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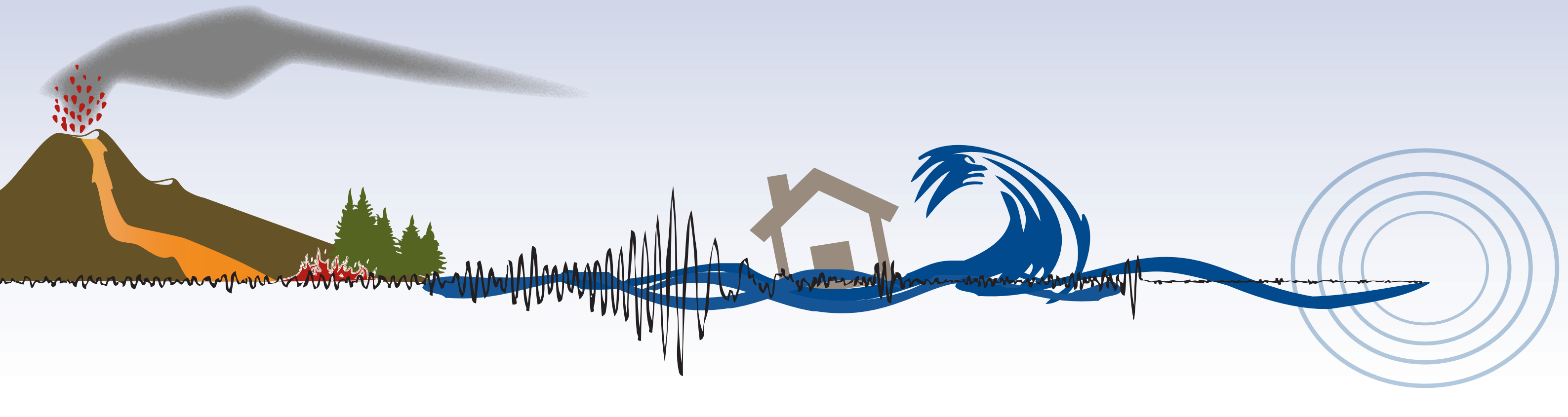

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The low-likelihood challenge: Risk perception and the use of risk modelling for destructive tsunami policy development in New Zealand local government

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Abstract

The Hikurangi Subduction Interface, located 50 to 100 kilometres off the east coast of New Zealand's North Island, has the potential to generate the most destructive tsunami New Zealand is likely to encounter over a 1000-year timeframe. Yet, while such a severe risk hangs over the area, the number and detail of tsunami risk management policies do not match this risk. This article presents research on the influence of low-likelihood on perceptions for developing destructive tsunami risk management policy. It explores the thoughts and opinions of natural hazard risk practitioners in regards to tsunami risk management policy, along with the use of risk modelling (RiskScape) for tsunami policy development. Results highlight risk perceptions associated with the low-likelihood of a destructive tsunami, including such an event being perceived as "not happening here" and the development of tsunami risk management policy perceived as sitting in the "too hard basket". We discuss how these risk perceptions could be influenced by cognitive biases due to their seemingly illogical nature and how risk modelling can be used as a communication tool to help overcome these perception challenges. We conclude with some recommendations for how we could better match tsunami risk management policy with tsunami risk through further developing local government provisions for risk management, the influence of cognitive biases, risk modelling, and policy flexibility.

Keywords: *Tsunami, risk perception, policy development, risk modelling, cognitive bias, local government*

The Hikurangi Subduction Interface is capable of producing an all-of-interface megathrust earthquake ranging in magnitude from M7.5 – 9.0 (Power, 2013). Figure 1 sets out the location of the Hikurangi Subduction Interface off the east coast of New Zealand's North Island, presenting how a tsunami generated within the interface could affect 200-300 kilometres of the nearby coast, potentially impacting on the Gisborne, Hawke's Bay, and Wellington regions, along with a small amount of the Manawatu region (excluded from this study). Table 1 provides the modelled median tsunami wave heights and direct losses, derived using the RiskScape model (King & Bell, 2005; King & Bell, 2009), that each of these regions could expect from a M9.0 rupture along the length of the Hikurangi Subduction Interface.

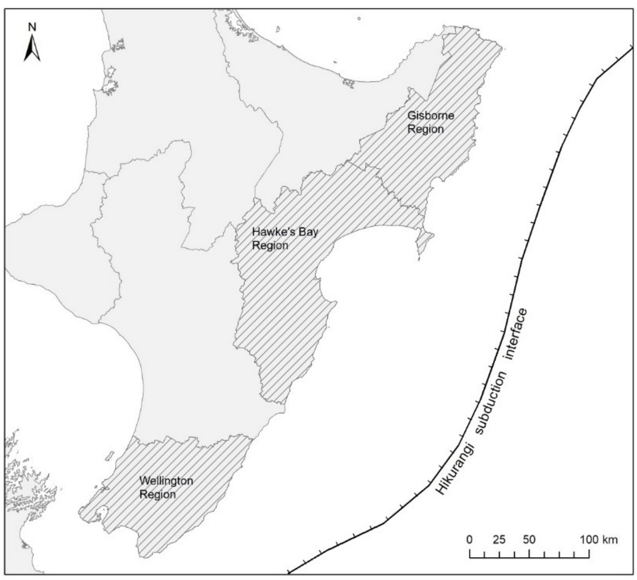

Figure 1. The Hikurangi Subduction Interface and the Gisborne, Hawke's Bay, and Wellington regions.

Table 1.
Modelled median wave height and direct losses from M9.0 rupture on the Hikurangi subduction interface.

Location	Wave height (m)	Deaths	Injuries	Economic loss ($m)
Wellington	7.4	2198	1792	5,556
Hawke's Bay	8.4	4895	3752	5,211
Gisborne	8.0	982	829	1,734

Note. Table adapted from Gill, Clough, and Webb (2015) and Horspool, Cousins, and Power (2015).

With such severe consequences impacting these regions, it is understandable that tsunami have been identified as potentially New Zealand's most severe natural hazard (Department of the Prime Minister and Cabinet, 2007). However, considering the comparatively high risk from tsunami, New Zealand spends relatively little on mitigation. This is evidenced in Table 2, which presents public spending on tsunami risk management compared to other risks.

Table 2.
Public spending on tsunami risk management compared to other risks.

Event	Government spending 2008/9, $m	Average annual individual fatality risk/100,000	Spending per unit of risk $m
Assaults	$122	1.3	$93.85
Workplace accidents	$85	4.1	$20.73
Vehicle accidents	$854	9.2	$92.83
Tsunami	$2.55	2.8	$0.910

Note. Table from Gill et al. (2015; p.4).

Our capacity to withstand and recover from the impacts of destructive tsunami is achieved through a combination of scientific research to build our understanding of the hazard and local government policy which enables the risk to be assessed, communicated, and managed within our communities. However, natural hazard risk management in New Zealand local government is challenged by a complex legislative environment, lack of data, misconceptions and biases, limited resources, and the differing requirements of numerous actors (Crawford, Crowley, Potter, Saunders, & Johnston, 2018; Glavovic, Saunders, & Becker, 2010; Kilvington & Saunders, 2016; Saunders, Grace, & Beban, 2014). While the devastating impacts of recent tsunami in the Indian Ocean, 2004, Samoa, 2009, Japan, 2011, and Indonesia, 2018, have raised awareness and spurred tsunami policy development (Johnston et al., 2014; King, 2015), local government has been slow to integrate such lessons into natural hazard risk management policy (Basher, 2016; Lawrence, 2018; Local Government New Zealand, 2014).

This research aims to understand how tsunami risk management policy and procedure relates to tsunami risk in Gisborne, Hawke's Bay, and Wellington. It explores practitioners' perceptions of low-likelihood, destructive tsunami, their views on tsunami risk management policy, and the use of risk modelling as a communication tool for tsunami risk management. The rest of the introduction describes the complex legislative structure for how tsunami risk management is achieved in New Zealand and introduces risk modelling as a communication tool for tsunami risk management. The method section explains the mixed method approach of qualitative interviews and document analysis used to gain a deeper understanding of practitioners' views on tsunami risk management policy distribution and how tsunami policy is corroborated by practitioners' perceptions of tsunami risk. The findings presented in the results section highlight a paucity of tsunami risk management policy across the study area and sets out three key themes that emerged from analysis of the qualitative interviews: disassociation from tsunami risk, reduced motivation for developing policy, and risk modelling challenges. Following these results, we discuss how cognitive biases associated with low-likelihoods influence tsunami risk perceptions and challenge motivation for tsunami policy development. We propose that risk modelling is a valuable tool that can help address this challenge. In the discussion section we also provide recommendations for how risk modelling can work in combination with risk management, cognitive debiasing techniques, and long-term planning to overcome the low-likelihood challenge for tsunami risk management policy development in New Zealand local government. However, we argue that before this is achieved, fundamental challenges for how natural hazard risk is governed need to be addressed.

Natural Hazard Risk Management, Tsunami Risk Management, and Risk Modelling in New Zealand

Natural hazard risk management. We view risk as "uncertainty about and severity of the consequences of an activity with respect to something that humans value" (Aven, Renn, & Rosa, 2011, p. 1074). Risk is managed through arrangements for designing, implementing, monitoring, reviewing, and continually improving activities for its control (International Organization for Standardization, 2009). When applied to natural hazard management in New Zealand, risk management sits within a complex, interrelated system of devolved legislation (Local Government New Zealand, 2014). Figure 2 sets out the relationship across New Zealand legislation for the management of natural hazards.

Within this breadth of legislation, four key statutes provide a framework of responsibilities for how natural hazard risk management is applied:

1) The Local Government Act (LGA) – A local authority must manage risks to infrastructure from natural hazards (Section 101B (3)(e); New Zealand Government, 2002b).
2) The Resource Management Act (RMA) – A local authority shall manage risks for the use, development, and protection of resources (Section 6 (h); New Zealand Government, 1991).
3) The Civil Defence Emergency Management Act (CDEMA) – A local authority shall encourage and enable communities to achieve acceptable levels of risk (Section 3 (b); New Zealand Government, 2002a).
4) The Building Act (BA) – A local authority must manage consent for construction or alteration of buildings subject to natural hazards (Section 71; New Zealand Government, 2004).

While intending to work seamlessly together, each piece of legislation is applied through separate local government functions which often have limited integration and effectiveness for natural hazard management. This is reflected in Saunders, Grace, Beban, and Johnston's (2015) review of local government natural hazards management, where they note that collaborations across different natural hazard practitioner roles are not commonly encouraged for sharing information, good practice, and understanding of roles.

Tsunami risk management. Tsunami risk management sits within this challenging policy environment. While it would ideally be a joint responsibility across the local government land use planning, emergency management, and building control functions, it has historically sat within emergency management for application (Johnston et al., 2008; Johnston et al., 2014; King, 2015; Saunders, Prasetya, & Leonard, 2011; Webb, 2005). Webb (2005) explains that while all tsunami risk can be managed through land use planning arrangements, "due to a public desire to use coastal areas and the relatively long return period of damaging tsunami, regulations and land use planning are in reality unlikely to provide effective mitigation for the entire risk" (Webb, 2005, p. 64). As such, the residual risk is managed through a readiness and response approach of public education, warning, and evacuation

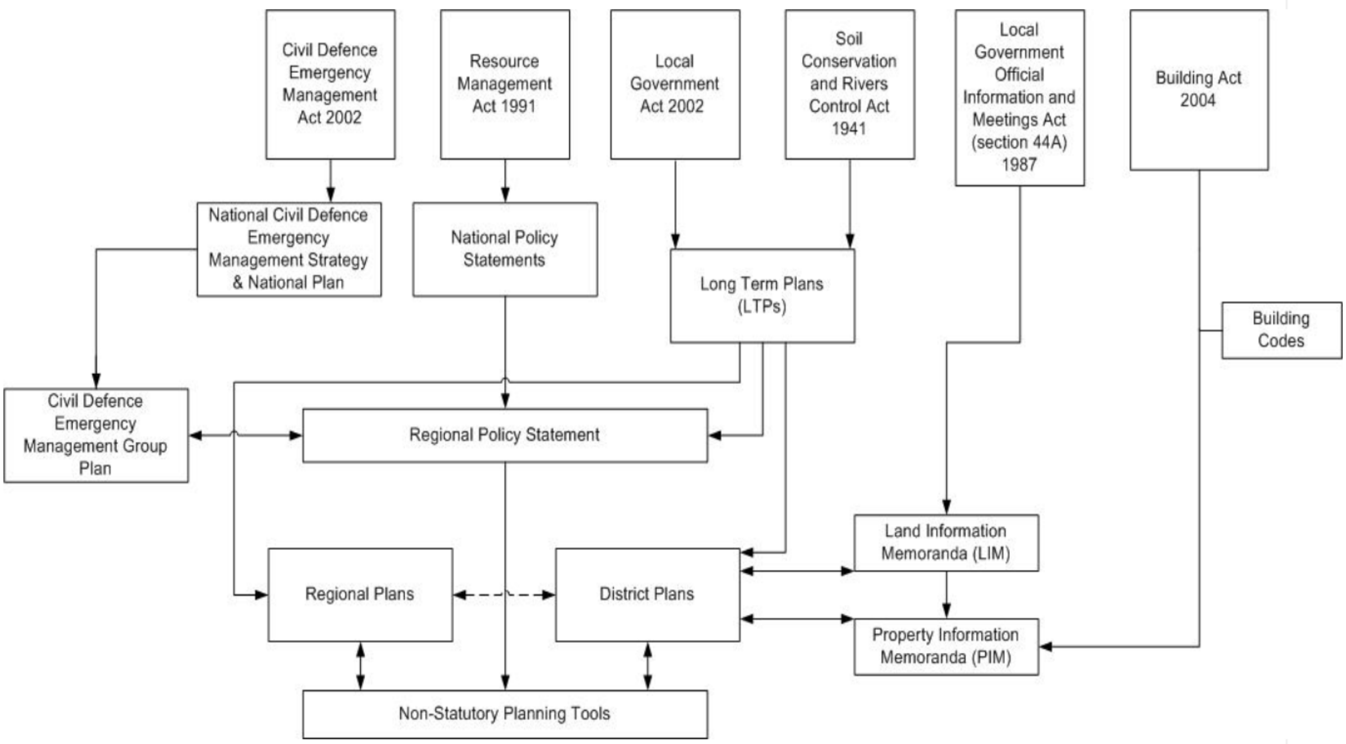

Figure 2. Relationships between legislation for the management of natural hazards (The Resource Management Act Quality Planning Resource, n.d.).

measures, which are commonly regarded as emergency management functions.

However, over time the growing recognition of risk reduction for natural hazard management has called for greater involvement of land use planning and building control (Beban & Saunders 2013; Glavovic et al., 2010; Saunders & Beban, 2012; Saunders et al., 2015; Saunders, Forsyth, Johnston, & Becker, 2007; Saunders et al., 2011). This is reflected through specific reference to tsunami risk management in Policy 25 of The New Zealand Coastal Policy Statement (Department of Conservation, 2010), and also with the recent amendments to Section 6 of the Resource Management Act (New Zealand Government, 1991), where the management of "significant risks" from natural hazards is now a matter of national importance.

Natural hazard risk modelling: RiskScape. One avenue for assessing and communicating natural hazard risk is through the use of risk modelling. Quantitative risk modelling combines deterministic or probabilistic hazard models with data detailing the type and location of assets that are exposed to the hazard, along with models that assess the vulnerability of that asset to the hazard. The result is an assessment of consequence, most often depicted as economic loss, but that can also be depicted through infrastructure or societal impacts dependent on the risk management objectives. Risk modelling then acts as an assessment and communication tool that presents the risk information in a way that assists decision makers and communities to better understand their risk and make more informed risk management decisions (Global Facility for Disaster Reduction and Recovery, 2014a; Global Facility for Disaster Reduction and Recovery, 2014b; Global Facility for Disaster Reduction and Recovery, 2014c; Pondard & Daly, 2011).

The risk modelling software used in this research is *RiskScape*[1]. RiskScape has been developed through scientific collaboration between NIWA and GNS Science[2] to meet the demand for a natural hazard impact and loss modelling tool for New Zealand conditions (King & Bell, 2009). RiskScape allows its users to assess tsunami-related risk through existing scenarios saved within the application, or to upload their own hazard scenario. Users then apply the hazard scenario to an asset database dependent on the asset for which they are assessing risk. The RiskScape asset database holds data on buildings but also includes data for electricity cables, roads, and reticulated water services. The hazard and asset data are then combined with a fragility function which calculates the probability or severity of damage for the asset given the intensity of the specific hazard. The output is an estimated loss or consequence as illustrated in Figure 3.

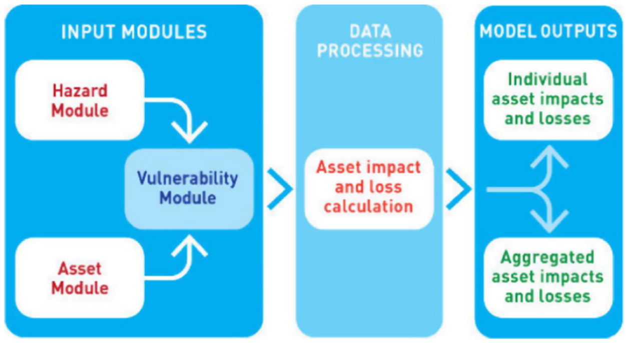

Figure 3. RiskScape modelling framework for how natural hazard and asset modules are combined with a vulnerability module to produce quantitative risk information. From Crawford, Crowley, et al. (2018).

The results from RiskScape modelling are presented in spreadsheet or map form, as shown in Figure 4, and can be aggregated. The results can also be exported into geographic information system (GIS) applications for further application and integration with other risk assessment and decision-making or planning tools.

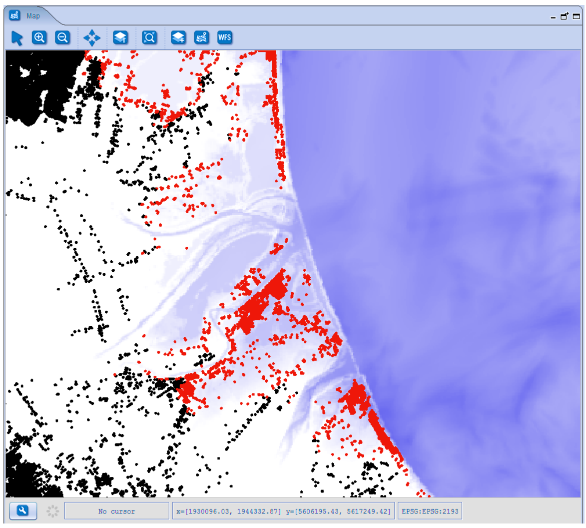

Figure 4. RiskScape modelling results shown in map form. The map shows a scenario of individual building exposure to tsunami inundation in Napier City following a M 8.9 earthquake generated in the Hikurangi Subduction Interface. The blue colours (located amongst the dots) represent the extent of tsunami inundation, the red dots represent buildings that have been impacted by tsunami inundation, and the black dots represent buildings that have not been impacted. (R. Paulik, personal communication, June 06, 2018).

1 https://www.riskscape.org.nz/
2 The National Institute of Water and Atmosphere (NIWA) and the Institute of Geological and Nuclear Science (GNS Science) are New Zealand Crown Research Institutes charged with promoting the transfer and dissemination of research, science, and technology.

Methods

Risk perception is subjective, involving people's feelings, beliefs, attitudes, and judgements about the harm and loss associated with the consequences of an event (Aven et al., 2011; Barnes, 2001; Mileti & O'Brien, 1992; Slovic, 1987). However, it is also framed by culture and society (Doyle, McClure, Paton, & Johnston, 2014), with our risk perception contextualised and informed by local values and norms and dependent on disciplinary frameworks (World Social Science Fellows on Risk Interpretation and Action, 2014). As such, this research is based on a social constructionist epistemology, where our meaning of reality is informed by creating models of the social world and sharing these models through communication (Young & Collin, 2004). The research follows a qualitative methodology, used because it examines the "why" and "how" of decision making, seeking to understand the depth and variety of people's feelings and perspectives, rather than quantities and distributions as studied through a quantitative methodology (Creswell, 2007).

Two methods were used in this research. Document analysis was used to gain an overview of the extent of tsunami risk-based policy, which was then corroborated with qualitative interviews. Qualitative interviews were used to gain a better understanding of subjective views towards tsunami risk management policy and of risk modelling as a communication tool. Each method is described in the following sections.

Document Analysis

Document analysis is a systematic procedure for reviewing or evaluating documents. When used qualitatively, this method requires data be examined and interpreted in order to elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009). Document analysis has been used in this research to gain an overview of the distributions or patterns of local government tsunami risk management policy to corroborate the findings from the qualitative interviews. It does not seek to analyse the strength or significance of the policy.

New Zealand national legislation, local strategy, and planning policy documents were analysed for their provisions relating to natural hazards, risk management, and tsunami. Documents selected were required to be operational at the time of analysis and refer to natural hazard risk management within the Wellington, Hawke's Bay, or Gisborne regions. It is recognised that national tsunami warning arrangements are relatively well advanced, but wider risk management documentation is either still needed or in development.

Fifty-eight national and local policy documents were identified via a combination of internet searches and documents provided by participants. Examples include The New Zealand Coastal Policy Statement (Department of Conservation, 2010), The Hawke's Bay Regional Council - Long Term Plan 2012 – 2022 (Hawke's Bay Regional Council, 2012), and the City of Lower Hutt District Plan (Hutt City, 2016). A full list of the documents is given in the Appendix.

The documents were analysed using deductive analysis in accordance with predetermined criteria (Stemler, 2001). Previous analyses of New Zealand local government natural hazard policy were considered in determining criteria (Becker & Johnston, 2000; Glavovic et al, 2010; Kilvington & Saunders, 2016; Lawrence & Haasnoot, 2017; Saunders & Beban, 2012), with the criteria for this study primarily based on Saunders et al.'s (2015) evaluation of the use of land use and emergency management policy documents for natural hazards in New Zealand local government. In their study, a plan was considered to be best practice based on eight indicators including hazard identification, the inclusion of hazard specific rules, and the use of risk management language (e.g., consequence and likelihood). This study adapted Saunders et al's. (2015) best practice indicators to explore four objectives: the distribution pattern for natural hazards policies in general, the distribution pattern for tsunami policies specifically, the distribution pattern for risk-based policies in general, and the distribution pattern for tsunami risk-based policies specifically. Table 3 sets out these four objectives along with the predetermined criteria which inform each of them.

Limitations for this method are that relevant policy documents or references within the documents may have been missed from the analysis. Considering 58 documents were analysed covering central government legislation and local government strategy and planning policy, we are confident that our data reached the point of saturation (Patton, 2015), and that any missed documents or references would not have significantly altered the patterns identified from the analysis.

Qualitative Interviews

Exchange of dialogue, fluidly structured, and covering certain issues are common features of the qualitative

Table 3.
Document analysis criteria with objectives.

Criteria	Objectives
The document analysed:	
• has a section on natural hazards • has a definition for natural hazard • includes natural hazard policies	Explores patterns generally associated with natural hazard management policies.
• lists tsunami as a natural hazard • refers to tsunami as potentially affecting that district/region • includes tsunami policies • refers to tsunami inundation maps	Explores patterns specifically focussing on tsunami hazard management policies.
• has a definition of risk • sets out a risk based management model • includes risk based policies • links to risk management policies in other documents	Explores patterns generally associated with risk based policies.
• refers to tsunami risk – e.g. likelihood and consequences of certain magnitude events • includes tsunami risk based policies	Explores patterns specifically focussing on tsunami risk based policies.

interview, where meanings and understandings are co-produced through interaction (Edwards & Holland, 2013). Interview participants were identified and invited by a *gatekeeper* within each region who was able to transfer external information to colleagues within their organisation (Macdonald & Williams, 1993). The gatekeepers were all council staff who worked with the participants of this research. The gatekeepers were known to the lead author of this article, who had worked with them in previous, related research (Crawford, Crowley, et al., 2018; Crawford, Saunders, Doyle, & Johnston, 2018).

Twenty-three participants were interviewed across the Gisborne, Hawke's Bay, and Wellington regions, whose roles included the following functions:

- policy making;
- environmental science;
- land use planning;
- building control;
- emergency management;
- asset management;
- engineering; and
- hazard modelling.

The qualitative interview guide used in the interviews is presented below. The guide provides a semi-structured approach to the interview, to ensure that the same general areas of information are collected from each interviewee. "This provides more focus than the conversational approach, but still allows a degree of freedom and adaptability in getting information from the interviewee" (McNamara, 2009).

Objective 1: Encourage participants to express their thoughts, feelings and experiences on natural hazard risk management policy in NZ local government, especially what they think are the barriers for its development, and what the enablers are. Start by asking how natural hazard policy works in that Council. Capture discussion on:

- Its level of importance;
- How often policy is developed;
- How policy is applied;
- The local governance environment/mandate for policy development;
- RMA amendments to include risk focus;
- Risk based policy;
- Tsunami risk management; and
- Links across council for tsunami risk management.

Objective 2: Review participants' views on the use of risk modelling software (RiskScape), compared to without the use of risk modelling. Try to elicit thoughts and feelings on whether they think risk modelling can better communicate tsunami risk to influence decision maker perceptions, and willingness to engage in improved policy and procedure. Capture discussion on:

- Whether risk modelling changes the way participants perceive this risk;
- Whether risk modelling better communicates the risk, why and why not;
- Whether participants think risk modelling is better at creating motivation for developing more risk informed policy and procedure;
- What participants think are the barriers for the communication, perception, and motivation for this risk; and
- What participants think are the enablers for the communication, perception, and motivation for this risk.

Each interview lasted between one and one and a half hours with data captured through recordings which were transcribed and thematically analysed; thematic analysis "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex account of data" (Braun & Clarke, 2006. p.5). Themes were identified using an inductive *bottom-up* approach, where the themes emerge from the data itself (Patton, 2015). The NVivo software package (Bazeley & Jackson, 2013) was used to assist with the analysis, categorisation, and organisation of the data into main themes with contributing subthemes.

Limitations for this method are that participants may feel uncomfortable revealing certain information, or the interviews may not capture the intended data. These were respectively managed via participants being assured that all data collected was anonymous and pooled across locations in the study area, and through the guidance of the qualitative interview guide to capture the intended data.

It is important to acknowledge the lead author's own positionality, having worked in risk and local government emergency management, and how this background has influenced his interpretation of the interview data (Landström et al., 2011; Whitman, Pain, & Milledge, 2015). When conducting the interviews, the lead author automatically adopted the position of *participant as observer* (Bryman, 2008) where he interacted with the participants and expressed his own views from experiences working in local government natural hazard risk management, while participants were also aware of his status as a researcher.

Results

The results section is separated into two parts reflecting the two different research methods used. The first section gives results for the policy document analysis, highlighting a paucity in local government risk-based tsunami policy. The second section (including its subsections) gives results from the qualitative interview analysis, identifying three emergent themes: "Disassociation and inability to internalise tsunami risk", "Reduced motivation for developing destructive tsunami policy", and "Risk modelling is valued but challenging".

Document Analysis

Fifty-eight central and local government policy documents across the Wellington, Hawke's Bay, and Gisborne regions were analysed for their policies relating to natural hazard, tsunami, and tsunami risk management. Our findings have been grouped in accordance with the four objectives of the document analysis as presented in Table 3: natural hazard policy distribution, tsunami policy distribution, risk based policy distribution, and tsunami risk-based policy distribution. Table 4 presents an overview of the distribution of natural hazard policy and risk-based policy across the documents, both in general and specifically.

Table 4.
Distribution for natural hazard, tsunami, and risk-based policy across central and local government policy documents.

Objectives & Criteria		Central Government	Local Government	
			Regional / Unitary Council	District Council
		(13 documents reviewed)	(17 documents reviewed)	(28 documents reviewed)
Natural hazard management policies	Has a section on natural hazards	1	12	2
	Has a definition for natural hazard	5	10	5
	Includes natural hazard policies	9	13	14
Tsunami hazard management policies	Lists tsunami as a natural hazard	5	14	16
	Refers to tsunami as potentially affecting that district/region	0	15	17
	Includes tsunami policies	2	5	2
	Refers to tsunami inundation maps	0	2	0
Risk-based policies	Has a definition of risk	2	6	1
	Sets out a risk based management model	2	8	4
	Includes risk based policies	9	12	17
	Links to risk management policies in other documents	3	3	2
Tsunami risk-based policies	Refers to likelihood and consequence for certain magnitude tsunami events	0	1	0
	Includes tsunami risk based policies	1	1	1

Table 4 shows that natural hazard management is important for local government. This was stated by participants in the interviews and is reflected by the wide distribution of policy referring to general natural hazard management across long-term strategic plans, environmental policy statements, resource management plans, emergency management plans, and plans with specific focus areas such as coastal hazard management. The majority of resource management and emergency management plans for regional councils contain natural hazard-focussed sections, where long-term strategic plans tend not to specifically focus on natural hazards but refer to their general management throughout the document. While the documents contain policy specific to certain natural hazards, the majority of policies within and across the different document types take an *all-hazards* approach, where policies are designed to manage a generic range of hazards. Of the specific hazard policies, the majority focus on more frequent, experienced, and escalating hazards such as flooding, erosion, and sea level rise. These findings are similar to those presented by Saunders et al. (2015).

At the central government legislative level, tsunami is listed as a hazard or emergency in the Resource Management Act (New Zealand Government, 1991), the Civil Defence Emergency Management Act (New Zealand Government, 2002a), the Local Government Act (New Zealand Government, 2002b), the New Zealand Coastal Policy Statement (Department of Conservation, 2010), and the National Tsunami Advisory and Warning Supporting Plan (Ministry of Civil Defence and Emergency Management, 2017). Interestingly, and somewhat problematically, is how tsunami is not listed as a natural hazard within the Building Act (New Zealand Government, 2004), which instead refers to the less specific description of *inundation*. At the local government level, tsunami is recognised as a hazard across the majority of the policy documents analysed. While many of the documents state that tsunami could significantly impact their region, many rate other hazards such as earthquake or flooding as posing a greater risk. Of the 45 local government policy documents analysed, only seven documents contain policy addressing tsunami management. Of those seven documents, the majority of policy is general, for example "contingency plans shall be implemented for emergency events such as… tsunami" (Wairoa District Council, 2015, p. 48).

The only central government documents that define risk are the Civil Defence Emergency Management Act (New Zealand Government, 2002a) and the National Civil Defence Emergency Management Strategy (Department of Internal Affairs, 2008), defining it as the likelihood and consequences of a hazard. This scarcity of risk definition is reflected in local government documents, with only a few defining natural hazard risk as a combination of likelihood and consequence of a certain magnitude hazard. Of these documents, the majority are emergency management plans and coastal hazard strategies. When referring to risk, most local government policy documents are high-level and all-hazard, calling for the identification, assessment, communication, avoidance, and reduction of risks in general. While the documents contain policy requiring the management of risks, there is a paucity of policy setting out frameworks for how this is achieved. Of the documents that do contain risk management frameworks, the majority focus on frameworks for asset management, followed by water quality, hazardous substances, and contaminated site management. Only three of these documents refer to natural hazard risk management; these are contained in either emergency management or coastal hazard management plans.

Of the 58 national and local policy documents that were analysed, three contain specific tsunami risk-based policy. The New Zealand Coastal Policy Statement (Department of Conservation, 2010) does so at the central government level, with The Tairawhiti Civil Defence Emergency Management Group Plan 2016 – 2021 (Gisborne District Council, 2016) at the regional council level (as a unitary authority[3]) and The City of Lower Hutt District Plan (Hutt City, 2016) at the district council level. Whilst some further documents contain risk-based policies specific to coastal hazards, they are generic and do not specifically relate to tsunami risk management.

Qualitative Interview Analysis

Disassociation and inability to internalise tsunami risk. Interview participants commonly used return periods to describe tsunami likelihood, ranging from 500 to 3000 years. They stated that these numbers were unrealistic, or not something they would probably see in their lifetime. In general, participants conveyed that the likelihood of destructive tsunami was so remote that its risk was hard to understand:

> It's not been in my lifetime, why would I worry about it? Therefore, when you start getting shown maps it's

3 A unitary authority is a territorial authority that has the responsibilities, duties, and powers of a regional council.

> like the whole area's new and it's like...It's not real. (Participant).

While participants logically understood that a destructive tsunami could impact at any time and that the consequences would be severe, they had difficulty internalising what the consequences would mean for them. Instead, participants chose to disassociate themselves from the risk, preferring to assure themselves that a destructive tsunami was very rare and that a tsunami "won't happen here":

> I think ever since the Indonesian event in 2004, and then that big follow up by what happened in Japan in 2011, there's a real fear and perception out there that if we get a decent tsunami it's going to create devastation, huge devastation, but at the same time there is this, just this general thing "oh well but what is the chance of that happening, it won't happen here" sort of thing. (Participant).

Common across participant discussions was how important the coastal area was for their community to use and enjoy. Many participants lived in coastal areas and stated that, despite awareness of tsunami risk, living on the coast was preferable to living outside of a tsunami inundation area:

> I live at Westshore, a big tsunami zone and I'm not going to move. I like living on the coast. It's worth my while, I think, to have that enjoyment as a trade-off for the risk that I think about. (Participant).

As such, even though the consequences of destructive tsunami are severe, participants stated that the "un-realness" of the likelihood and consequences in combination with people's affinity for living on the coast meant that they are prepared to accept the risk, believing that destructive tsunami will not happen to them:

> People are willing to take a bit more risk around those areas and just accept the fact that there is tsunami, or these one-off major events, which have a return period of I think, two and a half thousand years, which is the largest modelled one. So most people go "well two and a half thousand years, I'll take my chances". (Participant).

Reduced motivation for developing destructive tsunami policy. Participants stated that currently there was not the same degree of focus within policy frameworks to cover the extremely rare events such as destructive tsunami, which are spaced out over hundreds or thousands of years. In-line with this short-term policy focus, participants found it easier to talk about risk management measures in place for more frequent, experienced hazards such as noise pollution, flooding, and erosion. Participants conveyed that these hazards were more pertinent issues that policy makers, decision makers, and the community could see every day, happening in front of their eyes. As such, policy for managing these more frequent hazards was well understood and received greater acceptance within the community. Participants stated that while tsunami was a coastal hazard, it was easier to separate tsunami from coastal hazard policy development and deal with more immediate concerns:

> It's pretty easy to deal with some short-term stuff, you know, don't build on that hillside because it's in a slip zone, but tsunami is… you know… you're talking about hundreds and hundreds of years, so how do you identify what the risk is, how do you identify the policy response? (Participant).

Participants also stated that the cost of implementing tsunami risk management policy would outweigh its benefits, especially when viewed in conjunction with shorter-term planning timeframes for natural hazard management. They believed that while highly concentrated populations, such as Japan, may have the means to reduce tsunami risk by relocating their built assets or through building large protective structures, New Zealand did not have the population concentration or economic means to make that option realistic. Furthermore, participants referred to where tsunami protection walls were overtopped in the Great East Japan earthquake and tsunami of 2011, stating that even if there were means to build protective structures, this did not guarantee community protection. They thought that considering the "extremely unlikely" event of a large, destructive tsunami, they would deal with the consequences if they occurred, rather than pay for protective structures which could fail anyway.

Similar to their views on the cost-benefit of applying policy for tsunami protection, participants stated that a precautionary policy approach for destructive tsunami risk management would effectively prohibit community development and economic benefit. Given that community and economic development is central to the objectives of local government (New Zealand Government, 2002b), prohibiting development to manage tsunami risk "just doesn't stack up". This is especially relevant given that the major cities in the Gisborne, Hawke's Bay, and Wellington regions are already located within tsunami inundation areas. Participants stated that policy which limited development of existing buildings in tsunami inundation areas was an issue that would potentially affect too much land and too many assets (built and human). Given the low-likelihood of destructive tsunami, participants were uncertain as to how policy could be developed where the benefit from applying the policy would be greater than the cost. Participants stated that there were more options for applying policies to manage development in *greenfield* areas where no existing building had taken place; however, they doubted whether policies that restricted greenfield development could be applied without property developer, community, and jurisdictive resistance:

> The uncertainty of tsunami risk sits in the really hard basket when you're looking at established development areas, obviously when you're planning new ones you can take those things into account, but if you're looking at managing existing areas it's really difficult. (Participant).

> It just doesn't stack up and I doubt whether we will, as an organisation, head to the Environment Court[4] to try and fight for those provisions and I don't think the Environment Court would be very receptive. (Participant).

Because of the low-likelihood of destructive tsunami and the uncertainties that they entail, policy development to manage tsunami risk is perceived as being in the "too hard basket". As such, planning and policy initiatives to reduce tsunami risk are less explored. One option for better communicating low-likelihood, destructive tsunami risk is through the use of risk modelling. However, as pointed out in the following section, risk modelling comes with its own challenges when applied within local government.

Risk modelling is valued but challenging. While some participants were not as familiar with the use of tsunami risk modelling as others, they all agreed that risk modelling was beneficial, especially as it can produce a visual representation of the risk with which people can more easily identify. Some participants referred to the colloquialism that "a picture is worth a thousand words". They added that the ability of risk modelling to spatially distribute natural hazard risks on maps made it a valuable communication tool for community awareness campaigns, for media use, and for increasing decision makers' risk awareness.

Participants also valued the ability of risk modelling to provide loss estimates for planning purposes. They stated that the ability of modelling to tabulate comparisons of loss, depending on differences in exposure and vulnerability of assets, made it useful for *Section 32* analyses (New Zealand Government, 1991), where benefits and costs, and considerations of alternatives, are required to be considered for the development of policies. They also referred to the value of risk modelling for emergency management, where modelled estimates of consequences can be used to inform readiness arrangements and pre-event recovery planning.

Almost all participants believed, especially in the case of low-likelihood hazards such as destructive tsunami, that modelled outputs which clearly and succinctly set out aggregated economic and infrastructural losses were beneficial for communicating risk and influencing decision makers' risk perceptions. However, participants expressed uncertainty as to whether risk modelling would actually change how decision makers would act. Some participants told of previous experiences where decision makers had rejected risk modelling outputs. These participants stated that officially, decision makers did not want to act because they were unsure of the quality of the modelled results; whereas unofficially, decision makers may not have wanted to act on the modelled results because of political reasons:

> I don't think anyone politically wants to say "yeah, the legacy I left in my tenure was to make sure that there were protection and policies in place to hamper the growth of a city because it exists in a tsunami zone..." (Participant).

In line with this, participants held reservations over the assumptions and uncertainties inherent within risk modelling. They expressed that risk modelling needed more transparency, rather than being a "black box", so that users could see how data was manipulated within the model and have more confidence in what it was telling them. They expressed that the assumptions of the models and lack of transparency were the first things that get contested by decision makers and the judicial system (e.g., Environment Court) when risk modelling had been used in the past to defend policy proposals.

4 The Environment Court of New Zealand works to solve issues relating to the Resource Management Act 1991. The court largely deals with appeals about the contents of regional and district plans and appeals arising out of applications for resource consents.

Further concerns that participants had regarding risk modelling was that input data, in a usable format and quality, was very scarce, that data generation was very costly, and that their councils did not have the spare capacity or capability to support in-house risk modelling. Consequently, risk modelling had not yet been able to provide the specific level of information needed to inform detailed land use and urban planning:

> The thing with planning is that it requires pretty detailed information in order to justify putting in those policy constraints at the end of the day. You have to absolutely have it backed up 100 percent because you will be fighting it through councils, politicians themselves are not going to approve something unless it's fully sound. (Participant).

As such, while participants saw risk modelling as beneficial, they were clear to state that it could only ever be a support tool for decision-making. Many referred to risk modelling as a communication tool, capable of conveying information in a way that influences risk awareness and perception, to help start decision maker discussions for policy development:

> That's probably a nice turn of phrase "as a communication tool" because I'm a firm believer that any model is there to support decision making not to make decisions. Only humans can do that in full judgement of the information available. So as a communications tool risk modelling is still quite valid. (Participant).

Discussion

> [Natural hazard preparedness] involves understanding how people construe the relationship between themselves, the hazard and the protective measures available to them and assisting their protective decision making within this socio-ecological context. (McIvor, Paton, & Johnston, 2017. p.45)

The results from the policy document analysis show that while natural hazard management is important for local government, there is a paucity of risk-based policy for tsunami management. Factors contributing to this are that the majority of policy takes a generic all-hazards approach, that existing policy tends to focus on more frequent, experienced, and escalating hazards, that the majority of tsunami-specific policy is unclear and non-prescriptive, and that risk-based policy is high-level and lacks reference to frameworks for how risk management would be achieved. As such, of the 58 national and local policy documents that were analysed, only three contain specific tsunami risk-based policy.

This paucity of tsunami risk management policy reinforces similar findings on the need for more specific hazard policy in New Zealand local government (Becker & Johnston, 2000; Glavovic et al, 2010; Local Government New Zealand, 2014; Saunders et al., 2014). The tendency to refrain from developing hazard-specific risk policy in favour of an all-hazards approach could be attributed to policy makers trying not to miss hazards out, as well as resource issues pushing them to achieve the greatest policy coverage with limited budgets. However, given the qualitative interview results where participants logically understand tsunami risk but choose to disassociate from it, we propose that the paucity in specific risk-based tsunami policy could also be attributed to cognitive biases.

Cognitive biases are a human condition where heuristics can sometimes cause us to behave in contrary or seemingly illogical ways. Over 100 cognitive biases have been recognised (Ehrlinger, Readinger, & Kim, 2016), with many acting in contradictory ways to others. While the following discussion focusses on how cognitive biases can influence people to under-perceive risk, other types of cognitive bias can influence people to over-perceive risk (Notebaert, Clarke, & MacLeod, 2016).

While the results show that participants logically understand that an unlikely, destructive tsunami can occur at any time and that the consequences will be severe, their difficulty in internalising the consequences from such an event shows a disassociation from the risk: that "tsunami won't happen to us". Research has established a number of reasons for this. People tend to have a poor understanding of low likelihoods (Doyle & Potter, 2015; Shoemaker 1980; Slovic, Fischoff, & Lichtenstein, 1982). Slovic et al. (1982) found that people are insensitive to differences in very low probabilities and that below a certain threshold, low probabilities are perceived as the same and tend to zero. Shoemaker (1980) stated that people either ignore low probabilities or are unable to make rational decisions involving low probabilities. Henrich, McClure, and Crozier (2015) reported that people have difficulty perceiving low-likelihood disaster risk especially when it is framed as a recurrence interval (e.g., 1/ 1000 years). McClure, Allen, and Walkey (2001), Khan, Crozier, and Kennedy (2012), and Baytiyeh and Naja (2016) stated that people are less likely to prepare for disasters due the belief that disasters are too destructive to prepare for successfully. Fraser et al. (2016), Mileti and O'Brien (1992), and Solberg, Rossetto, and Joffe (2010) referred to how warning fatigue and normalisation bias can drive people to underestimate the risk of natural hazards.

Cognitive biases which can influence practitioners to disassociate themselves from tsunami risk include:

- The Ostrich Effect: a tendency to disbelieve or ignore something that has a negative emotional effect, even if there is evidence to the contrary;
- The Optimism Bias: a tendency to underestimate the likelihood that negative consequences will occur from future threats;
- The Confirmation Bias: a tendency to search for, interpret, favour, and recall information in a way that confirms one's own pre-existing beliefs or hypothesis; and
- The Amnesia Bias: a tendency to forget too quickly the lessons of past disasters.

The results show that because of the low likelihood of destructive tsunami and the uncertainties they entail, practitioners perceive that developing policy to manage tsunami risk sits in the "too hard basket", which results in a paucity of tsunami risk management policy. Cognitive biases which can influence practitioners' motivations towards developing policy include:

- The Myopia Bias: a tendency to focus on overly short future time horizons when appraising costs and the potential benefits of protective investments;
- The Availability Heuristic: a tendency to act on threats which have previously been experienced, or are easy to imagine;
- The Inertia Bias: a tendency to maintain the status quo or adopt a default option when there is uncertainty about the potential benefits of investing in alternative protective measures; and
- The Bandwagon Effect or Groupthink: a tendency for people to do something primarily because other people are doing it, regardless of their own beliefs, which they may ignore or override.

The types of cognitive biases that influence policy development for low-likelihood, destructive tsunami are difficult to overcome. This is because these biases tend to be resistant to logic, deconstruction, or the use of training tools (Montibeller & von Winterfeldt, 2015; Weinstein & Klein, 1995). *Debiasing* measures that can improve decision maker risk perceptions include (Montibeller & von Winterfeldt 2015; Parkhurst, 2017; United States Government, 2009):

- Clear, easily digestible communication of the risk;
- Identification of the consequences associated with the risk;
- Provision of alternative scenarios and counterexamples; and
- Use of diverse expert information.

We propose that risk modelling can reduce the impact of these types of cognitive bias and therefore support the development of tsunami risk-based policy. The model used in the interviews (RiskScape) visually presents information in map form, which participants found easy to understand and with which to identify. The framework for the RiskScape model has been developed using robust science (Schmidt et al., 2011), is populated with diverse expert information for hazard and fragility models (Bell, Paulik, & Wadwha, 2015; Cousins, 2015; Kwok, 2016; Uma, 2009), and is capable of presenting modelled consequences in map form and as numerical tables.

The results highlight how participants thought "a picture is worth a thousand words", implying that the risk model visually communicated risk in a way that they found more informative and easily digestible than other traditional methods. Furthermore, even though they had not personally experienced the low-likelihood tsunami scenario depicted in the risk model, they stated that after seeing the results, they were better inclined to act on the information presented. Participants also thought that the aggregated economic and infrastructural consequences presented in the numerical tables was beneficial for influencing decision makers' risk perceptions. As such, participants agreed that the ability of RiskScape to communicate consequences visually and numerically could help reduce misperceptions associated with a tendency to forget the lessons from similar disasters or underinvest in risk reduction measures. Participants also valued the ability of RiskScape to provide alternative scenarios. While this enables them to perform cost-benefit analyses for different risk reduction measures, it also provides more certainty around investing in those measures, thus enabling decision makers to move past biases associated with maintaining the status quo.

However, even though participants see risk modelling as beneficial for communicating past cognitive biases and risk perceptions for low-likelihood tsunami, this has not yet been achieved. Concerns relating to data availability, quality and cost, the capacity and capability to use risk models, and trust in modelled results mean that modelling is not widely used in New Zealand local government (Crawford, Saunders et al., 2018). Also of concern are participants' views that while decision makers may correctly perceive the risks communicated through risk modelling, they may not act upon them for political reasons.

Recommendations

This research reveals a number of challenges for low-likelihood, destructive tsunami risk management:

- A paucity of tsunami risk based policy;
- Cognitive biases influencing tsunami risk perception;
- Challenges for how easily risk modelling can be used within local government; and
- Concerns about decision maker motivation to enable tsunami risk management policy development.

As such, we recommend the following solutions to further develop a pathway forward for how local government could better match tsunami risk management policy with low-likelihood, destructive tsunami risk:

1) Further resource national risk management initiatives, for example the Local Government Risk Agency[5], to better enable the development and application of natural hazard risk management frameworks within local government. This could be achieved through structured collaboration and training across the different local government functions responsible for natural hazard risk management (Crawford, Saunders et al., 2018; Saunders et al., 2014). One option is regular risk management workshops to assess risks and what can be done to reduce them. The result is a shared understanding of each other's risk management roles (Doyle & Paton, 2018), greater integration across functions, and an improved ability to develop specific risk-based policy for destructive tsunami, rather than an all-hazard policy approach.
2) Include debiasing techniques as part of natural hazard risk management workshops so that practitioners and decision makers are better informed about how innate cognitive biases influence their perceptions that destructive tsunami "won't happen here". While increased awareness of cognitive biases may not change risk perceptions, it provides greater context when considering how acceptable the risk information is, allowing practitioners and decision makers to make more informed decisions.
3) Co-develop risk modelling through a bottom-up, participatory approach to enhance the usefulness and usability of the models (Newman et al., 2017). This approach would enable local government users to influence model development so that models can process a wider range of data formats (therefore increasing data availability), have a more intuitive user interface, and have increased quality of information output (Global Facility for Disaster Reduction and Recovery, 2014a; Global Facility for Disaster Reduction and Recovery, 2016). This would tie in with initiatives to increase local government understanding of risk management so that practitioners and decision makers have a better understanding of the capability and value of risk models and greater confidence in modelled information.
4) Review the flexibility of natural hazard policy instruments to enable policy for low-likelihood hazards that have intervals over thousands of years, thus providing a way forward for long, long-term planning instruments (Lawrence et al., 2015). These long, long-term planning instruments could operate outside of shorter-term planning cycles and apply policy across 100 – 500 years, incrementally reducing community exposure and vulnerability to natural hazards over generations. A long, long-term plan would separate low-likelihood, destructive tsunami risk management from the more immediate political, financial, and community development issues which currently influence decision makers to perceive it as sitting in the "too-hard-basket".

Furthermore, we propose that these challenges arise from more fundamental issues relating to how natural hazard risks are governed in New Zealand and other countries. When discussing this with practitioners in the interviews, they referred to:

- A complex natural hazard management legislative environment;
- Limited national-level clear, structured guidance;
- Lack of any mandate within local government to lead cross-council natural hazard management functions;
- Misperception or lack of integration across natural hazard management functions;
- The scarcity of available natural hazard data and information;
- A disconnect between science and policy;
- Mismatched policy and planning timeframes across land use planning, emergency management, building codes, and local government responsibilities;

5 Local Government New Zealand (LGNZ) has proposed a Local Government Risk Agency that pools and coordinates local government resources to lower the risk and cost of disaster. https://www.lgnz.co.nz/our-work/local-government-risk-agency/

- The differing requirements of decision makers across different practitioners' functions, politicians, and between practitioners and politicians; and
- A shortage of resources impacting on capacity and capability.

These issues are complex, interrelated, and entrenched within local government. Participants reported that these issues result in long timeframes for natural hazard policy development, a paucity in risk-based policy, and a reduced ability to apply natural hazard management solutions such as risk modelling (Crawford, Crowley et al., 2018). Considering this, we recommend the ongoing review of the interrelationship across natural hazard provisions in New Zealand to further explore governance approaches which can more effectively enable the application of natural hazard risk management solutions.

Conclusion

While the regions of Wellington, Hawke's Bay, and Gisborne are at risk of experiencing the most destructive tsunami that New Zealand is likely to encounter over a 1000-year timeframe, this risk is not currently matched by tsunami risk management policy. An analysis of 58 central and local government policy documents for those regions reveals only three that contain specific tsunami risk-based policy. We propose that this paucity in policy is influenced by cognitive biases which can cause people to disassociate themselves from low-likelihood tsunami risk and reduce motivation for developing risk-based policy. We argue that risk modelling (RiskScape) can help overcome these cognitive biases and aid policy development. While participants see value in risk modelling as a tool to communicate tsunami risk in a way that is more digestible and useful, they are uncertain of how easily it could be used and how acceptable its information is for decision makers. As such, we recommend participatory risk modelling to work in combination with risk management training, cognitive debiasing techniques, and long, long-term planning to overcome the challenge of low-likelihood tsunami risk perception. The complexity of New Zealand's natural hazard governance system remains an issue. However, with a deeper understanding of how New Zealand's natural hazard governance system impacts on the development and application of natural hazard policy, we can better apply solutions and enable our communities to become safer, sustainable, and more resilient.

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Appendix

Natural hazard policy documents included in document analysis

1	Resource Management Act 1991
2	Building Act 2004
3	Civil Defence Emergency Management Act 2002
4	Local Government Act 2002
5	Environment Act 1986
6	Local Government Official Information and Meetings Act 1987
7	New Zealand Coastal Policy Statement 2010
8	National Civil Defence Emergency Management Plan Order 2015
9	Department of Internal Affairs (2008) National Civil Defence Emergency Management Strategy
10	Building Regulations 1992
11	MCDEM (2016) National Tsunami Advisory and Warning Supporting Plan [SP 01/16]
12	MCDEM (2015) CDEM Group Planning - Director's Guideline for Civil Defence Emergency Management Groups [DGL 09/15]
13	The Building Regulations 1992
14	Hawke's Bay Regional Council (2006) Hawke's Bay Regional Resource Management Plan including the Regional Policy Statement (RPS).
15	Hawke's Bay Emergency Management Group (2016) Group Plan 2014 – 2019.
16	Hawke's Bay Regional Council (2014) Hawke's Bay Regional Coastal Environment Plan.
17	Hawke's Bay Regional Council, Napier City Council, Hastings District Council (TBC) Clifton to Tangoio Coastal Hazards Strategy 2120
18	Hawke's Bay Regional Council (2011) Strategic Plan
19	Hawke's Bay Regional Council (2011) Long Term Plan 2012 – 2022
20	Gisborne District Council (2013) Gisborne CDEM Group Tsunami Contingency Plan
21	Gisborne District Council (2016) Tairawhiti Civil Defence Emergency Management Group Plan 2016 – 2021
22	Tairāwhiti Resource Management Plan 2017 - Part B - Regional Policy Statement
23	Tairāwhiti Resource Management Plan 2017 - Region Wide Provisions
24	Gisborne District Council (2015) Tairāwhiti First! 2015-2025 Long Term Plan
25	Gisborne District Council Hazard Risk Profile 2015
26	Wellington Region Emergency Management Group (2013) Wellington Region Civil Defence Emergency Management Group Plan 2013 – 2018
27	Wellington CDEM Group Distant Source Evacuation Plan
28	Greater Wellington Regional Council (2013) Regional Policy Statement for the Wellington Region
29	Greater Wellington Regional Council (2000) Regional Coastal Plan for the Wellington Region

30	Greater Wellington Regional Council (2004) Wairarapa Coastal Strategy
31	Napier City Council (2015) Napier City Council Long Term Plan 2015 – 2025
32	Napier City Council (2011) City of Napier District Plan Chapter 62 Natural Hazards
33	Napier City Council (2011) Safer Napier Policy
34	Napier City Council (2016) 2016/17 Annual Plan
35	Central Hawke's Bay District Council (2015) Long Term Plan 2015 – 2025
36	Central Hawke's Bay District Council (2003) Central Hawke's Bay District Plan
37	Hastings District Council (2015) Proposed Hastings District Plan
38	Hastings District Council (2012) Hastings District Plan
39	Hastings District Council (2000) Hastings Coastal Environment Strategy Technical Paper #4
40	Hastings District Council Hastings Coastal Environment Strategy (in HDC 2015 proposed plan)
41	Hastings District Council (2014) Local Governance Statement
42	Hastings District Council (2013) Waimarama Community Plan
43	Hastings District Council (2015) Long Term Plan 2015-25
44	Hastings District Council (2016) Annual Plan 2016-2017
45	Wairoa District Council (2005) Wairoa District Plan
46	Wairoa District Council (2014) Significance & Engagement Policy
47	Wairoa District Council (2004) Wairoa Coastal Strategy
48	Wairoa District Council (2015) 2015-2025 Long Term Plan (LTP)
49	Wairoa District Council (2016) Wairoa District Council Annual Plan 2017/18
50	Hutt City (2015) Long Term Plan 2015-2025
51	Hutt City (2016) Annual Plan for 2016-2017
52	Hutt City (2016) City of Lower Hutt District Plan
53	Wellington City Council (2017) District Plan
54	Wellington City Council (2015) Long-term Plan 2015–25
55	Wellington City Council (2015) Annual Plan 2016/17
56	Wellington City Council (2016) 100 Resilient Cities Preliminary Resilience Assessment
57	Wellington City Council (2011) Towards 2040: Smart Capital Strategy
58	Wellington City Council (2014) Draft Wellington Urban Growth Plan 2014 – 2043

Surabaya Resilience Index for potential earthquakes: An institutional perspective

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Abstract

The earthquake map released by the Indonesian National Earthquake Board in 2017 categorized Surabaya as prone to earthquakes caused by the Kendeng Thrust. In order to anticipate this new threat, this study assesses Surabaya's current earthquake and disaster resiliency. Despite being one of Indonesia's most successful cities, receiving many honours nationally and internationally, Surabaya's institutions still have a mediocre performance in terms of resiliency, with middle-to-high performance for resilience to general disasters and middle-to-low resilience to potential earthquakes. Surabaya has an average performance compared to 19 other cities around the Asia-Pacific; however, Surabaya scores the lowest for mainstreaming potential for earthquakes in public planning indicating that the city has not anticipated this new threat. Thus, Surabaya needs to enhance its resiliency in the near future due to the unidentified risk, response and emergency-centred actions, and limited public documents considering the risk.

Keywords: *Resilience index, Earthquake, Kendeng Thrust, Institution, Risk Management*

Surabaya is the second largest city in Indonesia, with a population of approximately 2.9 million people in 2015 (Surabaya Government, 2017). Surabaya is the capital of East Java Province and is a centre of development with trading, hotels, restaurants, catering, and industrial activities as its economic core. Currently, the growth of the gross regional domestic product of Surabaya is around 6.0% (Surabaya Government, 2017) making it one of the fastest growing cities in Indonesia. This fast growth of economic activities intensifies developments resulting in increased economic performance, driving the migration of people and workers into the city and increasing building developments. From the perspective of risk management, these fast growing phenomena can increase the vulnerability of the city in the near future.

The National Earthquake Centre of Indonesia (Pusat Gempa Nasional; PUSGEN) has released a new version of their earthquake map in which Surabaya has a significantly increased potential earthquake

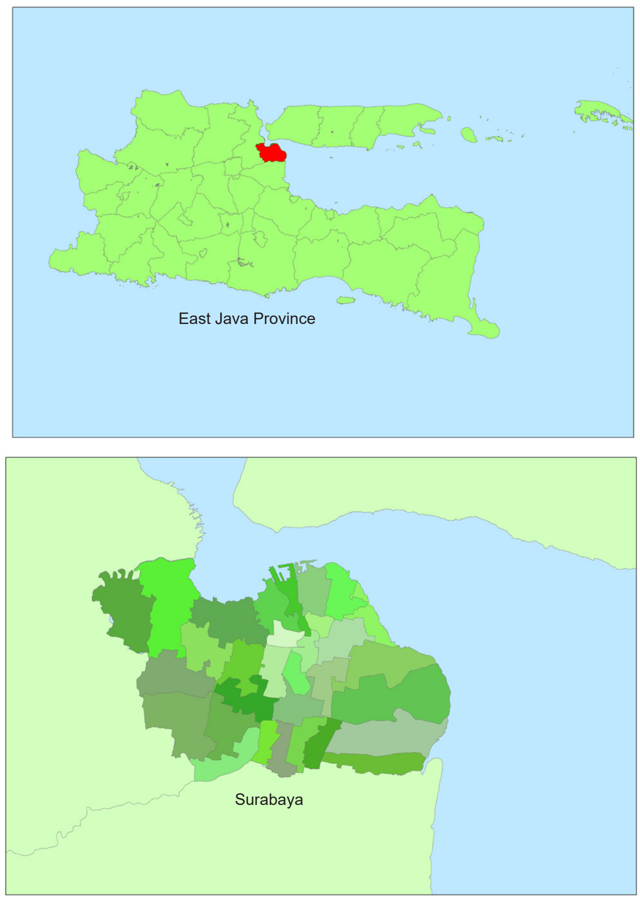

Figure 1. Location of Surabaya City.

threat (Pusat Gempa Nasional, 2017). The velocity of a potential earthquake has been increased from 0.3-0.4 G in 2010 to 0.4-0.5 G in 2017 (Figure 2). Some research related to the increased earthquake potential in Surabaya also mentions that the new *Kendeng Thrust* affects the southern part of Surabaya (Meilano, Susilo, Gunawan, Sarsito, & Abidin, 2016) and could cause a magnitude 6.5-7.5 earthquake (Irsyam, 2016). Furthermore, the potential risk is increased by the soil characteristics of the region which means that the tremors can easily travel from the epicentre to surrounding areas including the city of Surabaya (Solikhin, 2016). These research outputs highlight an increase of potential risk to Surabaya, in particular that of earthquakes.

The new earthquake map, showing that Surabaya is an earthquake-hazard area, and the fast growth of the city increasing vulnerability, leads to an increase in known risk in Surabaya, as risk is a function of vulnerability and hazard exposure (Moe, Gehbauer, Senitz, & Mueller, 2007; Shah Alam Khan, 2008). Disaster risk management uses the concept of resiliency in order to decrease earthquake risk. Resiliency refers to the ability to respond and to recover from stress (Masten et al., 1999; Wagnild & Young, 1993) and is an outcome of current adaptations (Pamungkas, 2013). Three main characteristics of resiliency are the ability to absorb shocks, to bounce back to a previous level or situation, and to improve outcomes in future disaster events via learning and adaptation (Barrett & Constas, 2013).

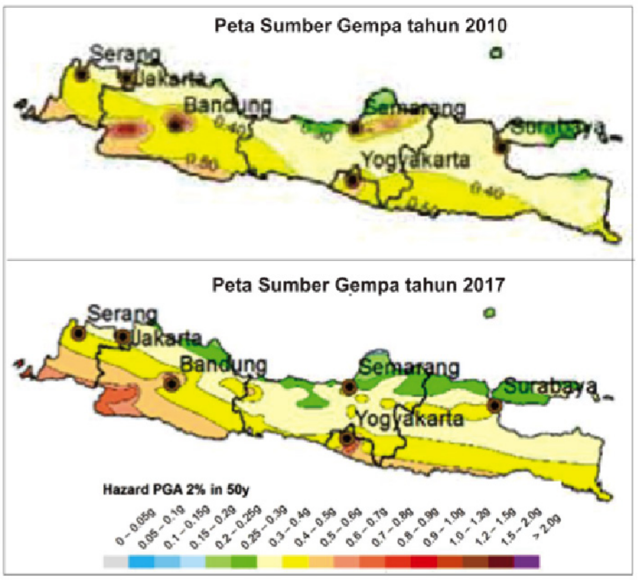

Figure 2. Study output of Peak Ground Acceleration (PGA) and short period acceleration spectral (0.2 seconds) and 1 second with augmentation possibility of 2% in 50 years based on data from 2010 to 2017. From Adjani (2017).

The United Nations in 2012 noted that the financing of US$1 in disaster risk management to enhance resiliency can decrease the cost of emergency response and recovery by US$7 (United Nations, 2012), highlighting the importance of applying the concept of resiliency in managing disaster risks.

In terms of assessing urban resilience, the assessment process is dependent upon the range of indicators and variables involved. This is due to the multi-dimensional nature of the resilience concept which requires many aspects to be taken into consideration. A more complex and wider coverage of indicators and variables leads to a more comprehensive assessment compared to when only using simple and limited coverage indicators and variables. Usamah (2013) identified four key dimensions discussed in the literature concerning resilience: physical, institutional, social, and economic. Although a complex study using a wide coverage of indicators and variables will improve the assessment process, in terms of accuracy, it is unable to uncover detailed information. The Indian Ocean Tsunami Warning System Program (IOTWS; 2007) has provided a resilience assessment scheme weighting and scoring each indicator and variable. Usamah (2013) highlighted similar weighting and scoring assessment processes as a basic calculation method in measuring resilience levels, such as in Cutter et al., (2010), Shaw and Sharma (2011), and Joerin and Shaw (2011). Although these types of weighting and scoring processes are common in resilience assessment, these studies were conducted without any in-depth discussion with the respondents, which is important to ensure that the resilience variables and indicators are correctly defined in terms of the context to which they are being applied. The discussion with participants in the assessment should be supported empirically to confirm the reliability of the weighting and scoring process. Consequently, a combination of quantitative and qualitative methods can increase the level of reliability of a resiliency assessment. This idea is the key concern of this paper.

Assessing the current resiliency level in a region is part of the early stages of developing an integrated approach for future disaster risk management. This first stage is appropriate in this context as the earthquake potential in Surabaya is considered to be a new challenge for future development. In this study, the assessment of resiliency in Surabaya will focus on the institutional aspects of resiliency rather than the whole spectrum of the index. Because there is still hesitancy at the institutional level about this new earthquake risk, it is important to test resiliency at this level as changes here will have the largest impact. Besides the main objective of the assessment of the resiliency of Surabaya for the new threat (earthquakes), we also conducted an assessment for disasters generally (e.g., flooding) in Surabaya, as the long history of this natural hazard in the region provides a useful reference point of resilience to a well-known risk. A new type of hazard can reduce resiliency due to lack of response by the local government; however, the local government has experience responding to a range of natural hazards generally, in particular floods. Therefore, comparing the results of these two assessments can uncover relevant ideas for disaster risk management programs in Surabaya addressing the increased risk of earthquakes.

Method

The assessment of resiliency can be done in many ways. Since the idea of the assessment is to understand the strengths and weaknesses of Surabaya towards earthquakes, we use the Climate and Disaster Resilience Index (CDRI) from Sharma and Shaw (2011) as the main assessment tool. The CDRI assessment process highlights important key factors of resiliency. The use of this index here also enables us to compare Surabaya with other cities around the Asia-Pacific where this index has previously been applied. Therefore, the

1.1 Mainstreaming of disaster risk reduction and climate change adaptation measures in the city's land use plans

1	2	3	4	5	Rating
Not incorporated	Poor	Limited	Moderate	Fully incorporated	

1.2 Incorporation of disaster risk reduction and climate change adaptation measures in the city's housing plans and policies

1	2	3	4	5	Rating
Not incorporated	Poor	Limited	Moderate	Fully incorporated	

1.3 Incorporation of disaster risk reduction and climate change adaptation in the city's school education curriculum

1	2	3	4	5	Rating
Not incorporated	Poor	Limited	Moderate	Fully incorporated	

A

1.4 Incorporation of disaster risk reduction and climate change adaptation in city's transport plans and policies

1	2	3	4	5	Rating
Not incorporated	Poor	Limited	Moderate	Fully incorporated	

1.5 Incorporation of disaster risk reduction and climate change adaptation in the city's environmental plans and policies (e.g., flood risk, biodiversity, urban green space, air quality, etc.)

1	2	3	4	5	Rating
Not incorporated	Poor	Limited	Moderate	Fully incorporated	

Weighted factor: Please rank the variables between 1 and 5 (5 = most important, 1 = least important). No ties/same ranking between two or more variables.

1.1	1.2	1.3	1.4	1.5

B

Figure 3. Instrument for assessing the institutional aspect of Surabaya's resiliency to earthquakes. The A shows the performance of each influential variable, while B reflects the importance ranking of variables within an indicator.

assessment presented here will follow the guidelines of Sharma and Shaw.

The CDRI has five aspects: economic, physical, social, institutional, and environmental (Sharma & Shaw, 2011). Since we focus on the institutional aspect, the main discussion of the resilience level will be around mainstreaming disaster risk reduction to local planning products, the effectiveness of crisis management, knowledge dissemination, institutional collaboration, and good governance. All five indicators were assessed based on the expert opinions of high-profile stakeholders to determine the current resiliency level of Surabaya. Each stakeholder was asked to rate the performance of Surabaya for each indicator. The rating process used Sharma and Shaw's (2011) questionnaire to increase the validity of comparing Surabaya with other cities. Figure 3 shows an example of the questionnaire.

In terms of aggregate value of the index, Sharma and Shaw (2011) provided the simple formula of calculation below;

$$\text{Index value:} \quad = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} = \frac{(w_1 \times x_1) + (w_2 \times x_2) + (w_3 \times x_3) + (w_4 \times x_4) + (w_5 \times x_5)}{w_1 + w_2 + w_3 + w_4 + w_5}$$

Note:
w = variable rank
x = variable value

Based on the formula above, the index is then categorised into five groups. The division of groups refers to Sharma and Shaw (2011) and is as follows: Very High = 5; High = 4; Middle = 3; Low = 2; and Very Low = 1.

The assessment of Surabaya's resiliency comprises a simple rating process. We took three steps to enhance the quality of assessment and ensure the validity of the self-ratings. First, this study complemented the simple rating process above with interviews to gain an in-depth knowledge of the current situation. The interviews provided insights into the key argumentation by the respondents which was used as a way to confirm the self-ratings.

Second, the respondents' ratings and comments were validated using secondary data (e.g., government publications, media reports). An additional note on the validity of the ratings is that respondents typically gave their assessment as an expert in the field rather than as a representative of a government agency which is responsible for the implementation of resiliency measures in Surabaya. This expert perspective, combined with validation from secondary data, should improve the objectivity of the ratings. Using both interviews with the respondents and secondary data to support the accuracy of the self-ratings means that a relatively simple rating process such as that used here can demonstrate good validity.

Third, the assessment involved high-ranking respondents who are experts in the field of development in Surabaya. We used purposive sampling to find valid respondents for this study. Furthermore, we selected relevant stakeholders based on their interests and influences (Bryson, 2004; Reed et al., 2009). Table 1 describes the selected stakeholders and their relevancy for this research. We distributed our questionnaires to all nine potential stakeholders, including high-ranking local government officers, a specified national government officer of land and spatial planning, and the chairs of various types of related expert associations (i.e., urban planning, architecture, construction, and geology). From the nine potential stakeholders there were two agencies which did not provide valid responses after several rounds of contact were made: the Disaster Planning Board and Community Protection of Surabaya (BPB-Linmas) and the Housing, Residential, Public Works and Spatial Planning Agency of Surabaya (DPRKPCKTR). However, these are technical agencies with the main task of following through and implementing plans made by the Surabaya Planning Board (Bappeko). The Surabaya Planning Board has full authority over planning and strategic management of the city including for the issue of potential earthquakes. Therefore, the missing stakeholders will not influence the validity of the aggregate responses.

Findings and Discussion

Since earthquakes are a new threat in Surabaya, most of the stakeholders have not yet realised the potential hazard and its impacts. Consequently, before completing the index, the authors explained to the stakeholders about the current findings of Surabaya's earthquake potential. Afterward, the stakeholders were asked to value Surabaya's resilience in two phases: assessing for general disasters and assessing for the specified disaster of earthquakes. The findings presented below

Table 1
Relevant stakeholders in assessing the resiliency of Surabaya to potential earthquakes

Stakeholder	Interest	Influence
Geology expert	A particular concern about geological disasters.	Providing a wide perspective on earthquakes and the thrust.
Ikatan Arsitektur Indonesia – IAI (Indonesian Architecture Association – East Java Chapter)	Designing buildings that are included in the elements at risk.	Providing a wide perspective on designing resilient buildings.
Kamar Dagang dan Industri – KADIN Surabaya (Industry and Trade Chamber – East Java Chapter)	Trading most goods and services including in the property market.	Providing a wide perspective on urban economics and markets of specific goods including the property market.
Pihak Badan Perencanaan Pembangunan Kota – Bappeko (Surabaya Planning Board).	A local government body that is responsible for directing Surabaya's future development.	Authorized to direct the development process in the future.
Pihak Ahli Konstruksi – Construction Expert	A particular concern about constructions.	Providing a wide perspective on building construction and how to make constructions resilient to earthquakes.
Pihak Ikatan Ahli Perencana – IAP (Indonesian Planning Expert – East Java Chapter)	A particular concern about urban development and planning.	Providing a wide perspective on developing urban resilience to disasters.
Departemen Agraria dan Tata Ruang (Department of Agrarian and Spatial Planning)	A national government that has the responsibility to manage spatial planning.	Setting the planning standard for future development.
Badan Penanggulangan Bencana dan Linmas - BPB-LINMAS (Disaster Planning Board and Community Protection of Surabaya)	A local government that has the responsibility to manage risk in Surabaya.	Providing protection for the community in the case of disaster events.
Dinas Perumahan Rakyat dan Kawasan Permukiman Cipta Karya dan Tata Ruang (Housing, Residential, Public Works and Spatial Planning Agency of Surabaya-DPRKPCKTR)	A local government that has the responsibility to ensure the development process is in line with future challenges and standards.	Progressing the development proposals.

are based on a combination of self-ratings (corroborated by interviews) and secondary data.

Surabaya's Resiliency for General Disaster based on its Institutional Aspects

Surabaya has a high level of resiliency with an index value of 4.02 out of 5 for general disaster (see Figure 4). The knowledge dissemination and management indicator had the highest performance (4.55), while mainstreaming of disaster risk reduction performed the lowest (3.45). Based on the interviews, all stakeholders' responses are mainly focused on reducing flood risk. A long history of flooding has therefore likely contributed to Surabaya's high resiliency from an institutional perspective.

Disaster response is a key strength of Surabaya's disaster risk management. Even though Surabaya has just formed its local disaster board in January 2017 under the Mayoral Regulation No. 72 in 2016, the existence of BPB-Linmas, a board for community protection, significantly contributes to minimising the impacts of disasters. Effendi (2017) expressed that the BPB-Limnas has roles not only in disaster recovery but also in educating, socialising, and simulating community responses in times of disaster. The Surabaya Government also conducted disaster awareness training such as disaster rehabilitation and reconstruction for 40 local agencies on June 8th, 2017 in Tambaksari District, Surabaya (Surabaya.go.id, 2017). Furthermore, Surabaya also showed a special concern for its disaster response by establishing five fully-staffed emergency centres (Nurwawati, 2017).

Strong leadership by the mayor is also one of the key aspects of Surabaya's successful disaster response. Strong leadership is required for minimising the impact of disasters, and is one of the critical components in risk management (Awalia, Mappamiring, & Aksa, 2015; Baas, Ramasamy, Dey de Pryck, & Battista, 2008). Multiple cases have shown that the strong leadership of Surabaya's mayor has minimized the impacts of disasters in Surabaya (Detiknews, 2015; Hidayat, 2013; Zahro, 2017).

Surabaya's Resiliency for Potential Earthquakes from the Institutional Perspective

Compared to the high level of institutional resilience for general disasters, Surabaya has a low index for responding to potential earthquakes with a total score of 2.58 (Figure 5). Knowledge dissemination and management again scored the highest while mainstreaming of disaster risk reduction was the indicator with the lowest score. One of the major causes for the low index score is the fact that earthquakes are a new potential threat in Surabaya. The new map of earthquake risk released by PUGSEN (2017), showed that the threat to which Surabaya is prone is significantly higher than previous estimates. This new threat is not yet fully understood by stakeholders in Surabaya resulting in a lack of specific responses from the institutions to reduce the impacts of potential earthquakes. Figure 5 describes the level of performance for each variable of the institutional aspect of resiliency.

The resilience concept can be used to understand disaster preparedness. The core resilience components of bouncing back, absorbing shocks/stress, and adaptation from learning reflect preparedness towards potential future hazards. After comparing Surabaya's resiliency to general disasters and to potential

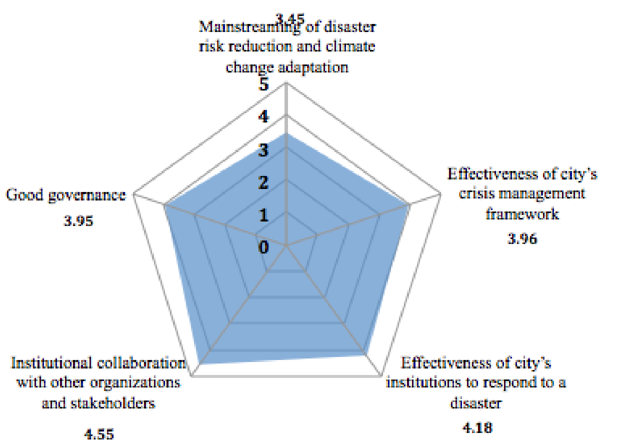

Figure 4. Resilience index for Surabaya's institutional performance in general disasters.

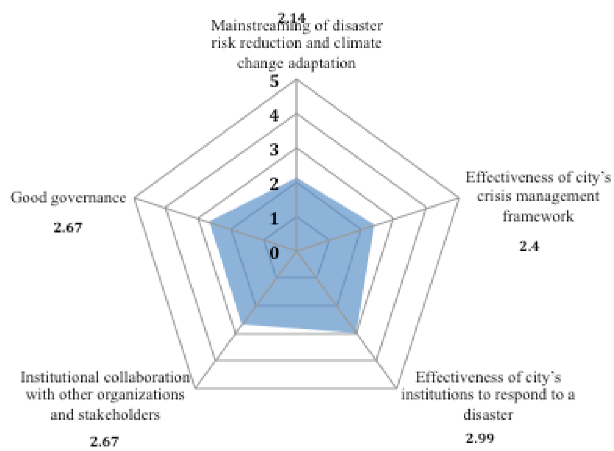

Figure 5. Resilience index for Surabaya's institutional performance in potential earthquakes.

earthquakes, we can see that Surabaya is not as prepared for potential earthquakes as it is for other, more well-known and understood hazards such as flooding. This low level of preparedness can lead to potentially high impacts for the city as the Kendeng Thrust is an active fault. Recent earthquakes around the northern part of Java (such as in Madura, 20 February 2017) confirms the earthquake potential posed by the active Kendeng Thrust (see Table 2).

Table 2
Earthquake events around Kendeng Thrust between 1900 and 2016

No.	Date	Depth (km)	Location	Magnitude
1.	27 July 1984	33.00	Bojonegoro	4.7
2.	14 May 1992	33.00	Java Sea (South of Madura)	4.7
3.	28 July 2006	10.00	Grobokan	4.5
4.	24 January 2007	35.00	Bojonegoro	4.3
5.	28 February 2015	44.06	Java Sea (South of Madura)	4.1
6.	25 June 2015	9.77	Bojonegoro	4.3
7.	4 November 2016	17.87	Ngawi	4.7
8.	20 February 2017	10.00	Madura	3.7

The total score for mainstreaming disaster risk reduction is 2.14, which means that there is little integration of earthquake risk management into government plans. The level of integration is the lowest for incorporating risk into housing plans (1.68), while the highest performance is for incorporating risk into environmental plans (2.94; Figure 6). If we compare these numbers to general disasters, mainstreaming disaster risk reduction is one of the weaknesses of Surabaya's risk management. For general disasters, mainstreaming disaster risk reduction scored between 2.50 (integrating risk into schools' curriculum) and 3.92 (integrating risk into land use plan). The biggest gap in scores is between general disasters and earthquakes in land use and housing plans and policies. The unidentified potential for earthquakes has led to this risk not being included in spatial plans. Meanwhile, other risks which have been identified and assessed by the stakeholders are incorporated in the spatial plans, thus resulting in a higher index score.

The main reason for the lack of integration of earthquake risk into disaster risk reduction is because previously there had been no identification of a potential disaster in Surabaya caused by an earthquake. Most stakeholders explained that earthquake potential had not been anticipated, and thus it had not been included in current public documents, especially in various development plans. The Surabaya Regional Spatial Plan of 2016 only mentions earthquakes as one of the hazards posed to the area with no further regulations discussing the consequences of this on spatial plans (Regional Regulation No. 12 in 2014). The limited coverage of risks in the plans can also be seen from the following comment:

> ... Sudah, sudah tergabung baik. Waktu yang di RTRW kemarin kan memang kita menyoroti karena masih framing-nya ke banjir sama kebakaran… Terus yang di RPJMD kemarin ya memang untuk yang gempa nggak spesifik disebutkan, tapi juga sudah ada gambaran... Masih terbatas kayaknya... … [disaster risk] has been very well integrated. For RTRW [the Surabaya Regional Spatial Plan], we highlighted [disaster] with special concern on flooding and fire… Then, in RPJMD [the Medium-Term Development Plan], earthquakes are not specifically mentioned, but there are some descriptions [on it] … [its discussion] still limited… (Bappeko).

Incorporating disasters in land use plans is also a new challenge in Indonesia. The national regulation does not properly define how to incorporate risk into the spatial plan. In the future regulation (as it is still in the draft version), the disaster-prone areas will be classified into protected areas, which is insufficient in terms of disaster risk management.

> … di pedoman yang baru, kita sudah masukkan konsep itu. Jadikan letak lokasi rawan bencana itu kan ya sebuah output ya, pola ruang lindung berarti ya. … in our new guideline [the draft version], we already considered that [disaster risk management] concept.

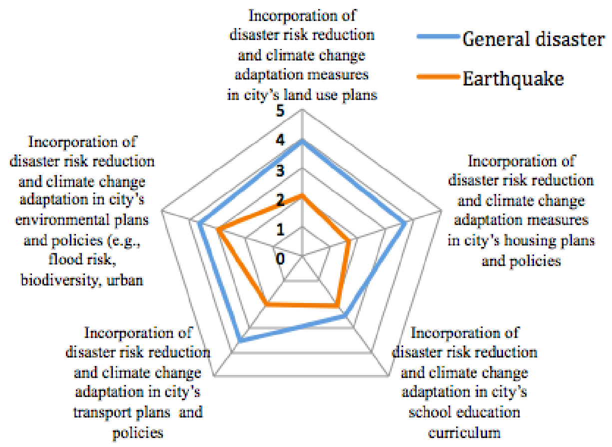

Figure 6. Surabaya's level of mainstreaming of disaster risk reduction and climate change adaptation.

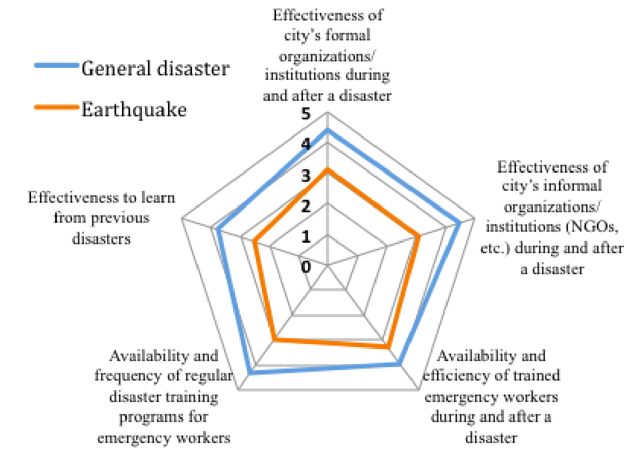

Figure 7. Level of effectiveness of the crisis management framework in Surabaya.

> [We] define the location for disaster prone areas as the output of the plan, thus [as] protected zones. (ATR).

Surabaya's crisis management indicator of earthquake resilience is still low, at only 2.40 out of 5. Among the variables in the indicator, the existence and effectiveness of emergency teams during a disaster has the highest score (3.27). BPB-Linmas, formerly named Bakesbanglinmas, is the central government agency in charge of emergency situations. The agency coordinates the relevant agencies to minimise the impact of disaster events. A long history of disaster risk management focusing on disaster response leads to a relatively good level of emergency team performance.

> Kalau secara keseluruhan masih baik. Overall [emergency response] is still good. (Geology expert).

> Gempa kayaknya masih nomor 2 [nilai rendah], mungkin... Hampir semua [semua indikator rendah]. For earthquakes, [Surabaya is] still number 2 [low level], probably … almost all of them [most variables have low performance]. (Construction Expert)

Furthermore, strong leadership of the mayor is also key to successful emergency actions. Consequently, in terms of general disasters, the effectiveness of the disaster management plan and the emergency team are valued high (Figure 7). The 'overly' strong leadership can however lead to the belief that it is a 'one-man show', which causes the destabilization of the emergency system for the city. Therefore, the Surabaya Government is still pushing to put into place an emergency system which includes providing an emergency call service via a partnership between Surabaya City and the Ministry of Communication and Information (Putri, 2015), establishing a command centre (Liputan6, 2017), and providing CCTV for most major roads (Surya, 2017). Learning about earthquake characteristics and impacts is the initial step for preparing an effective response to a potential earthquake for all parties in Surabaya. A newly established cooperation between the Centre for Earth, Disaster, and Climate Change (PSKBPI - Pusat Studi Kebumian, Bencana dan Perubahan Iklim) and the Surabaya Disaster Management Board (BPBL) has been formed to develop a roadmap for earthquake risk management. Besides this, there are other efforts such as campaigning by an ITS team with BPBL (Figure 8) to key stakeholders in every district of Surabaya to raise awareness of the existence of the Kendeng Thrust and its impacts.

The lowest performance in crisis management is the incorporation of the uncertainties of climate change in

Figure 8. Collaboration between ITS team and BPBL in an Earthquake Awareness Campaign (own photo).

the disaster management plan. Although earthquakes are unrelated to climate change, the idea of uncertainties in the future is applied in this assessment. The score for incorporating uncertainties for future challenges is low because the main concern of the government is only on short to medium-term development, due to the current political circumstances.

Institutional collaboration in potential earthquake events also has a low performance (Figure 9). The institutional collaboration between the city and the national government during and after a disaster and the extent of dependency on external institutions and support in response and recovery were rated the highest, at 2.81 and 2.85 respectively. The variable of interconnectedness, which refers to networking and collaboration with neighbouring cities for emergency management during and after a disaster was rated the lowest at only 2.24 out of 5. When compared to the higher resilience scores for general disasters, these findings suggest that the lack of understanding of the previously unidentified earthquake risk is the main cause for having a low performance in collaboration for potential earthquakes.

> Ada [program pelatihan untuk para pekerja kedaruratan]... Kan memang masing-masing UPD yang menangani ini secara reguler sudah disiapkan rencana dan anggaran untuk training mereka. There is [a training program for emergency teams]… every local government agency deals with this [risk management] regularly, planning and budgeting has been prepared for their training. (Bappeko) Kalo gempa ya belum [efektifitas lembaga atau organisasi formal kota selama dan sesudah bencana]. For earthquakes, [formal organizations] are not yet ready [since it is newly identified]. (Geology Expert).

In terms of collaboration, strong NGO involvement and partnerships with neighbouring municipalities in responding to flooding have been a good example, as well as a good resource, for facing potential earthquakes in the future. A call centre (Putri, 2015) and the partnership between Surabaya and the Netherlands (Riski, 2014) are two examples of good partnerships between Surabaya City and other units and organisations.

In terms of good governance, the lowest performance is for the existence and frequency of drills for disaster scenarios led by the city government (2.40; Figure 10). Most stakeholders have the same opinion that governance is not yet at a good level because of unidentified risks, incompatibility of the local disaster organizational structure with the organizations in provincial and national levels, and unsupportive conditions of emergency situations.

> Yang banjir kita sudah siapkan [Early Warning System]. Yang gempa belum. For flooding, we have prepared [the Early Warning System]. For earthquakes, [we] have not yet. (Bappeko).

> Dulu sebelum kita punya BPBD itu dari provinsi dan dari nasional itu mau membantu kita itu agak sulit, bukan agak sulit, gak bisa… Nah karena nggak ada BPBD di Surabaya mereka mau mengintervensi itu agak susah, menjadi gak bisa. In the past before [Surabaya] BPBD [local disaster board] was founded, support from provincial and national level is hardly executed, not hardly executed, [but] impossible to be

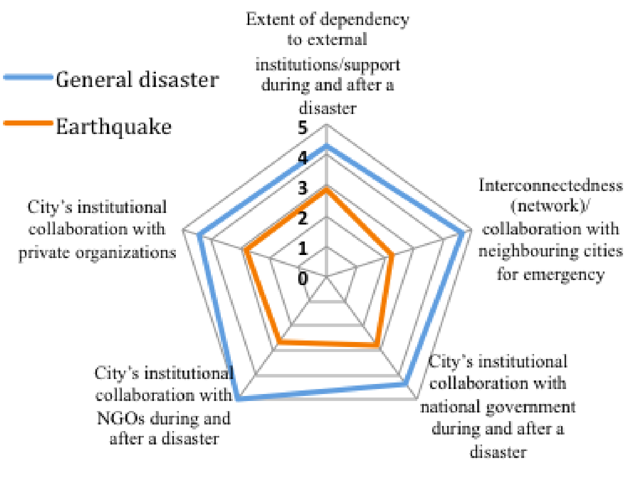

Figure 9. Institutional collaboration with other organizations and stakeholders.

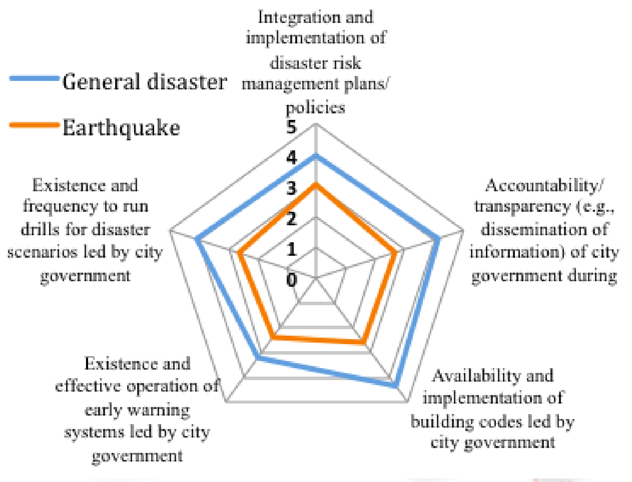

Figure 10. Scores for disaster-related governance in Surabaya, with higher scores indicating better governance.

> executed… Because there was no BPBD in Surabaya this made them [provincial and national BPBD] hard to support, more like cannot support [BPBD in Surabaya] (Bappeko).

> Ini, ini nih yang kadang nggak transparansi. Masalah bantuan katakanlah itu ya, itu kan bagian bagaimana distribusinya kita nggak... nggak tau gitu lho maksudnya. Buruk. This, sometimes there is no transparency. The problem is, let's say, disaster aids, in the distribution part, we do not know [cannot fully trace the distribution aids process]. Bad [practices]. (ATR).

Within the good governance indicator for resilience to general disasters, the existence and effective operation of early warning systems by the city government had the lowest position, although it is still at a mid-level performance (3.20). This is similar to the findings for earthquake resilience, where the same variable scored the lowest. As we would expect the score to be lower for earthquakes, which has not been a known risk for long enough for systems to be developed, these findings suggest that the current disaster early warning system in Surabaya needs improvement. For example, Surabaya should provide a more advanced system by incorporating an information system in disaster response as discussed in crisis management.

Surabaya's Resiliency in Relation to Other Cities

The resiliency index of 19 cities around the Asia-Pacific has been examined using the same questionnaire. Thus, we can compare Surabaya's index with these other cities as in Figure 11. From an institutional perspective, Surabaya still needs to enhance its resiliency for both general disasters and especially for potential earthquakes. The current achievements in Surabaya's development both nationally and internationally cannot guarantee that Surabaya will excel in resiliency. Some critiques made by the local stakeholders are that disaster risk management in Surabaya focuses on emergency situations, while there is limited integration with public planning processes. Moreover, the bureaucratic culture focuses only on short-term outputs, lacks the understanding of potential earthquake risks, and only focuses on selected disaster types. This is true not only for the case of Surabaya but many major cities in Indonesia which face significant challenges in harmonizing development pressure with potential future risks. Despite these challenges, the resiliency of Surabaya needs enhancement to ensure that its inhabitants' risk from disasters, especially potential earthquakes, is reduced.

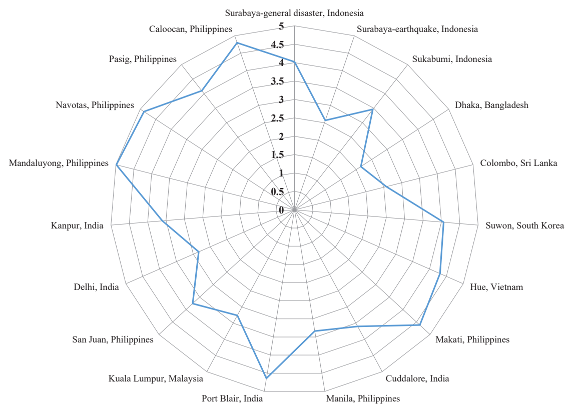

Figure 11. Position of Surabaya's resilience score for general disasters compared to 19 Cities in the Asia-Pacific region. Adapted from Asharose (2015), Kyoto University, CITYNET, UNU, UNISDR, and RFT-URR (2009), and Sharma and Shaw (2011)

Conclusion

Based on the new earthquake map from the Indonesian National Earthquake Centre in 2017 (Public Works Ministry, 2018) which identifies the threat of the Kendeng Thrust, Surabaya is now deemed at risk of a damaging earthquake. Furthermore, the rapid developments in Surabaya increase its elements at risk resulting in high vulnerability in the city. Surabaya's risk from a potential earthquake is likely to increase significantly as this development continues.

As a means to anticipate the risk, the assessment of resiliency is the first step to identify the weaknesses of the city in facing potential threats such as earthquakes. After assessing resiliency using the CDRI, we found that the success of Surabaya's development has not yet increased its resiliency. In terms of responding to general disasters, Surabaya has middle to high resilience. Unfortunately, its performance decreases for responding to potential earthquakes, with middle to low performance. Among the indicators of resiliency from an institutional perspective, mainstreaming disaster risk in public planning is Surabaya's greatest weakness. From the variables of all indicators, the three greatest weaknesses are: the incorporation of disaster risk reduction and climate change adaptation measures in the city's housing plans and policies, the existence and effectiveness of the city's disaster management plan, and the incorporation of uncertainties in disaster management plans.

Since mainstreaming disaster risk in public planning has the lowest index score, discussing the new earthquake map and its impact to the stakeholders in Surabaya is critical. The PSKBP-ITS team started risk conversation via public media, social media, advocacy to government officers, and scientific meetings in 2017. These strategies have resulted in a positive response from the local government. In 2018, the ITS team had ongoing discussions with BPB-Linmas on making a roadmap to increase urban resilience to earthquakes. Bappeko and DPRKPCKTR also responded positively. These two local agencies had intensive discussions with the ITS team to integrate the potential earthquake risk into their spatial planning products such as the Surabaya Regional Plan No. 12 in 2014 (which was evaluated in 2018) and the Detailed Spatial Plan (which was legalised in 2018).

Since the rating assessment process has limitations on its validity, a more confident rating process was attained by including high-profile respondents who were involved in their capacity as experts in the field, rather than as representatives of particular agencies which could lead to biases, and using interviews to understand the reasons for their ratings and thereby increase their validity. Further, the respondents' comments were clarified with objective information from secondary data. Therefore, the final score for every variable and indicator was defined more confidently than in previous studies simply applying subjective ratings on resiliency indices.

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