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Reactions to earthquake hazard: Strengthening commercial buildings and voluntary earthquake safety checks on houses in Wellington, New Zealand

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ABSTRACT

Although many countries have legislation requiring strengthening of earthquake prone buildings, there are significant obstacles to retrofitting these buildings to make them more resilient. This research examines actions in regard to earthquake prone commercial and public buildings in Wellington and checks on private homes following the 2010/2011 Canterbury earthquakes and the 2013 Seddon/Cook Strait earthquakes. The study obtained data on commercial and public buildings removed from the Wellington City Council Earthquake-prone Buildings List (EQPB List) from 2012 to 2016 due to various mitigation actions (e.g., demolition and strengthening). The study also obtained rates of self-initiated voluntary Quakecheck home assessments for the same period. Results indicate ongoing removal of significant numbers of buildings from the EQPB List in this period, with strengthening being the most frequent action. This finding suggests that despite real obstacles, various incentives including legislation are leading to consistent earthquake preparation over time, often before the legislative deadline. In contrast with the EQPB data, the Quakecheck data indicate a sharp but short-lived spike after the Seddon / Cook Strait earthquakes. As a marker of self-initiated mitigation action, this brief spike suggests that in the absence of relevant legislation or insurance incentives, citizens' actions are only briefly influenced by the experience of an earthquake. These contrasting findings for EQPBs and Quakechecks suggest the value of legislation to drive mitigation actions for all buildings.

Earthquakes are unpredictable events that occur infrequently in any one location yet can have disastrous consequences. Large damaging earthquakes have occurred recently in several countries, including Japan, Tibet and Haiti. Seismic activity in New Zealand was recently demonstrated by a series of destructive earthquakes in 2010 and 2011 in the Canterbury region, followed by the 2013 Seddon and Cook Strait earthquakes (near the city of Wellington) and the 2016 Kaikoura Earthquake. The February 2011 Christchurch earthquake triggered widespread damage and 185 fatalities [12].

Although earthquakes are uncontrollable, damage in earthquakes can be mitigated. The disaster that occurs in earthquakes is not the hazardous earthquake itself, but rather the damage resulting from inadequate preparation [2]. Preparation can greatly reduce the potential harm from earthquakes [14]. Many preparation programmes emphasize actions to increase survival after an earthquake, such as storing water [19]. However, preparation should also include actions to mitigate damage from earthquakes such as strengthening buildings [24,30].

1. Strengthening buildings and legislation

Strengthening earthquake-vulnerable buildings is a key preventative measure to reduce the harm triggered by earthquakes, as the major cause of fatalities and losses in earthquakes is building collapse [29]. This is most obvious in countries where earthquake legislation is not strongly implemented, such as Nepal, but it also applies in countries with such legislation. For example, fatalities from the 2011 Christchurch earthquake resulted from the collapse of buildings and facades on commercial buildings [23]. Although the majority of fatalities were due to the collapse of two relatively modern commercial buildings, the remainder were caused by collapsed facades and parapets in older unreinforced masonry buildings built before 1976.

Strengthening buildings is beneficial not only to reduce fatalities in an earthquake, but also to reduce economic losses. As illustrated by the \$40 billion rebuild cost from the 2011 Christchurch earthquake (more than 20% of GDP), the cost of earthquake recovery is high [45]. Over 150,000 homes were damaged from this earthquake, with 30,000 in-

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curing serious damage [21]. Buildings that met the New Building Standard (Appendix A) fared better than those that did not, confirming that strengthening buildings reduces losses in earthquakes [23].

Robust legislation on the strengthening of buildings vulnerable to earthquakes is therefore vital for successful damage mitigation [29]. When comparing regions that enforce earthquake legislation to those that do not, it is clear that this practice plays a key role in reducing harm in earthquakes [2,28]. Due to a lack of building legislation and/or the failure to enforce legislation, countries like Haiti and Nepal are vulnerable to earthquakes and suffer many fatalities [13,2,29]. In contrast, New Zealand, California, Japan, and Chile all have more robust earthquake legislation that is enforced and as a result, represent some of the world's most earthquake resilient communities [29]. As a result of Japan's robust building codes, most buildings withstood the powerful 2011 Tohoku earthquake, if not the subsequent tsunami [2].

In New Zealand, national legislation requires that commercial and public buildings built before 1976 that do not meet 33% of the New Building Standard are classified as earthquake prone buildings (EQPBs) and must be strengthened or demolished within a fixed time frame (for details, see Appendix A; for examples of buildings affected by the code, see Appendix B and C). Regions in New Zealand are now categorised into low, medium, and high risk (i.e. hazard) zones (Appendix A). In the Canterbury earthquakes, most buildings that met current building standards survived the earthquakes, leading to lower fatalities, although many of these buildings were subsequently demolished due to owners' decisions to claim the insurance rather than repair the buildings [45].

2. Motivations for strengthening buildings

In addition to relevant legislation, there are a number of other reasons why people undertake earthquake prevention measures such as strengthening buildings. Several motivations support the decision to strengthen EQPBs, including economic and psychological reasons. One reason pertains to long-term economic benefits where owners reduce possible economic losses after an earthquake [45]. Building owners may also strengthen earthquake-prone buildings to increase their sale value [31], as commercial buildings classed as earthquake-prone have lower values, particularly in high hazard zones such as Wellington [8]. Even in regions not directly affected by the Canterbury earthquakes, the heightened sense of risk produced by these earthquakes was enough to reduce the market price of some buildings. Timar, Grimes and Fabling [37] found that an official earthquake-prone declaration on commercial buildings in Wellington city following the Christchurch earthquakes lowered the sale price of these buildings.

Awareness of seismic hazard in the property market affects the sales of, and rental income for buildings and the ability to attract and retain tenants [31,5]. Filippova [7] found that many high profile commercial tenants in Auckland (deemed a low risk region) became more concerned about seismic risk following the Canterbury earthquakes. Commercial buildings deemed to be below standard have become less attractive for these reputable tenants, and may be left vacant. Further, these buildings are more difficult to insure, and may have higher insurance premiums. Earthquake strengthening makes these buildings more attractive to these tenants and may also reduce insurance premiums. These factors provides an incentive for owners to undertake earthquake strengthening.

The Wellington City Council offers other incentives for owners to strengthen EQPBs, including a rates reduction when buildings are empty during strengthening and a subsidy for strengthening [43]. Incentives also exist for heritage buildings via The Built Heritage Incentive Fund (BHIF), where grants are given to building owners to assist efforts to strengthen and restore heritage buildings.

There are also psychological reasons why people strengthen buildings, such as to reduce anxiety [22]. Moderate anxiety serves to motivate people to prepare for earthquakes, whereas high anxiety tends to

increase denial [12,3,6]. Preparation also reflects the personal experience of an earthquake, which increases concern and preparation [3,27]. For example, citizens in Christchurch prepared more following the Canterbury earthquakes than before [16].

The perceived level of the hazard of earthquakes is also a motivating factor. Citizens in Portland Oregon, supported greater preparation when new seismic reports showed the earthquake hazard was higher than previously believed [9]. New Zealanders see a major earthquake as more likely in Wellington than other large cities [17], with 98% of Wellington residents aware of the risk from earthquakes [12]. Citizens know that Wellington is situated near several fault lines and is classified as a high risk (i.e., hazard) zone for seismic activity ([32,41]). The fact that building codes set a higher standard in Wellington than Christchurch prior to the Christchurch earthquakes reflects this greater perceived risk [44].

3. Barriers to strengthening buildings

Despite these benefits of mitigating actions, many people do not strengthen their EQPBs, reflecting a number of barriers to these actions. Research has examined why some building owners have not adopted earthquake mitigation measures, focusing on building stakeholders [5]. Several factors emerged as impeding owners from adopting mitigation measures.

Firstly, earthquake risk is poorly accounted for in property valuations [5]. These valuations often ignore seismic risks or give varied estimates of the cost of earthquake strengthening. Other barriers include a lack of knowledge or information about seismic risk. Related research examined the regulations for EQPBs following the Canterbury 2010–2011 earthquakes [4]. The authors claimed that mandatory disclosure of a building's seismic risks would highlight these risks and encourage owners to adopt mitigation measures for EQPBs. This recommendation has since been adopted in the 2016 amendment (Appendix A).

Owners of EQPBs also claimed that the short-term cost of strengthening a building is high and would not be recovered in the long term [5]. A key factor is high, non-risk-based insurance premiums, so the significant cost of strengthening may not always lead to lower insurance [5]. Owen and Noy [20] observe that disaster economists have argued for a risk-based insurance regime, as this would allow insurers to lower premiums for properties where owners have taken steps to avoid risk. Egbelakin et al. [5] note that insurers have been reluctant to introduce a fully risk-sensitive regime, as assessments for individual buildings can prove costly and difficult. Despite these barriers and concerns, IAG, one of New Zealand's largest private insurers, has stated that insurance premiums will increase, particularly in high-risk regions such as Wellington [36]. This suggests that insurers may be moving toward a risk-based insurance model, following the experiences of the Canterbury and Kaikoura earthquakes.

Egbelakin et al. [5] also found that building owners said that they might strengthen their buildings if the cost could be recovered through increased rent or property value, but they believed that tenants were unlikely to pay a higher rent for a retrofitted building. Many owners of EQPBs claimed that strengthening their buildings would result in a net loss of revenue. Building owners also claimed that there is little demand for older buildings to have improved performance [5] as buyers prefer newer buildings that are more energy efficient. A further factor is that buildings classed as heritage buildings cannot be demolished or modified without Council permission [10].

Hence, for building owners who have not strengthened their EQPBs, there are a number of obstacles, of which the most important is cost. It is important to note that Egbelakin et al. [5] collected their data before the Canterbury and Cook Strait earthquakes, and some of the views they report may since have changed. Thomas et al. [35] found that rates of strengthening for buildings in Wellington increased markedly immediately following the Canterbury earthquakes. Filippova [7] also

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