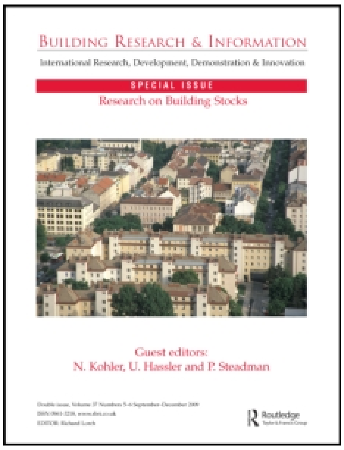

Building Research & Information

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713694730

Challenges to successful seismic retrofit implementation: a socio-behavioural perspective

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Online publication date: 11 April 2011

BRI BUILDING RESEARCH & INFORMATION (2011) 39(3), 286–300
Routledge Taylor & Francis Group

RESEARCH PAPER

Challenges to successful seismic retrofit implementation: a socio-behavioural perspective

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Seismic retrofit implementation has been a major challenge in many earthquake-prone cities. This paper examines why building owners are reluctant to adopt measures to reduce earthquake losses despite advancement in seismic design methods and the enactment of intervening legislative frameworks. A case study approach revealed the socio-behavioural barriers affecting seismic retrofit implementation. Significant barriers identified included the perception of earthquake risks, a lack of trust in seismic strengthening techniques and a lack of support for pro-social mitigation behaviours from public authorities. The findings suggest that a reappraisal of the policy implementation approach used by government agencies is required, and that greater attention should be given to seismic designs recommended by professionals and approved by regulatory authorities in order to earn building owners' trust regarding the efficacy of earthquake risk-reduction measures.

Keywords: building owners, decision-making, earthquake-prone buildings, public policy, risk perception, seismic retrofit, stakeholder behaviour

La mise aux normes parasismiques des constructions existantes est un défi majeur dans de nombreuses villes sujettes aux tremblements de terre. Le présent article examine pourquoi les propriétaires d'immeubles sont peu disposés à adopter des mesures permettant de réduire les sinistres dus aux tremblements de terre en dépit des progrès réalisés dans les méthodes de conception parasismique et malgré la promulgation de cadres législatifs d'intervention. Une approche par étude de cas a mis en évidence les barrières sociocomportementales affectant la mise en œuvre des normes parasismiques dans les immeubles existants. Ont été identifiés parmi ces obstacles importants la perception des risques de tremblements de terre, un manque de confiance dans les techniques de renforcement parasismique et un manque de soutien de la part des autorités publiques en faveur de comportements pro-sociaux permettant d'adoucir ces politiques. Les résultats obtenus suggèrent qu'il est nécessaire d'opérer une réévaluation de l'approche utilisée par les organismes publics pour mettre en œuvre ces politiques, et qu'il devrait être porté une plus grande attention aux conceptions parasismiques recommandées par les professionnels et homologuées par les organismes de réglementation de façon à gagner la confiance des propriétaires d'immeubles, s'agissant de l'efficacité des mesures de réduction des risques liés aux tremblements de terre.

Mots clés: propriétaires d'immeubles, prise de décision, immeubles sujets aux tremblements de terre, politique publique, perception des risques, mise aux normes parasismiques, comportement des parties prenantes

Building Research & Information ISSN 0961-3218 print/ISSN 1466-4321 online # 2011 Taylor & Francis
http://www.informaworld.com/journals
DOI: 10.1080/09613218.2011.552264

Introduction

Large-magnitude earthquakes are low-probability, high-consequence disaster events that typically involve severe fatalities, damage to properties and infrastructure, and social disruption. However, earthquake losses can be minimized or avoided with the appropriate implementation of mitigation decisions (Bostrom et al., 2006). In particular, the implementation of seismic rehabilitation of earthquake-prone buildings (EPBs) can significantly reduce earthquake damage to buildings and infrastructure (Dowrick, 2003). An EPB is considered in the current research as a building that will have its ultimate capacity exceeded in a moderate earthquake and would likely collapse causing injury or death to persons in the building or those on any other property or damage to any other property (Department of Building and Housing (DBH), 2004). Many communities within active seismic zones have placed much emphasis on understanding the scientific nature of earthquakes and developing technical solutions and legislative means to ensure that EPBs are seismically retrofitted to reduce earthquake losses, but these efforts have not resulted in satisfactory success (Tierney, 2005). Seismic rehabilitation of EPBs lags behind advances in scientific and engineering understanding because little attention has focused on understanding and developing strategies to overcome the barriers associated with implementing seismic retrofit solutions (Alesch and Petak, 2002). Critical barriers to successful seismic risk mitigation encountered by building owners were examined in the current study by adopting a socio-behavioural perspective and the paper sought to understand how these barriers affect seismic retrofit decisions. The research findings will assist in increasing the likelihood of building owners undertaking mitigation actions to reduce earthquake hazard vulnerability.

This research focused on pre-1976 buildings used for commercial purposes in the central business districts of many New Zealand cities, such as retail and office spaces. These older commercial buildings are often earthquake prone due to inadequate seismic strength, age and deterioration of construction materials. For instance, Wellington (New Zealand's capital city) has about 52% of its building stock classified as potential EPBs, deduced by raw property counts (Stevens and Wheeler, 2008). These potential EPBs were determined by a visual screening method, using the criteria specified in the local earthquake policy.

Background

Seismic retrofit implementation

The severity of past earthquake disaster losses has demonstrated the seismic vulnerability of various communities (Spence, 2007). Many seismologists and engineers have concluded that earthquake events should not necessarily lead to severe loss of life and property, if adequate pre-disaster mitigation measures are implemented to reduce seismic risk vulnerability of the built environment. As buildings with insufficient seismic capacity increase the seismic hazard vulnerability of the built environment and are the key contributor to earthquake losses (Spence, 2007), adequate seismic rehabilitation of potential EPBs will significantly reduce loss of life and damage to property from earthquake disasters (Bostrom et al., 2006). In this study seismic retrofitting refers to the application of pre-disaster measures such as structural and non-structural mechanisms to rehabilitate existing buildings that are otherwise vulnerable to earthquake hazards.

Individuals' response to hazard and risk mitigation differs, despite its many considerable benefits such as improved safety, social well-being and increasing building functional life, historic conservation, reduced property damage, and minimal business and individual dislocation during disaster (Rose et al., 2007). Some people respond to earthquake risk reduction by adopting mitigation measures; some choose to ignore it; while others accept the risk without undertaking any protective measures (Burton et al., 2002). Despite substantial research on earthquake hazard mitigation, increased public risk awareness and the development of effective mitigation measures such earthquake policies and structural design solutions, the frequency of seismic retrofitting of EPBs in New Zealand is low. The subsequent section discusses an overview of the New Zealand's earthquake mitigation policy and implementation process to offer insights on building owners' mitigation behaviours.

Seismic retrofit implementation in New Zealand

The New Zealand government enacted legislation in the Building Act (2004) to reduce seismic damage from EPBs, which has several implications that affect the adoption of seismic-mitigation measures. The legislation relating to EPBs seeks to reduce the level of earthquake risk to the public over time and targets the most vulnerable buildings. The Act stipulates that an existing building that requires alteration or a change of use must comply with the building code in the same manner as a new building (Sections 112–113). In compliance with the Act's regulations, seismic rehabilitation of EPBs often triggers other building code requirements such as fire performance and disability access. Cost implications due to these triggers often discourage building owners from voluntary seismic mitigation (Nakhies, 2009; Egbelakin and Wilkinson, 2008).

The Act recommends a minimum seismic retrofit level of 33% of the strength of a new building, referred to as the New Building Standard (NBS). The New Zealand

Society for Earthquake Engineering (NZSEE) (2006) guidelines report that a 33% NBS or less corresponds to a building being assessed as potentially earthquake prone in terms of the Act, and a more detailed seismic evaluation is required by law. A building seismic performance standard assessed as greater than 33% NBS means that the building is outside the requirements of the Act and the law requires no further action, while a 67% NBS or more means the building is not considered a significant earthquake risk. The minimum requirement of 33% NBS by the Act does not completely eliminate the non-ductile failure mechanisms or critical structural weaknesses in EPBs (DBH, 2008), and the NZSEE (2006) considered a 67% NBS as a more suitable minimum standard. The minimum earthquake performance level adopted by the Act and the differing NZSEE's recommendation of a higher seismic performance standard for buildings has created confusion and misinterpretation amongst building owners and other retrofit stakeholders regarding the retrofit level that provides the optimal result in terms of seismic strength and rehabilitation cost (Egbelakin and Wilkinson, 2008). Some building owners were found to adopt the lowest cost-permissible retrofit level without considering the hazard implication of such structural performance level (Hopkins, 2005).

The Act requires territorial authorities (TAs) to adopt and implement an EPB policy that addresses the issues of EPBs, while considering other community demands on available funds and resources. The Act allows TAs to determine the seismic retrofit level, policy implementation approach and timelines for strengthening EPBs, suitable to their respective regions (Sections 131–132). Despite the NZSEE's recommendation of a higher seismic standard, 73% of the TAs adopted seismic retrofit levels between 34% and ≤67% NBS, while 27% of TAs adopted 67% NBS (DBH, 2005). Anecdotal evidence suggests that the retrofit levels adopted by the different jurisdictions relate more to available human and financial resources, political demands and earthquake experience, rather than to seismicity. The Act's minimum requirement affects the TAs' commitment to earthquake hazard mitigation (Egbelakin and Wilkinson, 2008), which in most cases will not lead to consistent, strongly implemented, risk-reduction programmes across the medium- to high-risk jurisdictions (May and Birkland, 1994). Most TAs that adopted less than 50% NBS are unlikely to have proactive risk-reduction programmes, as evidenced in the adopted policies, with 27% of the TAs not specifying timetables for strengthening of the identified EPBs and 31% of the TAs having no public awareness programmes to promote mitigation within their jurisdictions (DBH, 2005). Conversely, adopting a high seismic level in local mitigation policy is politically difficult because additional economic burden is created for building owners and property developers (May and Birkland, 1994). Likewise, adopting a high seismic strengthening level in local TA policies is difficult for policy-makers because the benefits of seismic rehabilitation cannot be easily demonstrated, as these benefits only accrue at the time of an earthquake (Earthquake Engineering Research Institute (EERI), 1998).

In addition, the TAs could choose a passive, an active or a combined active–passive approach towards implementing their earthquake policy. The active approach includes a rigorous identification and detailed assessment of the potential EPBs, followed by either retrofitting or demolishing the identified EPBs within a time period of three to ten years, while in the passive approach seismic strengthening is triggered only by the application for a building alteration, change of use and the extension of the building's functional life. A total of 45% of the TAs chose the active approach; 32% chose the passive approach; and 23% chose the combined active–passive approach (DBH, 2005). TAs were advised to undertake an initial evaluation procedure (IEP) to identify the EPBs within their jurisdiction through a desktop review approach of councils' property documents (DBH, 2005). The owners of identified EPBs will be issued formal notices to strengthen or demolish their vulnerable buildings or to provide any building-specific information that may affect the initial evaluation within six months of receiving the notice (NZSEE, 2006). An IEP carried out by a high seismic-risk city (Wellington) reported that approximately 65% of identified potential EPBs owners did not respond to the notices issued to them, while 43% of EPBs owners who responded requested time extensions ranging from 15 to 25 years to implement seismic upgrade of their EPBs (Stevens and Wheeler, 2008). The low responses from EPBs owners to the IEP further indicate that EPBs owners are reluctant to implement risk-reduction measures, despite the potential vulnerability of their buildings to seismic hazard. Hence, it is necessary to understand the constraints that commercial building owners face when making retrofit decisions. An understanding of these barriers will help to develop strategies that could motivate building owners to strengthen their EPBs beyond the minimum required level. This study sought to examine the socio-behavioural constraints affecting seismic mitigation uptake.

Perception of earthquake risks and mitigation

Perception of risk affects how people make hazard-related mitigation decisions (Lindell and Prater, 2002). The relationship between risk perception and mitigation decisions has been widely studied across several disciplines (Lepesteur *et al.*, 2008; Tierney *et al.*, 2001; Lindell and Prater, 2002; Mulilis and Duval, 1995; Weinstein *et al.*, 1998; Lindell and Prater, 2000). According to Dash and Gladwin

(2007), risk perception is mainly shaped by how people interpret and personalize hazard and its related impacts. The impact of perceived personal risk from seismic hazard on mitigation decisions has been attributed to various factors such as earthquake occurrence and severity (Lindell, 1994; Mileti and Peek, 2002). The continuing uncertainty associated with earthquake risks impedes the ability to make the best possible decision (Bradley et al., 2008; Nigg, 1982). Likewise, less severe earthquake events with little or no impact can make people perceive the adoption of mitigation measures as less significant (Tierney et al., 2001).

Many theoretical models relating to the adoption of precautionary behaviours underscore the importance of understanding the role of perception in the uptake of mitigation measures. Protection Motivation Theory (PMT) (Rogers and Prentice-Dunn, 1997) postulates that perception regarding the severity and vulnerability of a threat (e.g., earthquake disaster) and the effectiveness of response options (e.g., mitigation measures) underlie people's adoption of protective behaviours. Similarly, the Theory of Planned Behaviour (TPB) (Ajzen, 1991; Ajzen and Fishbein, 1985) argues that behaviour is a product of intentions predicted by three factors: people's attitude toward the target behaviour, perceived subjective norm (their judgments about social pressures to perform an action) and perceived behavioural control (perception of how difficult it is to perform the target behaviour). TPB claims that people's response to a situation (e.g., their preparation for a hazard) is affected more by their beliefs about the efficacy of the response behaviour (e.g., mitigation measures) than by their beliefs about the hazard itself (e.g., earthquake event). In addition, the Protective Action Decision Model (PADM) (Lindell and Perry, 1992; Lindell and Prater, 2003) also emphasized the role of perception on protective behaviours. PADM posits that perception of risk and beliefs, alternative protective actions and the prevailing conditions that allow one to pursue protective options consequently affect the type of mitigation decisions made. These theoretical models are supported by several research on household vulnerability to earthquake risks reviewed by Lindell and Perry (2000), and the findings regarding the correlations that exist between the factors affecting households preparedness towards reducing seismic risks (Lindell et al., 2009; Lindell and Prater, 2002; Whitney et al., 2004).

Although preparedness towards an earthquake event such as seismic retrofitting of EPBs can reduce earthquake disaster impacts, a number of seismic zone residents hold a fatalistic belief that implementing mitigation measures will not prevent damage from earthquakes (Turner et al., 1986; Lindell and Perry, 2000). A fatalistic attitude hinders disaster reduction (Smith, 2009; Lindell and Hwang, 2008) and has been attributed to a lack of awareness of effective measures that can reduce disaster damage or measures that meet individual resource constraints such as retrofit cost, knowledge and skills requirements (Lindell and Hwang, 2008). Perception regarding available resources to mitigate seismic risks (Lindell and Prater, 2002; Palm, 1995) is similar to the assumption of the Person Relative to Event Theory (PrE) (Mulilis and Duval, 1995), that an individual is likely to adopt strategies that will mitigate a threat such as an earthquake event, if the appraised available level of resources is adequate to reduce or avoid the threat. Palm et al. (1990) found that the cost of a mitigation measure such as an earthquake insurance when overestimated often increases individuals' perceived inability to afford it. Many empirical research studies on earthquake risk reduction adopting the aforementioned theoretical models show that modest levels of risk-reduction measures implemented relate to factors such as perception and beliefs about the hazard (severity and probability of occurrence), perception and appraisal of resources to mitigate risk, fatalistic attitudes, the efficacy of the mitigation measures, knowledge and skills requirements, and demographic characteristics (Whitney et al., 2004; Grothmann and Reusswig, 2006; Lindell and Hwang, 2008; Russell et al., 1995; Lindell et al., 2009; Lindell and Prater, 2000; Lindell and Prater, 2002; Weinstein et al., 1998; Eagly and Chaiken, 1993; Paul and Bhuiyan, 2010; Celsi et al., 2005).

Risk communication and an awareness programme are significant parameters that can ameliorate people's perception about risk mitigation (MacGregor et al., 2008; Keeney and Winterfeldt, 1986). Neuwirth et al. (2000) explored the use of PMT on the impact of perception on the risk communication and found that providing sufficient information about the risk and efficacy of mitigation measures produces greater rates of willingness to adopt protective behaviours. One of the concerns regarding risk communication is whether the information provided will be effectively communicated to generate enough concern and response. Bourque et al. (2010) suggested that in order to generate an effective response from risk communication, the distribution of earthquake preparedness materials should include a mix of passive and proactive approaches that utilizes both traditional and emerging information technologies. However, enhancing protective behaviours through risk communication and awareness programmes is challenged by several complex factors related to personal attitudes, socio-economic and cultural issues (Enders, 2001; Rohrmann, 1998). A better understanding of the interrelationships between risk perception and communication, socio-behavioural factors and mitigation decisions is necessary because such findings could highlight the constraints relating to the uptake of seismic mitigation measures and may suggest possible strategies to overcome such barriers.

Sociological perspective of seismic retrofit implementation

Research on hazard management in recent years has leaned towards understanding the impact of the social factors and processes on earthquake risk mitigation. The disparities that exist between experts and the public in hazard risk management has been the primary motivation for this research orientation (MacGregor et al., 2008). These disparities can be explained by the Social Amplification of Risk Framework (SARF) (Pidgeon et al., 2003), which provided a methodical approach for analysing how perceived risk and outcomes of disaster events interact with psychological, social, institutional and cultural processes to produce substantial impacts upon society and economy. Kasperson et al. (1988) explained that the interaction that amplifies risk perception occurs at two stages: in the transfer of risk information and in the society's response mechanisms. This interaction is characterized by factors associated with individuals, social or government agents, which include trust, confidence, expectations, and beliefs that people have in risk-management organizations and past experience of dealing with such organizations (MacGregor et al., 2008).

The role of trust and belief in the mitigation decision-making process is apparent in all aspects of social interactions, such as those that exist between government organizations, industry practitioners and the public (Douglas, 2008). According to Paton (2007), people tend to rely more on experts sources before making decisions due to their lack of experience, when they process information about risks and the proposed mitigation options. Inconsistency and disparity in risk information provided by presiding organizations reduce its credibility, diminish public trust and reduce the ability of the information to assist in making constructive mitigation decisions (Poortinga and Pidgeon, 2004; Paton, 2007). Similarly, Johnston et al. (2005) found that trust declined when residents perceived that civic agencies are putting economic factors ahead of community welfare, which was due to inadequacies in risk information. Earle (2004) explained that lack of trust undermined the assumptions people make concerning the motivation of those providing the information, their motives, competence and reliability of the information provided. Other sociological factors that affect how people perceive and respond to risk mitigation include individual and community interrelationships toward mitigation, pro-social mitigation behaviours within the community, and how the implementation of government-initiated programmes and policies affect preparedness towards reducing hazard vulnerability (Renn and Levine, 1991; Slovic, 2001; Horlick-Jones et al., 2003).

Government-initiated policies and programmes affect community preparedness towards seismic risk mitigation (May and Birkland, 1994). Policy-makers and governments have now realized the significance of community participation in the design, enactment, and implementation of mitigation policies and strategies. Successful preparedness towards natural hazards involves effective outreach and community agreement over mitigation approaches (McIvor et al., 2009; Burby et al., 2000). Community participation in the design and enactment of mitigation policies and programmes could legitimate the mitigation decision-making process and encourage support for policy choice (Donner, 2008). Pearce (2003) suggested that disaster management should incorporate community planning and public participation at the local decision-making level to achieve sustainable risk mitigation. Comerio (2004) recommended the use of performance-based policies that allow for change and a means of negotiation to achieve the desired mitigation objectives instead of the commonly use prescriptive policies. In summary, previous research on earthquake hazard and risk mitigation has used several measures to understand the factors affecting the uptake of mitigation measures. An important aspect of earthquake hazard reduction identified by the New Zealand Historic Place Trust (NZHPT) focused on how to understand the socio-behavioural constraints existing among several stakeholders involved in seismic retrofit implementation in different seismic risk regions in order to motivate EPBs' owners to improve their buildings seismic performance voluntarily (McClean, 2009). The findings from this study are intended to fill this gap.

Research method

The objective of the research reported in this paper was to investigate the socio-behavioural barriers affecting seismic risk-reduction measures. The identification of these barriers was approached in two ways: firstly, by examining and understanding the behavioural and sociological factors affecting seismic retrofit decisions; and secondly, by exploring the impacts of the regulatory framework on earthquake risk mitigation.

Case study

A case study research method was adopted and interviews chosen as the method of data collection. Cases and participants were selected through a purposeful sampling procedure based on the research objectives and questions, which are limited to the study populations and the example cases. An interview protocol was used as the data collection instrument (see Table A1). Thirty-five interviews were conducted in four geographic regions chosen using a risk-based selection method, with criteria such as seismicity, hazard factor, and percentage of retrofitted and non-retrofitted EPBs (Table 1). Standards New Zealand (2004) specifies the earthquake hazard factor (Z) (the equivalent to an acceleration coefficient with an annual probability of exceedance in 1/500)

Table 1 Summary of cases

Case number	Hazard factor (*Z*)	Level of earthquake risks	Last significant earthquake	Percentage of earthquake-prone buildings (EPBs)	Retrofit standard adopted	Mitigation approach	Number of interviewees	
1	0.13	Low	October 2010	42	33% NBS	Passive	BO = 3; PRO = 1; GO = 1; PV = 1	8
2	0.22	Medium	September 1888	48	33% NBS	Passive	BO = 4; PRO = 1; IP = 1; GO = 1; PV = 1	10
3	0.36	High	December 2007	68	67% NBS	Active	BO = 4; PRO = 2; IP = 1; GO = 1; PV = 1	7
4	0.40	Very high	August 1942	52	33% NBS	Active	BO = 4; PRO = 2; IP = 1; GO = 2; PV = 1	8

Note: BO = building owners; GO = governmental organizations; IP = insurance providers; NBS = New Building Standard; [Editor1]PRO = professionals; PV = property valuers.

for different locations in New Zealand. According to Standards New Zealand, earthquake hazard factor and seismicity are used to establish the probability and severity of a seismic event, which varies between provinces. Likewise, EPBs are determined using the performance achievement ratio (PAR), a measure of an individual building's expected performance in an earthquake event, independent of location and which primarily takes into consideration the critical structural weakness such as plan, vertical irregularity and pounding potential (Standards New Zealand, 2004).

The selection of the cases was also determined by the desire to understand the variations in people's perception of earthquakes and the impact of the regulatory framework on present mitigation efforts of the different jurisdictions. Four of the 15 cities in New Zealand selected for study showed diversity in seismicity, mitigation efforts, past earthquake events, economic resources and population (Statistics New Zealand, 2010). For instance, Case 4 is a city with a very high seismic risk, a population of 483,200 people and a sub-national GDP of US$142.5 million, but with no recent earthquake event since the last decade, while Case 3 is relatively a high-risk city with a recent seismic event, a population of 46,600 people and a sub-national GDP of US$66.3 million. Case 2, though identified as having a medium seismic risk, has a recent earthquake magnitude of 7.1 with severe damage to properties, infrastructure and lifelines.

The stakeholders selected for the research include building owners, property valuers, engineers and architects, managers of insurance, financial and governmental organizations that have been involved in the seismic rehabilitation of EPBs. Building owners include both persons who have and have not retrofitted their EPBs, while other participants chosen for the interview had at least a minimum of two years' recent involvement in EPB retrofit projects.

The primary research conducted the interviews within a period of three months, while participants were contacted via e-mail and telephone. A personal face-to-face interview technique was used because it allows an in-depth understanding of the research topic and the use of intensive probing questions to gain more insight into the research problem. A semi-structured questionnaire was adopted as the data-collection instrument because it allows for structure, spontaneous discussion and follow-up questions on the research topic. The interviews conducted ranged from one to two hours and were audiotaped, with the interviewee's permission. In identifying the critical barriers and analysing the interviews, the main questions explored were:

- How do you perceive the probability and severity of an earthquake event in your region?
- Given the nature of your business/profession, can you describe the strategies that you employ in reducing earthquake risks?
- What are the challenges that you encountered when you were involved in any seismic retrofit project?
- Can you describe the benefits and values you associate with retrofitting EPBs?

Data analysis

In order to analyse the data collected, the recorded interviews were transcribed. The transcripts provided a complete record of the interviews, which facilitated the content analysis of the discussions. All interview transcriptions were analysed thematically for qualitative content, using NVIVO software for qualitative data analysis. The software allows the development of themes and categories and the comparative analysis of the text codes under the same category to ensure consistent coding and interpretations. The main objective of the analysis was to identify trends or themes that appeared or were repeated in the interviews. In order to ensure the reliability and validity of the results, care was taken to ensure that the information provided by participants was transcribed accurately and validated by them. The interview analyses were done in two ways. Firstly, each interview was analysed as an individual case study, using the participant as the unit of analysis, i.e. 'within case'. Secondly, the cases were analysed 'across cases' using each city as a case. The two-levelled analysis allowed theoretical explanations of themes and patterns, similarities, differences and outliers in the identification of the barriers that hinder the adoption of seismic mitigation measures. The use of an interview protocol and coding scheme ensured consistent coding. Independent checking of the coding scheme and interview coding were conducted to ensure data reliability. The research findings were sent to the participants and industry experts for confirmation and comments to establish the validity of the results. Finally, all the identified themes and subthemes were categorized separately and discussed in relation to the different cities (Tables 3 and 4).

Participant characteristics

Participants' characteristics are summarized in Table 2. A majority of participants were in the senior management category. A total of 45% were building owners, while 55% were other stakeholders' involved seismic retrofit decisions. Three types of owners were identified: private (53.3%), public (26.7%) and non-profit (20%). A total of 42% of the participants had personally experienced an earthquake. The average working experience of the participants in seismic retrofit building projects was 5.5 years, with a minimum of 3 years and and a maximum of 8 years. The average of 5.5 years' experience indicates that most respondents had reasonable working experience in seismic retrofitting of EPB projects.

Barriers to seismic retrofit implementation

The research findings showed the different sociological and perception-related barriers to seismic risk mitigation. The findings suggest the need to adopt a broad-ranging perspective in addressing these barriers to achieve meaningful impacts on earthquake risk mitigation.

Perception-related barriers

The reported findings in this section focused on how risk perceptions affect mitigation decisions. Table 3 illustrates how the perception of risk differs widely among the stakeholders involved in seismic retrofit implementation.

Perception about possible earthquake event and risks

The perception of risk plays an important role in decisions people make. Interview findings reported in Table 3 indicate that the participants living in cities with low (80%; Case 1) and medium seismic risks (60%; Case 2) are less concerned about earthquake risks and earthquake occurrence. A total of 58% of the building owners interviewed did not perceive that they or their buildings were at risk from earthquakes, regardless of whether they has been served notices by their territorial authority (TA). A total of 91% and 87% of the participants in Cases 1 and 2 respectively were not willing to undertake any mitigation actions in the next five years. These participants believed that an earthquake event would not happen in their lifetime or have significant impacts on their buildings and therefore there was little or no need to adopt risk-preventive measures such as seismic retrofit.

The passive mitigation approach adopted by the TAs could prevent owners from perceiving that their

Table 2 Participants' profile

Characteristic	Category	*n*	Percentage	Characteristic	Category	*n*	Percentage
Participants	Building owners	15	45.5	Years of experience with earthquake-prone buildings (EPBs)	≤ 5years	3	9.1
	Professionals	6	18.2		6–10 years	7	21.2
	Insurance providers	3	9.1		11–15 years	6	18.2
	Governmental organizations	5	15.2		16–20 years	8	24.2
	Property valuers	4	12.1		21–25 years	4	12.1
Type of ownership	Private owners	8	53.3		>25 years	5	15.2
	Public owners	4	26.7	Location	Wellington	8	24.2
	Non-profits	3	20.0		Gisborne	10	30.3
Designation	Upper management	23	69.7		Christchurch	7	21.2
	Middle management	7	21.2		Auckland	8	24.2
	Professionals	3	9.1	Personal experience of earthquake	Yes	14	42.4

Table 3 Perception related barriers

Barriers	Case 1: Low risk	Case 2: Medium risk	Case 3: High risk	Case 4: Very high risk
Perception about possible earthquake event and risks	80% of participants are less concerned about earthquake risks and occurrence 91% are not ready to take action	60% of participants are less concerned about earthquake risks and occurrence 87% are not ready to take action	2% of participants are less concerned about earthquake risks and occurrence 28% are not ready to take action	13% of participants are less concerned about earthquake risks and occurrence 10% are not ready to take action
Possible causes	*Low probability of earthquake risks Passive approach adopted by the territorial authorities (TA)*		*High probability of earthquake risks TA mitigation approach High public awareness of earthquake risks*	
			Recent significant earthquake Present insurance issues Future changes in earthquake policy	*Recent changes in earthquake policy*
Perception that earthquake risks and losses are unavoidable	28% of participants believed losses cannot be mitigated	37% of participants believed losses cannot be mitigated	37% of participants believed losses cannot be mitigated	18% of participants think believed losses cannot be mitigated
Possible causes	*Individual beliefs*	*Individual beliefs, professional understanding*		
Perception about financial involvement for earthquake mitigation	76% of participants perceived that a high seismic standard is equivalent to high cost	56% of participants perceived that a high seismic standard is equivalent to high cost	53% of participants perceived that a high seismic standard is equivalent to high cost	36% of participants perceived that a high seismic standard is equivalent to high cost
Possible causes	*Lack of cost–benefits analysis at the design stages Year of experience in earthquake-prone building projects Lack of in-house professionals*			

Table 4 Sociological barriers

Barriers	Case 1: Low risk	Case 2: Medium risk	Case 3: High risk	Case 4: Very high risk
Lack of trust and belief in seismic techniques and professionals	22% of participants lack trust in seismic design solutions and professionals	42% of participants lack trust in seismic design solutions and professionals	67% of participants lack trust in seismic design solutions and professionals	48% of participants lack trust in seismic design solutions and professionals
Possible causes	*Absence of any significant earthquake*	*Disparities among consulting engineers*	*Impact of a recent earthquake Disparities among consulting engineers*	*Disparities among consulting engineers*
Pro-social mitigation behaviours	22% of participants encourage a public recognition award for pro-social mitigation behaviours	72% of participants encourage a public recognition award for pro-social mitigation behaviours	56% of participants encourage a public recognition award for pro-social mitigation behaviours	61% of participants encourage a public recognition award for pro-social mitigation behaviours
Possible causes	*Heritage-related values Safety and public recognition*			

buildings were at risk from earthquakes. One owner in Case 2 mentioned that:

> I don't think my building is at risk again from earthquake since the last policy change because I have not been served any notice regarding it, but I think one of buildings in Wellington is at risk because I have been notified by the council.

From the findings, the perception about the possible occurrence of an earthquake disaster was associated with uncertainties in earthquake predictions, risk judgements, TAs' passive mitigation approach and the retrofit levels adopted in earthquake policies (Table 1). Conversely, 98% and 87% of the participants in high-risk cities (Cases 3 and 4) showed concern about earthquake risks, which was attributed to those cities' high susceptibility to earthquakes and the public's awareness of earthquake risks due to the TA's active approach to seismic hazard mitigation. Despite the concern about seismic risks, 28% of participants in Case 3 were not willing to undertake mitigation actions in the next two to five years, while 90% of the participants in Case 4 would delay implementing retrofit until after a period of 10–20 years. These findings revealed that irrespective of the high disaster-awareness level in New Zealand, a strong assumption exists among the interviewees that an earthquake event will always have less severe impacts on their buildings.

A willingness to implement mitigation measures among the participants in Case 3 relates to the recent significant earthquake, present insurance issues due to the earthquake and possible future changes in the TAs' earthquake policy. This willingness demonstrated by participants in Case 3 indicates that the recent earthquake promoted the efficacy of the mitigation measures adopted by some owners, thus diverting people away from their fatalistic attitude and belief. The delay in undertaking seismic retrofit implementation in Case 4 relates to the recent increased timeline to implement seismic rehabilitation adopted in the TA's earthquake policy. The findings also showed that owners' geographical distances from the building could influence their commitment to seismic retrofit implementation. Some owners who lived in low-risk regions, but who had properties in medium-risk regions, showed less concern about adopting mitigation measures.

Perception that earthquake risks and losses are unavoidable

The interviews showed that opinions regarding earthquake loss reduction differ. The majority of building owners believed that losses from large earthquake disasters were unavoidable, but that damage could be reduced substantially. A total of 66% and 72% of the participants in Cases 3 and 4 believed that adopting a high seismic standard during retrofit implementation could reduce earthquake damage. The belief about earthquake loss mitigation can be associated with individual beliefs, professional understanding of seismic risks, personal earthquake experience and years of experience in seismic retrofitting of EPBs (Lindell and Prater, 2002; Lindell et al., 2009; Mileti and Fitzpatrick, 1993). In Case 3, some of the participants who experienced the last significant earthquake mentioned that undamaged buildings were because of the higher strengthening level adopted during rehabilitation. One owner mentioned:

> Thank God I listened to the building officer at the district council, who advised me to adopt higher seismic standard, my building has very minimal damage unlike those of my neighbours. This earthquake has demonstrated the difference between high and low retrofit levels adopted.

A total of 87% of the building owners in Case 3 agreed that adopting a higher seismic standard before an earthquake event was profitable (when the cost of retrofit was compared with damage cost). This belief promotes protective behaviours among owners. Conversely, 22% of the building owners interviewed understood their city's seismic risks and vulnerability but would not undertake any mitigation action, as they believe that earthquake damage was not preventable. This misconception is predominant among owners of older buildings (more than 70 years) whose buildings were affected by earthquake despite previous seismic upgrade. It is possible that these building owners have a fatalistic and erroneous belief that dictates against attempts at risk-reduction measures (Lindell and Prater, 2002; Lindell et al., 2009; Mileti and Fitzpatrick, 1993; Alesch and Petak, 2002). Belief about seismic risk and mitigation can also relate to an owner's personal characteristics, financial circumstances (Lindell and Perry, 2000) and risk propensity (McClure et al., 1999).

Perception about financial involvement in earthquake mitigation

The financial implication of seismic retrofit of EPBs is a driving force affecting mitigation decisions (Egbelakin and Wilkinson, 2008). The interview findings revealed a preconception regarding the relationship between higher seismic strength and retrofit cost. This preconception involves the belief that doubling a building's seismic strength doubles the retrofit costs. Findings reported in Table 4 show that across the cases participants living in high seismic-risks cities (53%, Case 3; and 36%, Case 4) agreed that a high seismic retrofit level correlates to a higher cost while in Cases 1 and 2, 76% and 56% of the participants also believed this preconceived correlation, respectively. The percentages of participants who agreed to the higher standard–higher cost correlation in Cases 3 and 4 (high-risk cities) were lower than in Cases 1 and 2 (low- and medium-risk cities). It was deduced from the interviews that the perception of this correlation could be attributed to the high percentage of seismic retrofitted projects implemented within the cities. The various retrofit projects conducted within these cities increase experience in the project cost estimation, which consequently reduce the preconceived notion.

Furthermore, among building owners the belief that high seismic strength correlates to higher cost was found predominantly among private and non-profits owners (private owners, 35.7%; public owners, 7.43%; non-profits owners, 21.4%). Public owners do not share the higher standard/higher cost belief, which is due to the various EPB projects retrofitted by public owners. Private and non-profits owners' seismic strength versus cost understanding is due to a lack of experience in retrofitting EPBs. The cost of improving a building's seismic performance varies, making the total cost estimation difficult (EERI, 1998). The cost variation largely depends on a number of factors such as location, structure type, individual building characteristics, rehabilitation scheme, desired performance level and other works triggered by retrofit decisions (Bradley et al., 2008). One participant mentioned that in his recent retrofitted building the difference between adopting a lower (33% NBS) and higher (67% NBS) seismic retrofit level was only US$8400. Presently, evidence of a linear relationship is yet to exist between seismic retrofit level and retrofit cost even though the circumstance surrounding each building differs (Baker and Cornell, 2008).

Sociological barriers

Many international organizations and governments have recognized that sociological barriers to seismic hazard mitigation must be bridged in order to achieve successful implementation of hazard management strategies. Sociological barriers impeding the implementation of seismic retrofit implementation are discussed below.

Lack of trust and belief in seismic techniques and professionals

The interviews revealed that trust and belief in delegated authorities have a significant influence on mitigation decisions, revealing a need for owners of EPBs to have trust in the design engineers and a belief in the seismic structural solutions recommended. The findings in Table 4 show that trust and belief are highly interrelated; owners' trust in professionals influences their belief in the retrofit solutions. Participants' belief in seismic retrofit techniques differs between the cases. In Case 1, 22% of participants indicated that they do not believe the seismic retrofit techniques available in New Zealand. Participants' belief in Case 1 relate to the absence of any significant earthquake in the region, as the seismic retrofit solutions adopted are yet to be tested. Cases 2 and 4 have a close range of 42% and 48%, respectively; while Case 3 has the highest percentage of participants (67%) with no belief in engineering techniques.

Insights from the interviews suggest that the differences in the responses to questions about trust and belief in seismic retrofit techniques and engineers across the cases relate to the damage to new buildings by the recent earthquake event. Damage to new buildings with supposed high seismic strength affect people's perception of the design engineers and the efficacy of the structural solutions recommended. The study further discovered that disparities among consulting engineers in New Zealand contributed to the lack of trust in seismic retrofit professionals. Engineers do not have a consensus on the appropriate seismic level that should be adopted when owners are considering rehabilitating their EPBs. Most owners become confused when two engineers recommend strengthening levels that differ widely. They interpret the widely varying recommendations as incompetence.

Pro-social mitigation behaviours

Pro-social behaviour refers to voluntary actions that are intended to help or benefit another individual or society (Eisenberg and Mussen, 1989). In earthquake risk mitigation, pro-social behaviours include actions that an individual or group of people do to promote seismic rehabilitation of EPBs (Goodwin, 2009). The value that people ascribed to a particular attribute (e.g., heritage building) determines its importance, decision weight, which consequently promotes voluntary actions towards a target behaviour (seismic mitigation) (Dahlgaard and Dahlgaard, 2003). The findings reported here found that values that individuals or a group of people assigned to heritage buildings can promote mitigation behaviour and action towards such buildings. A total of 73–81% of participants across all cases (Cases 1–4) accorded high values to EPBs with heritage values. The participants emphasized heritage buildings as important cultural artefacts worth saving. The emphasis on the heritage values of EPBs is also evident in the TA's earthquake policy, which mandates higher seismic strengthening for heritage buildings and further provides monetary incentives for retrofitting. However, buildings without heritage value are not considered necessary for retrofitting by this group of people exhibiting the pro-social behaviours, thereby impeding the adoption of mitigation measures for non-heritage EPBs.

Another pertinent issue with pro-social mitigation behaviour is the lack of support for personal contributions to the preservation efforts of historic EPBs. A total of 56–72% of EPBs owners from Cases 2–4 explained that although the cities support heritage conservation of EPBs through incentives, personal contributions to preserve these buildings are not recognized. The absence of public recognition of efforts towards seismic risk mitigation does not encourage pro-social mitigation behaviour and investment in EPBs. Buildings retrofitted adequately should be publicized to increase public awareness about seismic retrofit implementation. However, in Case 1 only 22% of participants viewed public recognition award as a promoter of seismic mitigation of EPBs, which relates to the city's low seismicity (Table 1), signalling that the participants viewed seismic retrofit implementation as insignificant. However, in Case 2 the TA had embarked on appreciating building owners' contribution to seismic risk mitigation, leading to a slight increase in EPB retrofitted projects.

Discussion

Findings across all cases showed that people are generally aware of earthquake risks and severity within their regions, but most building owners are not willing to retrofit their EPBs. Sociological and perception-related barriers revealed in this study contribute to owners' lack of willingness to retrofit their EPBs. Significant perception-related barriers found are perception regarding a possible earthquake event, earthquake losses and the financial implication of seismic retrofit implementation. One participant (an owner of an EPB) mentioned:

> Every day, several earthquakes occur in New Zealand but I do not think a disastrous one can occur in the next 100 years. Moreover can one actually prevent the damages, well I don't think so.

This statement and several other similar assertions from the interviews indicate that perception regarding the uncertainty of earthquake occurrence, the impact of less severe earthquakes and the efficacy of mitigation techniques recommended by professionals deter building owners from adopting preventive measures. The research findings reported here confirm the results of Lindell and Prater (2002) on the perception of hazard-related attributes (earthquake uncertanity and severity) and efficacy of hazard adjustments (effectiveness of mitigtaion measures). One way to reduce the perception regarding earthquake uncertainty and severity is through adequate risk definition and provision of information implemented with sound communication principles (Tierney *et al.*, 2001). Appropriate risk communication can also help to reduce fatalistic mindsets and improve trust in seismic techniques (Neuwirth *et al.*, 2000). Incorporating recommendations by Bourque *et al.* (2010) discussed previously could improve the effectiveness of publicizing hazard-awareness programmes and mitigation efforts.

The appraisal and belief in the availabe resources to mitigate seismic risk can enhance the decisions to adopt risk-reduction measures (Ajzen and Fishbein, 2005; Mulilis and Lippa, 1990). The interviews showed that most participants have a preconceived notion that overestimate the cost of adequate seismic retrofit-mitigation measures that will sufficiently reduce the risks posed by EPBs, leading to underinvestment in risk-reduction measures. Hopkins (2005) found that some building owners adopt a lower seismic retrofit level, without considering the hazard consequences of their decisions. These findings confirm the assumption of the Person Relative to Event (PrE) Model and Theory of Planned Behaviour (TPB), and are consistent with the results of Lindell and Prater (2003) and Palm (1995) that relate to the availability of resources and opportunities to perform a target behaviour. Enhancing people's belief about the required capabilities and resources necessary to reduce earthquke risk could be achieved through public awareness regarding effective mitigation measures that are within individual resource constraints. Overcoming the perception-related constraints in seismic retrofit implementation is important because the likelihood of promoting the uptake of mitigation measures is dependent upon the perceived benefits and resources to reduce earthquake risks.

Insights from the interviews suggested that earthquake-mitigation approaches adopted by local authorities could affect how the stakeholders perceive seismic risks and make mitigation decisions. Several implications could result from the approach adopted by TAs. The active approach that includes proactive risk communication, awareness programmes and encouraging building owners to adopt adequate seismic retrofit standard for their EPBs will promote a constructive risk-preventive behaviour leading to an increase in the EPBs' rehabilitation projects, while a higher percentage of high-risk buildings remained untouched by the passive approach. Rigorous public awareness and participation in the design and implementation of hazard mitigation policies allow individuals and the community as a whole to perceive seismic risks as a potential threat, accept the risk and contribute to its mitigation (Bourque *et al.*, 2010). Community participation in formulating and implementing mitigation strategies that include popular approaches peculiar to the region and local opinions can increase the adoption of mitigation measures (Lindell and Prater, 2002).

The sociological barriers identified include a lack of trust and a belief in seismic techniques and professionals and a lack of appreciation for pro-social mitigation behaviour. These are widespread across the risk zones. The study found that trust could improve the effectiveness of interpersonal relationships that exist among the stakeholders when dealing with high-uncertainty risks such as earthquakes. Owners' lack of trust in the seismic retrofit professionals relate to their previous experience of dealing with them, leading some owners to discredit their advice on mitigation measures. The study found that disparities in advice from structural engineers contribute to the lack of trust in information about seismic techniques and professionals. Consulting engineers need to reach a consensus on the acceptable level for seismic retrofit necessary to eliminate the danger associated with EPBs and to avoid building owners' confusion and mistrust. One recommendation to increase trust between professionals and owners of EPBs relates to the advice that building owners received regarding possible outcomes of the retrofit solutions selected in the event of an earthquake. This advice might help to reinstate their recommendation in the event of an earthquake, which is evident from the findings reported in Case 3. Professionals and regulatory authorities should pay more attention to the structural designs they recommend and approve. Stakeholders involved in seismic retrofit decision-making process are therefore encouraged to develop a better understanding of the seismic risks and the implications of their corresponding retrofit decisions. Douglas (2008) explained that maintaining and developing trust in relationships is necessary to foster the successful implementation of earthquake hazard-mitigation strategies, and laid emphasis on the need to adopt a systematic development of insights into the role of trust in risk-management strategies.

A lack of encouragement for pro-social mitigation behaviours is another significant barrier that calls attention in earthquake risk management. One of the advocates for heritage preservation mentioned that:

> Our group have done so much to promote and rehabilitate many EPBs religious buildings in our community, yet nobody seems to notice our efforts.

A lack of support and incentives to promote heritage conservation of EPBs may cause advocates to lose interest in promoting the preservation philosophy and such behaviour may become extinct (McCoy, 1992). Besides, people exhibiting pro-social mitigation behaviours can become important entrepreneurs and advocates for issues they propagate. Prater and Lindell (2000) emphasized the importance of policy entrepreneurs in framing hazard-mitigation issues as significant, until adequate policy is formulated and adopted. It is recommended that programmes that will encourage and publicize positive pro-social mitigation behaviour should be initiated. However, the implementation and success of such programmes require further research.

Conclusions

Several social and perceptual barriers relating to the adoption of risk-reduction measures were revealed in this study. The identified perception-related barriers to seismic hazard mitigation in New Zealand concerned possible earthquake event and risks, earthquake losses, and the financial implication seismic retrofit implementation. The sociological barriers identified include a lack of trust and beliefs in seismic retrofit techniques and professionals, and a lack of support for pro-social mitigation behaviour. Differences in earthquake risk perception lie at the heart of disagreements about the best course of action between the various stakeholders involved in mitigation plans, which act as a barrier to seismic retrofit implementation. Hence, stakeholders should reach a consensus regarding the reasonable seismic retrofit level adequate for earthquake-prone buildings (EPBs) with minimal differing margins.

It is important to acknowledge the limitation of this research. Participants interviewed do not exactly mirror the population from which they are drawn, which raises questions about the generalization of the results.

Notwithstanding the sample's limitation, findings from this study do have several practical implications for policies that aim to increase building owners' adoption of seismic mitigation measures. An appraisal of the policy implementation approach adopted by some the territorial authorities (TAs) is needed. TAs within medium- to high-risk zones should adopt an active implementation approach, coupled with proactive public awareness programmes and community engagement in order to improve the TAs' commitment level and to achieve consistent earthquake mitigation strategies across the regions. This reappraisal should incorporate the suggestions from Comerio (2004) and Bourque et al. (2010) regarding performance-based policies, community participation and awareness programmes. In addition, the provision of financial incentives (such as loan interest loans and grants) specifically for seismic retrofitting should be introduced in the policy-implementation programmes, which can be partly funded by central government for jurisdictions that lack the necessary financial resources. The introduction of incentives will reduce the economic burden on building owners, thereby allowing owners to retrofit their EPBs. However, further research is needed in order to develop effective incentives and reward strategies that would enhance seismic retrofit decisions. Further research is also necessary to examine the interrelationships that exist between earthquake risk perception, vulnerability and the development of pro-social mitigation behaviour, as well as the adequacy of using publicity to promote pro-social mitigation behaviour.

Findings from this research are beneficial to both researchers and professionals involved in seismic rehabilitation of EPBs. The results of this current study add to the growing body of literature examining the socio-behavioural aspect of earthquake hazard mitigation by supporting the claims made by many theorists relating to the uptake of precautionary behaviours. The findings offer new insights into the impacts of expert-driven regulatory frameworks on mitigation decisions, across different ownership types and stakeholders involved in earthquake hazard mitigation.

Acknowledgements

This research is part of the collaborative project on implementing seismic retrofit solutions between the University of Auckland and Canterbury University in New Zealand. The authors gratefully acknowledge the support from the New Zealand Foundation for Research, Science and Technology (FSRT) under the Research Grant No. UOAX411. The authors thank the anonymous *Building Research & Information* referees for their useful comments.

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Appendix

Table A1 Interview protocol by research questions

Research question	Discussion areas or probes
How do you perceive the probability and severity of an earthquake event in your region?	• Understanding of seismic events, its frequency and severity • Awareness of seismic hazard and risk • Country and participant's residing region (location) seismicity knowledge • Earthquake experience and prior losses • Expected damage • Hazard concern • Prior adoption of mitigation measures
Given the nature of your business/profession, can you describe the strategies that you use in reducing earthquake risks?	• Structural design solutions (cost implications and perceived effectiveness) • Seismic retrofit standards • Compliance to earthquake policy • Insurance • Organizational or family support • Property market conditions • Motive of implementing mitigation
What are the challenges that you encountered when you were involved in any seismic retrofit project?	• Policy implementation process • Policy requirements • Trust • Stakeholder involvement • Retrofit professionals • Organizational or family support • Interaction with related council officers • Political support • Property valuation
Can you describe the benefits and values you associate with retrofitting earthquake-prone buildings?	• Personal attributes such as beliefs and values • Protecting family and property • Business or work interference • Heritage conservation • Financial gains