
Mitigation activities	1	2	3	4	5	6	7
MI1: Zoning and land use controls to prevent construction of roads in flood prone areas	☐	☐	☐	☐	☐	☐	☐
MI2: Analysing risks to measure the potential areas for floods	☐	☐	☐	☐	☐	☐	☐
MI3: Insuring roads and bridges to reduce the financial impact of floods	☐	☐	☐	☐	☐	☐	☐
MI4: Training and education on flood risk management	☐	☐	☐	☐	☐	☐	☐
MI5: Developing a master plan for flood disaster management	☐	☐	☐	☐	☐	☐	☐
MI6: Developing flood disaster information management systems among key stakeholders	☐	☐	☐	☐	☐	☐	☐
MI7: Providing timely and effective information related to flood disasters	☐	☐	☐	☐	☐	☐	☐
MI8: Developing engineering design standards for resilient roads and bridges	☐	☐	☐	☐	☐	☐	☐
MI9: Constructing flood retarding basins, barriers, culverts, levees, and drainage	☐	☐	☐	☐	☐	☐	☐

Part 7: Typical Transport Infrastructure Preparedness Activities against Flood

7.1 **To what extent does your council adopt the following preparedness activities?**

	Low	↔					*High*
Preparedness activities	1	2	3	4	5	6	7
PR1: Recruiting personnel for flood emergency services	☐	☐	☐	☐	☐	☐	☐
PR2: Developing flood emergency management systems	☐	☐	☐	☐	☐	☐	☐
PR3: Developing strategies for public education about flooding	☐	☐	☐	☐	☐	☐	☐
PR4: Budgeting for and acquiring flood emergency vehicles and equipment	☐	☐	☐	☐	☐	☐	☐
PR5: Maintaining flood emergency supplies	☐	☐	☐	☐	☐	☐	☐
PR6: Locating places for flood emergency operation centres	☐	☐	☐	☐	☐	☐	☐
PR7: Developing prediction and warning communications system	☐	☐	☐	☐	☐	☐	☐
PR8: Conducting flood disaster exercises to train personnel and test capabilities	☐	☐	☐	☐	☐	☐	☐
PR9: Using technology to identify and assess floods, and damaged roads and bridges	☐	☐	☐	☐	☐	☐	☐
PR10: Developing coordination and collaboration procedures with other stakeholders	☐	☐	☐	☐	☐	☐	☐

Part 8: Typical Transport Infrastructure Response Activities against Flood

8.1 **To what extent does your council adopt the following response activities?**

	Low	↔					*High*
Response activities	1	2	3	4	5	6	7
RS1: Activating the flood emergency operations plans and operations centres	☐	☐	☐	☐	☐	☐	☐
RS2: Evacuating threatened populations and vehicles	☐	☐	☐	☐	☐	☐	☐
RS3: Operating shelters and provision of mass care	☐	☐	☐	☐	☐	☐	☐
RS4: Estimating economic damages	☐	☐	☐	☐	☐	☐	☐
RS5: Establishing procedures to prevent and suppress secondary hazards	☐	☐	☐	☐	☐	☐	☐
RS6: Documenting lessons learned and best practices in response phase	☐	☐	☐	☐	☐	☐	☐
RS7: Implementing effective coordination with other stakeholders (e.g., RMS)	☐	☐	☐	☐	☐	☐	☐
RS8: Implementing effective logistics management (e.g., supply of equipment and services to flooded areas)	☐	☐	☐	☐	☐	☐	☐
RS9: Implementing effective mobilisation and disbursement of resources	☐	☐	☐	☐	☐	☐	☐
RS10: Providing information on flooded areas to public	☐	☐	☐	☐	☐	☐	☐

Part 9: Typical Transport Infrastructure Recovery Activities against Flood

9.1 **To what extent does your council adopt the following <u>recovery</u> activities?**

	Low	←→					*High*
Recovery activities	1	2	3	4	5	6	7
RC1: Cleaning flood disaster debris	☐	☐	☐	☐	☐	☐	☐
RC2: Considering sustainability in post-disaster reconstruction	☐	☐	☐	☐	☐	☐	☐
RC3: Shortening reconstruction time by applying quick mobilisation	☐	☐	☐	☐	☐	☐	☐
RC4: Selecting reconstruction contractors from a predetermined list of contractors	☐	☐	☐	☐	☐	☐	☐
RC5: Constructing temporary roads and bridges	☐	☐	☐	☐	☐	☐	☐
RC6: Implementing execution plan for post-disaster reconstruction	☐	☐	☐	☐	☐	☐	☐
RC7: Documenting lessons learned and best practices in recovery phase	☐	☐	☐	☐	☐	☐	☐
RC8: Applying lean construction in post-flood reconstruction (e.g. waste minimisation, get it right first time)	☐	☐	☐	☐	☐	☐	☐
RC9: Realigning roads and relocating bridges to lower flood hazard locations	☐	☐	☐	☐	☐	☐	☐
RC10: Acquiring stakeholders' approval (e.g., RMS) on transport infrastructure reconstruction	☐	☐	☐	☐	☐	☐	☐

Part 10: Council's Approaches against Flood in Transport Infrastructure

10.1 **To what extent does your council adopt the following approaches for managing flood disasters?**

	Low	←→					*High*
Flood disaster approaches	1	2	3	4	5	6	7
DR1: Proactive approach	☐	☐	☐	☐	☐	☐	☐
DR2: Reactive approach	☐	☐	☐	☐	☐	☐	☐

Proactive approach: Activities that are planned and conducted before a flood disaster with the aim of mitigation and preparedness.

Reactive approach: Activities of responses and recovery, which are conducted during and after a flood disaster.

10.2 **How would you rate the level of responsiveness of your council to flood disasters in transport infrastructure?**

Low	←→					*High*
1	2	3	4	5	6	7
☐	☐	☐	☐	☐	☐	☐

10.3 **To what extent does your council have the following attributes for flood disaster management?**

	Before flood							*After flood*						
	Low	←→					*High*	*Low*	←→					*High*
Attributes	1	2	3	4	5	6	7	1	2	3	4	5	6	7
PAT1: Power	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PAT2: Legitimacy	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PAT3: Urgency	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Power allows council to carry out its own will despite resistance to managing flood disasters. The power of council may arise from its ability to mobilise social and political forces as well as its ability to withdraw resources from the organisation in disaster situations.

Legitimacy gives opportunity to council to identify some sort of beneficial or harmful risk pertinent to its organisation in managing flood disasters.

Urgency is the degree to which council is able to call for immediate attention in managing flood disasters.

Part 11: Background Information (Optional)

1- What is your job title? ……………

2- Number of years you have been practicing in disaster management? ……………

3- It would be appreciated if you could kindly recommend us for further studies about disaster management in the built environment.

1. –
2. –
3. –
4. –
5. –

Thank you very much for your participation!