IMPROVING REGULATORY FRAMEWORKS FOR EARTHQUAKE RISK MITIGATION

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Abstract

The New Zealand's devastating Canterbury earthquakes provided an opportunity to examine the efficacy of existing regulations and policies relevant to seismic strengthening of vulnerable buildings. The mixed-methods approach adopted, comprising both qualitative and quantitative approaches, revealed that some of the provisions in these regulations pose as constraints to appropriate strengthening of earthquake-prone buildings. Those provisions include the current seismic design philosophy, lack of mandatory disclosure of seismic risks and ineffective timeframes for strengthening vulnerable buildings.

Recommendations arising from these research findings and implications for pre-disaster mitigation for future earthquake and Canterbury's post-disaster reconstruction suggest; (i) a reappraisal of the requirements for earthquake engineering design and construction, (ii) a review and realignment of all regulatory frameworks relevant to earthquake risk mitigation and (iii) the need to develop a national programme necessary to achieve consistent mitigation efforts across the country. These recommendations are important in order to present a robust framework where New Zealand communities such as Christchurch can gradually recover after a major earthquake disaster, while planning for pre-disaster mitigation against future earthquakes.

Keywords: Disaster, Policy and Regulation, Earthquake Risk Mitigation, Efficacy

Word Count: 8,045

1. Introduction

Earthquake policy and legislation are significant seismic risk mitigation mechanisms and are enacted with the objective of ensuring public safety from environmental hazard and reducing the impacts or consequences of disasters (Spence, 2004). These regulatory frameworks usually mandate local governments and property owners to plan and take action towards mitigating earthquake risks. Several earthquake-related regulatory frameworks, such as the Building Act (2004), National Building Code and several Standards have been enacted, in New Zealand to mitigate earthquake risks and disaster losses. Yet, the recent Canterbury earthquake swarm caused significant widespread damage to buildings and infrastructure, 182 deaths and various casualties. A majority of the damaged buildings are classified as earthquake-prone buildings (EPBs) (Canterbury Earthquakes Royal Commission, 2012). An EPB is considered 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, while a moderate earthquake is defined as the seismic activity that would generate shaking at the site of the building that is one-third as strong as what a new building at the same site would be designed to withstand (Department of Building and Housing, 2004). The terms “EPB” and “moderate earthquake” are standard terms used in New Zealand, other similar terms may be used in other countries.

The impacts of the Canterbury earthquakes suggest that some of the requirements in existing regulatory frameworks in New Zealand may be ineffective in promoting seismic rehabilitation of EPBs by property owners, thereby not meeting the primary enactment objective. The objective of this study is to examine the efficacy of existing earthquake-related regulatory frameworks for mitigating damage from earthquake disaster, specifically for ensuring seismic strengthening of EPBs. Ensuring that EPBs are adequately strengthened is important because these buildings contribute mostly to the severity of disaster losses. As conceptualised in this study, the efficacy of earthquake-related policies and regulations relates to the extent that their formulation and implementation affect property owners' adoption and implementation of seismic mitigation measures and the community view of acceptable risks (Burby, Salvesen, & Creed, 2006).

2. Regulatory Frameworks for Reducing Earthquake Risks

Appropriate formulation and implementation of earthquake-related regulations can substantially reduce the community's vulnerability to seismic hazard and disaster impacts, and assist in maintaining existing building stock (Malhotra, 2009). Yet, recent devastating earthquakes globally have reflected several inadequacies of existing regulations and policies to substantially reduce seismic risks and associated disasters. A majority of these regulations recommend a minimum safety requirement for ensuring public safety which has been found to increase seismic risk awareness and reduce fatalities, but have been inadequate to reduce the economic losses associated with seismic disasters (Lindell & Hwang, 2008; May, 2001). Most building owners were found to adopt this minimum requirement, without necessarily considering the impacts of earthquake on their property (Egbelakin, Wilkinson, Potangaroa, & Ingham, 2011b; Hopkins, 2005). Moreover, a majority of these regulations are not designed to support the use of economical seismic technical solutions, which renders the retrofitting of EPBs unaffordable (Comerio, 2004; May, 2004).

The implementation of earthquake-related policy and legislation to achieve risk mitigation objectives can be difficult. Without a state mandate, many local governments fail to plan for earthquake risk mitigation. Even when seismic mitigation plans are put in place, many local governments still fail to update plans to current standards, resulting from the very low priority attach to earthquake risk mitigation (Steinberg & Burby, 2002). Burby and May (1999) showed that most local governments in areas of low to moderate seismic hazard assigned low priority to the enforcement of seismic provisions. Most local governments have low-level priority and commitment to earthquake risk mitigation, which in most cases will not lead to consistent, strongly implemented risk-reduction programmes across medium to high-risk jurisdictions (May & Birkland, 1994). According to May *et al.* (1998), low public demand for seismic risk mitigation and the profusion of more immediate local concerns contribute to local government's lack of commitment to earthquake risk reduction.

The social and economic feasibility of the policy implementation process can affect earthquake risk mitigation. The adoption of earthquake risk mitigation policy places additional economic cost on some stakeholders, such as property owners, developers and investors (Gerber, 2007). According to Burby and May (1999), earthquake policies that are costly to implement by local governments are usually abandoned for more pressing needs. Dowrick (2005) emphasises the need for central government to consider the economic feasibility of earthquake policies and legislation on the implementing jurisdictions before they are passed into law, in order not to overstrain the jurisdiction's economic and human resources in the short-term to achieve long-term goals. Similarly, the disadvantaged political nature of earthquake risk mitigation via the formulation and enactment of earthquake polices is another significant factor affecting how people adopt risk mitigation measures (Prater & Lindell, 2000). The formulation of earthquake risk mitigation policies was found to be more politically-oriented than scientifically and technically-orientated, because implementing these policies involves a current investment in order to obtain an uncertain future benefit (Prater & Lindell, 2000). According to Prater and Lindell (2000), significant political factors affecting earthquake risk mitigation include: lack of a seismic policy entrepreneur who can frame hazard mitigation as a salient issue in the community, lack of constituency mobilisation and the absence of hazard-related professionals in the policy formulation and development process. The factors are significant because developing an earthquake policy often requires a coalition of people who understand and can agree on the nature of the risk, the best possible solutions and overall ways to achieve a hazard-resilient community.

Overall, the efficacy of earthquake mitigation policies requires a more comprehensive approach to strengthening existing buildings, due to uncertainty in earthquake probability and severity. An overview of New Zealand's earthquake-related regulatory frameworks and implementation is presented in subsequent section.

3. New Zealand Earthquake Regulatory System

In New Zealand, earthquake provisions for buildings became necessary after the disastrous Napier earthquake in 1931, which precipitated the publication of The "New Zealand Standard Model Building By-Law" toward requiring seismic provisions in the design and construction of new buildings (New Zealand Standards Institute, 1935). Compliance with earthquake provisions became mandatory in 1968 for seismic design of new buildings and strengthening of existing EPBs (New Zealand Parliament, 1968). Currently, the New Zealand

Building regulatory system comprised of the Building Act (2004) enacted to prescribe the requirements of the Building Code (2005) (a Schedule in the Building Regulations), local earthquake policies, various standards and several non-mandatory compliance documents for ensuring compliance with particular clauses of the Building Code. The system adopts a performance-based approach allows the design of structures to meet the desired performance objectives, while considering owner's and other stakeholders objectives and constraints from an engineering perspective (May, 2004). Overall, the system address life safety issues, prevent building collapse and control damages in minor and moderate earthquakes.

The Building Act mandates local or territorial authorities (TAs) to manage the mitigation of earthquake risks within their jurisdiction by developing and adopting a local policy that specifically addresses seismic risks. Although the Building Act (2004) and Building Regulations (2005) do not specify a mandatory minimum seismic strengthening level, the Act allows TAs to determine the seismic strengthening level, policy implementation approach and timeframes for strengthening the identified EPBs appropriate to their respective regions. Generally, an acceptable level among the engineering professionals and territorial authorities is the 33% NBS, which represents the minimum requirement necessary to reduce the seismic risk in EPBs to the public by targeting the most vulnerable buildings. A building having a seismic performance score less than 33% NBS is regarded as a high-risk building or EPB, a score greater than 33% NBS indicates a moderate risk and is outside the requirements of the Act, while 67% NBS or more is not considered a significant risk. The New Zealand Society for Earthquake Engineering (NZSEE) (2006) considered a score of 67% NBS a more suitable minimum level necessary to eliminate the non-ductile failure mechanisms found in EPBs, and recommends that buildings with <67%NBS should be considered for structural performance improvement (mainly for URM buildings), and at least when major alterations or refurbishments are contemplated (New Zealand Society for Earthquake Engineering, 2006). However, NZSEE (2006) further recommended that 33% NBS is considered a reasonable balance for other EPBs.

The present approach to seismic design philosophy in the New Zealand regulatory frameworks tolerates damage to the primary structure and to other building elements, but prevents building collapse in the event of a major earthquake. The definition of the building performance in a moderate earthquake provided in the Building Regulations (2005) has become condensed overtime to the shorthand of one-third or less of New Building Standard (NBS) (Canterbury Earthquakes Royal Commission, 2012), expressed with reference to the current New Zealand standard for earthquake loadings (NZS1170.5:2004). The engineering professionals and local territorial authorities have adopted the acronym NBS when assessing the potential seismic performance of an existing building to describe the comparison between the seismic resistance of an existing building compared to a new building at its ultimate limit state (ULS) (Canterbury Earthquakes Royal Commission, 2012), However, this is misleading because in an earthquake that exceeded the design earthquake for the ULS, an existing building would be likely to collapse before a new building. The misconceived acronym has caused misinterpretation among property owners and amongst building owners and other retrofit stakeholders regarding the retrofit level that provides the optimal result in terms of seismic strength (Egbelakin*, et al.*, 2011b).

Further, seismic strengthening level required for rehabilitating EPBs varies across the TAs, with 27% of the TAs adopting 67% NBS, while 73% adopted between 34% and 67% NBS (Department of Building and Housing, 2008), despite the NZSEE's recommendation of a higher seismic strengthening level. Anecdotal evidence suggests that the seismic retrofit levels adopted by the different jurisdictions relate more to political demands and available human and financial resources rather than the region's seismicity (Egbelakin*, et al.*, 2011b). 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 potential EPBs, followed by either retrofitting or demolishing the identified EPBs within three to ten years, while in the passive approach, seismic strengthening is triggered only by an 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 (Department of Building and Housing, 2008). Similarly, the timeframes for strengthening EPBs vary widely among the TAs. Most policies allow building owners to retrofit their EPBs within 5-35 years and allow for further time extension, depending on the policy implementation approach, building type, importance level and level of resources available to the TAs for policy implementation. TAs adopting the passive approach are not mandated to specify timeframes for mitigating seismic risk within their jurisdiction. In the interim, people still reside and work in these vulnerable buildings and they could be susceptible to risks posed by an earthquake disaster.

The Act further stipulates that an existing building that requires alteration including earthquake strengthening or a change-of-use must comply with requirements for access for disabled persons and fire escape “as nearly as is reasonably practicable” to the current Building code requirements (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 retrofitting of their EPBs (Egbelakin, Wilkinson, Potangaroa, & Ingham, 2011a).

The provisions of the earthquake risk mitigation regulations in New Zealand reflect the government’s broader concern to address life safety issues in a seismic event and facilitate successful risk reduction activities. The severity of the February 2012 earthquake estimated as a 1 in 2500 year event, although ensured that some modern buildings in Christchurch designed for a 1 in 500 year event performed well in the earthquake, most damage were to un-reinforced masonry buildings built before the recent code (Taig, 2012). Subsequently, the structural parts of the Building Code are currently undergoing review in light of the Canterbury quakes.

Overall, consequences from the Canterbury earthquakes have demonstrated that many EPBs built pre-1976 identified within the region have remained unstrengthened despite the mandate from relevant regulations and policies. 95% of the deaths from the Canterbury earthquakes were related to building structural failure, as well as the US$22 billion financial losses (Canterbury Earthquakes Royal Commission, 2012), suggesting that existing regulatory frameworks designed for earthquake risk mitigation are ineffective for reducing the consequences from earthquake disaster. Moreover, 80% of the people who died in the earthquake disaster were members of the public, such as pedestrians and motorists who were outside a building, demonstrating that lack of seismic retrofitting of EPBs constitutes a threat to the community as a whole.

4. Mixed-methods Approach

The objective of this research is to examine whether existing earthquake-related regulatory frameworks have been effective in improving seismic retrofit implementation of EPBs in New Zealand. To address this objective, the main research questions guiding the research reported in this paper were:

- How do existing regulations and policies pose constraints on seismic retrofitting of EPBs in New Zealand?
- What are the specific regulatory or policy requirements posing as impediments; and to what extent do these requirements influence seismic retrofitting of EPBs?
- How can these regulatory or policy requirements be improved to increase the likelihood of building owners undertaking adequate seismic strengthening in their EPBs?

A sequential mixed-methods approach comprising both qualitative and quantitative methods was adopted in this study because of the nature of the research objective, and to overcome deficiencies intrinsic to a single research approach. Document analysis, interviews and a survey were adopted. The evaluation of relevant regulatory documents highlights some of the constraints placed on the adoption of adequate risk mitigation measures by the existing legislative provisions. Semi-structured interviews allowed the different stakeholders involved in earthquake risk management to describe their experiences in the development and implementation of the relevant regulatory frameworks across the different seismic risk regions. A cross-sectional survey was used in order to capture responses from larger respondents and confirm or nullify some of the interview findings.

A combined purposeful sampling method that comprised snowball and criterion sampling as well as key informants' method and referrals, was used to select the participants in this study. This sampling method is appropriate in the context of this study because participants were selected based on their relevance to the research topic and objectives, geographic location, knowledge and experience in EPB rehabilitation projects and implementation of earthquake policy. The participants for this study were sourced from; the councils' database of approved seismic-related structural renovations approved from October 2007- April 2010, database of identified EPBs provided before and after the Canterbury earthquakes for each region; and the list of professionals would participated in the building assessment after the 2010 and 2011 earthquakes. Participants were randomly selected from these databases. The participants selected included building owners, property valuers, engineers, architects and managers of insurance and government organisations that included city councils and territorial authorities. Building owners include both people who have or have not retrofitted their EPBs and may have or have not been involved in the recent Christchurch earthquakes, and other participants must have at least a minimum of two years' recent involvement in retrofitting EPBs.

Forty-eight interviews were conducted in four cities in New Zealand, based on their seismicity, hazard factor, percentage of non-retrofitted and retrofitted EPBs, earthquake probability and likely severity. The selection of the cases was also determined by the desire to understand the variations in TA mitigation efforts, past earthquake events, economic resources and population, and the impact of the regulatory framework on present mitigation efforts of different jurisdictions.

The interviews ranged from one to two hours and were recorded. The interview transcriptions were analysed thematically using NVIVO qualitative data analysis software. Likewise, a total of 510 online questionnaires were administered nationwide. 200 surveys were used for analysis in this study, generating a response rate of 39.2%. Care was taken to exclude the interview participants from the survey. Respondents were mainly asked to indicate, on a five-point likert scale, the extent to which relevant provisions in earthquake-related regulatory framework affect the seismic rehabilitation of EPBs. The questionnaire was pre-tested in a pilot survey before an industry wide survey was conducted. The data were entered into Statistical Product and Service Solutions (SPSS) for analysis. The mean of each variable was compared by conducting an independent sample t-test (Compeau & Higgins, 1995). A test value of 4 was used to test whether the means were significantly different. Industry experts reviewed the findings for comments and confirmation in order to establish data validity.

5. Participants Characteristics

The interview participants and survey respondents' profiles are presented in Table 1. The research participants were used as the main unit of analysis. The analysis of the interviewees and questionnaire provides general demographic information about the research participants, and suggests that most of the participants are familiar with seismic retrofitting of EPBs as well the applicable regulations and policies. Hence, they are highly experienced on the subject matter and are in a position to provide reliable information. Likewise, the geographical distribution of the respondents indicates that people residing in low-to-moderate and high risk earthquake-prone regions are well represented in the study.

Insert Table 1 here

6. Findings

Research findings from this study established that some of the provisions in the current regulatory frameworks, such as Building Act (2004) and the TAs' earthquake-prone policies pose barriers to property owners' decisions to retrofit their EPBs, consequently impeding earthquake risk mitigation in New Zealand. Key research results are discussed in the following subsections within the context of the investigation and are summarised in Table 2.

Insert Table 2 here

6.1 Provisions of Building Act (2004)

Three provisions of the Building Act that constitute potential impediments to property owners' adoption of pre-earthquake disaster mitigation measures are discussed below.

6.1.1 Lack of Mandatory Minimum Strengthening Requirement

Analysis of the research data showed that a lack of a national minimum requirement for strengthening existing vulnerable buildings has led to significant inconsistency in local practice leading to poorly implemented earthquake-prone policies. This in no doubt has a trickle-down effect on property owners adopting adequate seismic performance level in their EPBs (see Table 2). 86% of building owners adopted retrofit levels ranging from <10% to <67% when retrofitting their EPBs. A majority of the EPB owners believed the minimum requirement of 33%NBS is the most adequate level, despite their engineer's recommendations of higher seismic performance, and without considering the economic implication of this performance level in an earthquake event. One of the building owners mentioned that;

> *“I believe that the 33% NBS requirement for retrofitting is the most appropriate. I think the government knows better and I am happy to abide with the regulation. Moreover, implementing the minimum standard is the cheaper option for me”.*

Likewise, participants’ responses to the question that explores the rationale behind the seismic performance level adopted when considering retrofitting of EPBs, illustrate that the seismic performance level adopted in most retrofit projects relates mainly to the TAs minimum seismic requirements, timeframes for retrofitting and heritage considerations specified in the TA policy as well as the high cost of retrofitting EPBs. Some of these owners explained that a lower standard adopted was primarily to avoid potential liability associated with non-compliance with regulatory requirements. It can be assumed that many private owners are not likely to adopt the seismic standard ≥ 67% NBS unless mandated by law or incentivised. Plausibly, the decision to adopt a lower retrofit level as appropriate strengthening standard can be attributed to the minimum requirement specified by the local TAs policy and consequently the lack of a national mandatory minimum requirement for strengthening EPBs.

Moreover, the 151 deaths resulting from the collapse of the CTV building are perhaps an outcome from a rare event that was not anticipated by the Act’s lack of a national mandatory requirement. Although many of the modern buildings within the Christchurch CBD ensured that people could safely vacate them immediately after the earthquake, many of these buildings were considerably damaged, while others needed demolition, causing significant economic implications for the Canterbury community and the country as a whole. Further, research findings show that the lack of a mandatory minimum by the Building Act, differing opinions among engineers regarding acceptable retrofit levels and the

NZSEE's recommendation indicate inconsistency in the requirements for strengthening EPBs. This inconsistency suggests the potential for a future change in legislation. Therefore, the need remains to implement consistent policies throughout New Zealand to address the potential threats posed to the community. Statistical results from the survey data show that the lack of minimum requirement significantly impedes adequate seismic retrofit implementation of EPBs ($t = 5.92$ and p-value $= 0.02$).

6.1.2 Change of Use Conditions

This study found that the provisions of the Building Act in Sections 112-115 specifically the change-of-use conditions, pose a constraint on the improvement of existing EPBS and property stock management (see Table 2). For instance, Section 112(b) requires that buildings that are altered shall comply structurally/seismically with the same extent they did before the alteration. Interview findings revealed that in most cases where retrofitting is implemented, a building that meets 40% NBS is technical outside the is outside the requirements of the Act and many TA policies could potentially be altered provided that the resulting capacity is still not less than 40% NBS, thereby discouraging the adoption of higher seismic performance standards during building alteration and rehabilitation. The implication of these provisions is clearly evident from the Christchurch earthquakes, as recently renovated and altered vulnerable buildings to less than <67% NBS were subsequently severally damaged. Across all participants interviewed and surveyed, there was a general consensus that these provisions have significantly increased the proliferation of substandard structures within the community leading, to a growing level of vulnerability to seismic disaster.

Furthermore, compliance with section 112 of the Building Act significantly increases the cost of retrofitting EPBs, which is considered by the participants is a major obstacle to strengthening EPBs. Some of the assertions made by the research participants are listed below.

- The provisions of the Building Act's typically requires additional works to be conducted alongside any seismic strengthening – paraplegic toilets and access etc. It is costly enough without having to bring other elements of the building to standards. Compliance to these regulations is usually difficult for owners.
- The extremely high costs associated with the retrofitting requirements affect decisions to strengthen older EPBs. The loadings code has dramatically increased in requirements since the transition from NZS: 4203 over to NZS: 1170. If a building originally developed in the time of NZS: 4203 didn't meet 4203 back then, it will be very costly to now have to bring it up to the NZS: 1170 standard
- The retrofitting project was abandoned as uneconomic and too expensive without support in terms of grants from the government.

While it is reasonable to support both of these objectives, the cost implications due to these triggers often discourage building owners from adopting adequate seismic performance voluntarily. There is a need to further investigate whether such requirements are justified in the interest of public safety and in relation to other relevant public policies. Statistical analysis supports the interview findings that the change-of-use conditions of the building Act pose a significant barrier to improving the seismic capacity of existing EPBs in New Zealand (t-value = 4.59 and p-value = 0.001).

6.1.3 Mandatory Disclosure of Seismic Risks

Findings from the qualitative study reveal that most of the stakeholders in the property market have little or no knowledge about EPBs, seismic retrofit standards, legal obligations and potential liabilities relating to the changes in the Building Act requirements and TA EPB policies, resulting in under-investment in earthquake risk mitigation. Currently, none of the regulatory mechanisms relevant to earthquake risk mitigation in New Zealand specifically addresses whether disclosure of building seismic risks should be mandatory or not. A lack of mandatory disclosure limits the different stakeholders' knowledge of issues related to seismic risk, specifically for participants within property market.

92% of the interview participants agreed that mandatory disclosure of a building's seismic risks in all transactions such as lending, selling and renovation is a strong motivator to invest in seismic retrofitting of EPBs, which could lead to an improved condition in existing EPBs. Mandatory disclosure of risks through relevant regulatory mechanisms, such as the Building Act and TA policy, would ensure that owners and property retailers are obligated to disclose a building's seismic risk to prospective buyers or tenants at the point of sale or lease. Disclosure of accurate risk information to buyers, insurers and lenders would consequently lead to an informed property market and increase in property value of retrofitted EPBs an increase in the property value would provide financial returns at the point of sale or letting to the owners, leading to the augmentation of property owners perceived benefits from strengthening their EPBs.

Equally, building occupants would begin to demand buildings that adequately ensure their safety when working or residing in them. For example, findings after the Canterbury earthquake revealed that the owner of the CTV building was unaware of the building's seismic risks at the time of purchase (Canterbury Earthquakes Royal Commission, 2012). There is a possibility that if the present CTV owner had been made aware of the extent of the building's vulnerability to earthquake risks, the cost of retrofitting could have been factored into the investment decision and retrofitting work possibly carried out. Mandatory disclosure of seismic risks would therefore provide a seal on potential EPBs while communicating more accurate information to the buyer, insurer and lending institution. Findings from this study presented in Table 2 provide empirical justification that mandatory disclosure of seismic risks by relevant regulatory frameworks is necessary to improve earthquake risk mitigation in New Zealand (t-value = 6.36 and p-value = 0.000).

6.2 Provisions in Earthquake-Prone Policies (Prepared by the TAs)

Some of the provisions in TAs' policy that act as obstacles to earthquake risk mitigation are discussed in this section.

6.2.1 Policy Implementation Approach Adopted

Insights from the interviews suggested that earthquake mitigation approaches adopted by local authorities affect how stakeholders perceive seismic risks and make mitigation decisions (see Table 2). The implementation approach adopted by a TA has several implications for improving the seismic performance of EPBs. These implications include high costs of implementing mitigation programmes for the active approach and a large percentage of high-risk buildings not being retrofitted due to the passive approach. Similarly, the social and economic feasibility of the policy implementation process can affect earthquake risk mitigation without significant assistance from the national government. The Christchurch earthquakes have demonstrated the ineffectiveness and significant economic implications of a TA policy having a passive implementation approach. One of the participants suggested there is a need to include proactive risk communication and awareness programmes in the implementation approach adopted by TAs for earthquake risk mitigation. This approach may encourage building owners to adopt adequate seismic retrofit standards for their EPBs that will promote constructive risk-prevention behaviour, leading to an increase in EPB rehabilitation projects. Results from the survey presented in Table 2, provide sufficient evidence that suggest that the policy implementation approach in TA policies to a great extent impede the strengthening of existing EPBs within the community (t-value =-4.28 and p-value = 0.000).

6.2.2 Seismic Retrofit Levels Adopted

The findings from this research presented in Table 2 recognise that the seismic retrofit level adopted in TA policies could largely impede the strengthening of existing EPBs. The choice of lower retrofit levels of ≥ 33% or ≤ 40% is predominant among TAs as the preferred performance standard, despite NZSEE recommendations, which was attributed to the presumed minimum requirement of 33% NBS by some TAs, as well as the TAs' lack of resources for risk mitigation. 64% of the private owners interviewed claimed that they preferred to implement seismic retrofitting at a future date, in order to avoid spending additional money on strengthening, as a result of possible amendment or enactment of new legislation. In addition, the disparities in the seismic retrofit levels adopted by TAs across the country, and policy implementation approaches among the different regions, have led to inconsistent earthquake mitigation strategies across the regions. An appraisal of the policy implementation approach adopted by some of the TAs is necessary, as statistical significance test showed that lower retrofit levels adopted in TA policies to a great extent, influence adequate seismic strengthening of EPBs (t-value = 5.67 and p-value = 0.004).

6.2.3 Timeframes for Retrofitting EPBs

As revealed in this study, longer timeframes impede the adoption and implementation of mitigation measures in EPBs (see Table 2). Consistent across the cases during the interviews, 59% of the owners are not willing to undertake any mitigation action in the next 10-25 years, therefore applying for time extension as allowed under the differing TA policies. Accordingly, many owners do not consider immediate action to be necessary regarding the implementation of seismic improvements to their EPBs. The long-time-range adopted by owners to retrofit EPBs was attributed to the timelines specified in the TA policies. The delays in undertaking the decision to adopt seismic mitigation indicate the impact of procrastination on retrofitting decisions, because the immediacy of threat is unjustified, as earthquake regulatory frameworks cannot specify an exact deadline before a disaster strikes. In the interim, people still reside and work in these vulnerable buildings and they could be susceptible to risks posed by a future earthquake disaster. The findings are further buttressed by the statistical results from the survey data analysis, which shows that timeframes for retrofitting EPBs in TA policies to a great extent, pose a barrier to seismic strengthening of EPBs (t-value = 8.32 and p-value = 0.01). A review of earthquake-prone policies requires effective timeframes for retrofitting EPBs, while considering regional hazard factor, resource availability and the effective life of the building.

7. Discussion of Findings

The analysis of the qualitative and quantitative data revealed that some of the provisions in the regulations and policies relevant to earthquake mitigation have several implications that can make seismic risk mitigation of EPBs a difficult challenge. Most importantly, the present seismic design philosophy in new building regulatory system significantly impedes adequate strengthening of EPBs. Although, the minimum requirement is intended to ensure public safety in an earthquake event, findings from this study show that this requirement in most cases it would lead to a complete economic loss of the buildings. Moreover, Canterbury earthquake swarm demonstrated significant economic, social and environmental implications of the current seismic philosophy requiring minimum seismic strengthening standard, to both property owners and the country as a whole. It is apparent that the enormous economic loss from the Christchurch earthquake disaster was not anticipated by this minimum requirement, suggesting a need to change present seismic design philosophy. Arguable, these findings are based on damage caused by a 1 in 2500 year event from the Canterbury earthquakes; however, this may not be the norm because of the unpredictability of earthquake disasters.

Likewise, the lack of a mandatory minimum requirement contributes to TAs' lack of commitment to earthquake hazard mitigation. This is evident in the implementation approach adopted in their policies, such as lack of public awareness programmes and longer timelines adopted for taking action to retrofit EPBs. The hands-off central government stance towards seismic hazard mitigation provides TAs with wide latitude in developing policy and programmes to foster earthquake risk mitigation at the local level. The decisions regarding the extent of mitigation programmes implemented are left primarily to TAs. One outcome of such a model is that some territories have good programmes in place to mitigate earthquake hazards, while other communities have done little or lack adequate resources to implement mitigation measures. TAs' lack of commitment in most cases will not lead to consistent, strongly implemented, risk reduction programmes across the country. In addition, several statements from the research participants revealed that the model of government in New Zealand indicates that TAs do not receive substantial financial support, if any, from central government for reducing earthquake vulnerability. This is notwithstanding the availability of the resources necessary to implement earthquake risk mitigation. Clearly, there is a need for central government to provide additional resources to local councils and TAs if New Zealand's non-tolerance of EPBs is to be increased. National government could support local authorities which have inadequate resources to mitigate seismic risks by introducing financial incentives specifically for seismic retrofitting of EPBs (Egbelakin*, et al.*, 2011a).

Justification for the provision of financial incentives is evident from the enormous losses from the Christchurch earthquake, which could have been reduced if an on-going maintenance, repair and strengthening programme had been implemented through the provision of incentives before the disasters happened. Plausibly it is the authors' opinion that Christchurch earthquakes have demonstrated that it is more cost-effective to take a proactive approach to strengthening buildings than expending money for emergency management, demolition, clean-up, disaster recovery and reconstruction. In contrast, reports provided by the Ministry of Business, Innovation and Employment (MBIE) (Jenkins, 2012) and Taig (2012) concluded that that raising the level from 33% NBS to 67% NBS and reducing timeframes reduces benefit/cost ratio of seismic strengthening of EPBs in relation to ensuring life safety. However, both reports acknowledged that significant social and economic benefits such as reduced social cost, demolition, clean-up, emergency management and recovery costs that may accrue from adopting high seismic strengthens after a seismic event were excluded from the cost-benefit analyses. The absence of these benefits in any cost-benefit analysis indicate the complexity of mitigating earthquake risks cost and its wider attribution to the governments who typically bear a significant share of associated costs of emergence management and recovery. Hence, there is need to develop a collaborative cost-sharing strategy towards earthquake risks mitigation.

In addition, these research results showed that mandatory disclosure of a building's seismic risks in all transactions would increase the salience of seismic risk issues, enhance the likelihood of property owners adopting adequate risk mitigation measures, and consequently, lead to improved earthquake risk mitigation in existing EPBs. Also, mandatory risk disclosure if earlier implemented before the Canterbury earthquakes, would have reduced some of the anomalies associated with the building safety evaluation processes and aided the investigations carried out by building inspectors and the Canterbury Earthquake Royal Commission (CERC). Information regarding the investigated sample buildings by the CERC such as the CTV, Pyne Gould Corporation building and Hotel Grand Chancellor would be easily accessible, if the law mandated concerned stakeholders disclosure of risk information rather than having to request information from various organisations and persons.

There is also the need to give credence to collaborative arrangements aimed at achieving earthquake risk mitigation objectives. This research study therefore suggests a need for a synergy of objectives amongst natural hazard and disaster management-related legislation for overall improved urban planning and natural hazard and disaster management. It is necessary to overlay most of the relevant policies and regulations related to natural hazard management and improved urban planning such as, the Land-use Planning, the Resource Management Act (RMA) (1991), Civil Defence Emergency Management Act (2002), historic preservation and disaster recovery with the seismic strengthening of EPBs. For instance, land-use planning could be incorporated with earthquake policies to achieve effective disaster mitigation goals. This study emphasises the need for a synergy of objectives amongst hazard management information and related legislation for improved urban planning and natural hazard and disaster management. Moreover, the coordination and a harmonisation of these different provisions and documents would enable professionals working in the hazard and disaster management field become more aware of commonly encountered issues and imperatives. Coherent coordination of hazard and disaster information would require the development or tailoring of policy and practices within the district plans and other regulatory mechanisms, which is not the case at present. Moreover, there is no existing regulation to guide how risk assessment information is being utilised or distributed among professionals, and the provision of an appropriate risk assessment tool is necessary in order to improve the level of investment in seismic hazard mitigation.

8. Recommendations

Recommendations are made in relation to the New Zealand's legislative documents examined in this study, and a review of regulatory systems relevant to earthquake risk mitigation in other seismically active countries such as USA, Japan, Italy, Haiti and Turkey (Comerio, 2004; Spence, 2004), serving as action points for appropriate policy consideration which are to other vulnerable countries.

The design of the seismic provisions over the years in many has been improved through lessons learnt from past earthquakes. However, constraints associated with earthquake regulatory frameworks have made seismic risk mitigation a difficult challenge in many countries. Generally, devastating earthquakes around the globe often necessitate a change in legislation, which are partly due to the public's increased risk awareness immediately after a disaster (Birkland, 1998; Lavell, 1994). This increased awareness creates an opportunity for policy makers to amend or introduce new legislation(s) within a short period after such severe disasters. However, decisions made within this short period are often referred to as a reactive decision approach to policy decision-making with significant shortcomings (Prater & Lindell, 2000). It is recommended that proactive or pre-emptive approaches rather than reactive decisions are necessary to formulate, adopt and implement an effective mitigation policy planned under a long-term strategy. Thus, on-going methods for reviewing present earthquake regulations are necessary.

Generally, ~~A~~a majority of the earthquake regulations do not usually specify seismic performance level but, sets out objectives that must be achieved with no mandatory minimum requirements. Lessons learnt from New Zealand showed that these non-mandatory minimum requirements are inadequate to reduce the economic, environmental and social losses associated with earthquake disaster. Attempts at reducing these losses should incorporate mandatory minimum requirements with specified reasonable timeframes for policy implementation and retrofitting of EPBs among all jurisdictions within seismically active regions. A mandatory minimum requirement for taking action about EPBs would ensure an average level of commitment among the local governments to earthquake risk mitigation. Moreover, the minimum requirements for earthquake-prone threshold in different regions should be reviewed and adjusted more effectively to reflect the regional hazard factor, while considering resource availability for implementing the requirements. In addition, the provision of a national guidance document on earthquake risk mitigation should be implemented by the central government. This guidance document coupled with proactive public awareness programmes and community engagement is necessary to improve the local TAs commitment level and to achieve consistent earthquake mitigation strategies across their regions.

Another significant lesson learnt from Canterbury earthquake relates to the lack systematic earthquake risk information system. Professionals in earthquake engineering industry are aware of the substantial information and knowledge about earthquake and the potential impacts on the built environment; however this knowledge is not available to property owners, other stakeholders involved in earthquake risk mitigation and the public. There is thus a gap between where the leading edge of knowledge on earthquake engineering has reached in various areas and the utility of, and access to, this information, which is a key impediment to seismic risk mitigation. For this vast knowledge about earthquake engineering to have its full and proper effect future earthquake risk mitigation, the disaster management sector itself will need to develop an “individual-property earthquake safety assessment information system. The system will bring together the disparate building’s seismic risk information and enable rapid access necessary to build more resilient and sustainable communities to earthquake disasters. An accessible building seismic risk information system can help improve public confidence that the risks posed by EPBs are managed at an acceptable level, and improve support for policy and implementation approaches provided by the local governments. Consequently, an improved public support could legitimate mitigation risk mitigation decision-making process at the individual and community levels.

Overall, policy makers at the central and local governments should realise that the available of information, community and stakeholders' participation is an important tool in the design and enactment of mitigation policies and strategies. The central and local governments should jointly promote collaboration, cooperation, knowledge-sharing and understanding of natural hazard and risk mitigation among related organisations. This collaborative approach would aid the prioritisation of earthquake risk mitigation across related organisations and regions.

9. Conclusion

This research examined the efficacy of the relevant regulatory frameworks for reducing loses from earthquake disasters. The findings from this research revealed that some of the provisions of these regulatory mechanisms pose constraints for successful earthquake risk mitigation specifically, seismic retrofitting of EPBs. These provisions include the current seismic design philosophy of requiring minimum safety provisions for seismic performance, lack of mandatory disclosure and non-availability of building seismic risk information, change-of-use conditions and ineffective timeframes for retrofitting. The research findings indicate that formulation of effective policy constitutes a central element in the overall framework for improving the seismic performance of EPBs, and recommended that the efficacy of earthquake-related regulations would be improved, if these regulations are designed with the objective of achieving consistent earthquake mitigation strategies across the country, with collaboration and support from the central government.

Findings from this research are beneficial for researchers, professionals involved in the seismic rehabilitation of EPBs, as well as the stakeholders involved in policy formulation and implementation within the natural earthquake risk management sector. Although the results of this study provide vital information for the earthquake hazard management sector globally, its application could have some limitation in countries with a different regulatory framework and background from New Zealand. Also, the variation in seismic risks in the different regions across the country, and the capacity of the construction sector to undertake the implications of the suggested recommendations should be taken into account. Overall, it could be surmised that earthquake-related regulations would be enhanced by providing legislative clarification and reappraisal with regard to requirements identified in this study. A review and realignment of all regulatory documents is also necessary to present a robust framework, where earthquake-prone countries can plan for pre-disaster mitigation against future earthquakes.

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