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Earthquake prone public buildings: balancing life safety risks and community costs

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ABSTRACT

The focus on seismic risk following the 2011 Christchurch and 2016 Kaikoura earthquakes has seen the closure of several public buildings across the country. The introduction of the Building (Earthquake-prone Buildings) Amendment Act in 2016 (The Act) has reinforced perceptions of risk through the legal requirement for certain buildings to have seismic assessments undertaken. The Act's requirements are based on %NBS ratings (percentage of the New Building Standard), with buildings rating less than 34%NBS being declared by the territorial authority to be earthquake prone, with defined time frames for remediation. A common misconception in some sectors is that if a building is rated as less than 34%NBS and/or declared earthquake-prone, then the building is dangerous and should be closed immediately. This has led to long periods when public facilities and services are not available to local communities, resulting in some notable socio-economic impacts.

There appears to be inconsistency in how territorial authorities, acting as public building owners, are approaching this challenge: some councils rapidly close buildings (even prior to earthquake prone decisions being made) and others keep buildings with lower seismic ratings open. This paper explores 1) legal obligations on territorial authorities around earthquake prone buildings; 2) processes territorial authorities currently use to make decisions around the closure of buildings categorised as earthquake prone; and 3) a potential approach to better balance the immediate and direct socio-economic impacts of building closure against the possible physical and human impacts of an event that occurs on a geological time scale.

1 INTRODUCTION

The 2011 Christchurch and 2016 Kaikoura earthquakes have heightened awareness of New Zealand's vulnerability to seismic hazards. The introduction of the Building (Earthquake-prone Buildings) Amendment Act in 2016 (The Act), and the associated seismic assessment process, has seen the closure of several public buildings across the country. The Act's requirements are based upon how a building performs as a percentage of the New Building Standard (%NBS). Buildings rating less than 34%NBS are generally declared by the relevant territorial authority (TA) to be earthquake prone (EQP) and subject to defined time frames for remediation. A common belief is that if a building is rated as less than 34%NBS or declared EQP, then the building is dangerous to life and should be closed immediately (Hare, 2019).

While %NBS may appear at face value a straightforward concept to describe how well a building will perform in an earthquake, the complexities of seismic events and the nuances of structural design mean that the link between %NBS and building performance is not always direct. How an earthquake affects a building depends on many factors. They include the earthquake itself (duration, amplitude and period of shaking), local and geotechnical features (e.g., soil conditions, presence of liquifiable materials, ground slope, water table), the characteristics of specific buildings (e.g. orientation and regularity of building footprint), and how these factors interact. For example, short sharp earthquakes will have the most significant impact on stiff, low-rise buildings. Long rolling earthquakes will impact high-rise buildings most significantly. Accordingly, %NBS does not predict seismic performance from one earthquake to the next (Hare, 2019).

A %NBS rating therefore does not represent an absolute assessment of risk or safety, and a rating of less than 34%NBS does not mean that a building poses an imminent risk nor is that building expected to collapse in moderate levels of earthquake shaking. The aim of the %NBS metric is to provide a relative assessment of seismic risk. It is not an absolute predictor of building collapse nor building performance. Unfortunately, this nuance is often not understood.

Indications are also that decisions to close buildings rating less than 34%NBS (both council-owned and in the wider commercial environment) are being driven by considerations of health and safety. In particular, the requirement of the Health and Safety at Work Act 2015 (HSWA) to *eliminate or minimise risks* appears to have dominated decision-making in many cases[1].

The reaction of some TAs to immediately cease occupancy of buildings rating less than 34%NBS has led to long periods where facilities and services housed in those buildings become unavailable to local communities, resulting in some notable socio-economic impacts. For example, closure of the Southland Museum affected 41 jobs (Harding, 2019). Closure of Naenae Olympic Pool in Lower Hutt created a sense

[1] An EQC-funded project, led by Dr Tracy Hatton (Resilient Organisations), is further exploring the role of the HSWA in organisations' risk reduction behaviours and actions (including building strengthening, emergency preparedness, and education). The project is due for completion in early 2021. https://www.resorgs.org.nz/our-projects/risk-and-resilience-decision-making/perceptions-health-safety-obligations/

of uncertainty in the community and led to the closure of some local businesses (Tso, 2019). The closure of the Wellington Central Library due to structural concerns with the library's floor seating had a significant community impact, including on Wellington's homeless population (Desmarais & Chumko, 2019). Such examples demonstrate that the wellbeing of communities is often interwoven with the bricks and mortar of public assets. Decisions by TAs to pre-emptively close public buildings while determinations about their operational future are still being made can therefore cause severe disruption to community life.

To date few TAs have adopted formal policies relating to occupancy of EQP public buildings. It is unclear how TAs approach these closure decisions and how seismic assessments are interpreted, life safety risk is evaluated and how, if at all, socio-economic impacts of closure are considered. This lack of transparency and consistency around publicly owned assets leave policy decisions open to challenge and could lead to detrimental effects on our communities.

This research, undertaken during the period April 2020 to April 2021, aims to better understand how TAs currently make and could better make occupancy decisions related to EQP buildings. We aim to combine legal, engineering, risk management, and behavioural theory to co-design a decision process that will support TAs to make robust building occupancy decisions.

In this paper we begin by presenting an assessment of the legal obligations on TAs relating to EQP buildings. Second, we describe the method used during this project to understand TA decision making processes and collaboratively develop a best practice decision framework. Third, we summarise the current approach to EQP building occupancy decision-making by TAs. Last, we present the key steps in our decision framework (tying in relevant legal, engineering, risk and behavioural theory where applicable).

2 SEISMIC RISK AND THE REGULATION OF PUBLIC BUILDINGS

2.1 The Building Act and the concept of earthquake prone buildings

Seismic resilience is addressed in New Zealand as part of a three-part legal framework. This comprises the Building Act 2004 (the primary legislation), the Building Code (a deemed regulation) and a number of regulations enacted under the (now revoked) 1992 Building Regulations Act. In practice the Building Code provides the minimum standards required for new building construction alongside a number of other regulations introduced to deal with specific issues, including seismic resilience (Specified Systems, Change the Use, and Earthquake-prone Buildings) (Building Regulations 2005). Thus, to understand the exact requirements for seismic building requirements in New Zealand requires an understanding of a number of legal requirements, not all of which are complementary.

Of relevance here are amendments introduced into the Building Act relating to seismic risk as a consequence of the Canterbury 2010–2011 earthquake sequence and the Royal Commission that followed it. The risk posed by existing buildings through the identification and regulation of 'earthquake prone buildings' was first introduced in the 1991 Building Act, and subsequently amended and extended in the 2004 revision of the Act. The Building (Earthquake-prone Buildings) Amendment Act 2016 created a more nationally focused and consistent system through new mechanisms such as the EPB methodology (MBIE, 2017), the requirement for engineers to use the seismic assessment guidelines (MBIE et al, 2017) and the establishment of a national EPB register.

The concept of an 'earthquake prone' (EQP) building is a legal term of art, rather than a normative indicator of the seismic safety of a building. To acquire the legal definition of earthquake prone, a building must be assessed as failing two tests – firstly, having the ultimate capacity of the building or its parts exceeded in a moderate earthquake, and secondly, if collapse were to occur (at any level of earthquake shaking) injury or

death would be likely to result to those in or around the building or adjacent buildings, or damage to any other property.

Owners of buildings designated as earthquake prone are subject to legal obligations around remediation. In particular they must be strengthened to bring their NBS rating above 34% or be demolished within a specified timeframe, depending on their seismic hazard zone (Building Act 2004, s 133AM). However, of particular note to this research, the Building Act does not preclude continued occupancy of earthquake prone buildings.

As well as the Building Act, TAs need to consider other relevant legislation such as Health and Safety at Work Act 2015 (HSWA) and public law requirements laid out in the sections below.

2.2 The Health and Safety at Work Act

The Health and Safety at Work Act 2015 (HSWA) is a general act which applies to all legal individuals (public and private) and does not specifically apply to seismically vulnerable buildings. It nevertheless has potentially significant implications for owners of such buildings and employers who operate businesses within them (as well as employees and users). The overall legislative position is laid out clearly in s37 of the HSWA which defines the key concept of a "PCBU":

> … a person conducting a business or undertaking (PCBU) who manages or controls a workplace must ensure, so far as is reasonably practicable, that the workplace, the means of entering and exiting the workplace, and anything arising from the workplace are without risks to the health and safety of any person.

A PCBU can include building owners even if they do not occupy the building, as the leasing of premises is, in itself, a business. A single building may have more than one PCBU liable for the activities within it, depending upon the nature of the specific relationship between the owner/landlord and tenant.

The duty is broad and requires PCBUs (and potentially others with responsibility) to protect the health and safety of workers (HSWA, s 36(1)(a)), protect the health and safety of other people (HSWA, s 36(2)), and to provide a work environment that is without risks to health and safety (HSWA, s 36(3)(a)). Such a duty must only be undertaken to the extent that it is "reasonably practicable", something to be decided by taking into account the likelihood and the degree of harm that might result from the hazard or risk; what the PCBU knows about the hazard or risk; and, ways of eliminating or minimising the risk plus the availability and cost of those actions. Should a PCBU be convicted for failing to comply with their duty, the consequences are personal and serious, including fines and imprisonment (HWSA, s 47, s49).

Enforcement of the HSWA largely falls to WorkSafe. WorkSafe has developed non-binding policy guidelines regarding earthquake-related health and safety risks (WorkSafe, 2018) that states WorkSafe will not enforce building safety to a higher standard than the Building Act 2004 (WorkSafe, 2018, at 1). In other words, if a PCBU owns or occupies an EQP building and they are complying with the EQP building framework, then WorkSafe has a policy not to enforce standards beyond those required by the Act.

Although this might bind WorkSafe's regulatory role to some extent (through the principle of legitimate expectation), this does not mean that the owner of such a building is not liable under the HSWA. WorkSafe has no role interpreting the Act itself and such decisions lie in the hands of a court. In the aftermath of a seismic event leading to building failure, prosecutions under the HSWA could conceivably eventuate from WorkSafe itself, other crown prosecution agencies or legal individuals (including companies).

In addition, WorkSafe's guidelines note that PCBUs must be aware of potential earthquake risks, and that they must consider any new information that might be relevant to the performance of their building in an earthquake (WorkSafe, 2018, at 2). This appears to indicate that, even if a building has not been identified as

EQP, the PCBU may be liable if they fail to minimise the risk of the building collapsing (or causing injury) in an earthquake if they were privy to the potential risk of this occurring or had concerns about the building's structural integrity.

The responsibilities of a building owner under the HSWA and that of the Building Act need to be considered separately. Regardless of whether a building is designated EQP, PCBUs have a responsibility to eliminate, or minimise, seismic risks, "so far as is reasonably practicable" under the HSWA (s30(1)). How the likelihood of a sufficiently damaging earthquake plays into what is "reasonably practicable" is unclear: it is yet to be tested in a court of law and due to the contextual nature of the issue, may never be specifically defined.

2.3 The Local Government Act

The Local Government Act (LGA) provides both statutory authority and limits to TA decision making, the purpose of which is defined as "to enable democratic local decision-making and action by, and on behalf of, communities, as well as promoting the social, economic, environmental, and cultural well-being of present and future communities" (Local Government Act 2002, s10). Until 2019, the LGA specifically required local authorities to "have regard" to "the avoidance or mitigation of natural hazards" in performing their duties. Although this is no longer the case, local authorities must still adopt an infrastructure strategy, "identifying and managing risks relating to natural hazards and by making appropriate financial provision for those risks" (Local Government Act 2002, s101B(3)e).

There are various general principles that local authorities must follow when performing their function, primarily related to democratic values, transparency and community engagement which could have relevance to decisions around community assets (Local Government Act 2002, (s14)). In particular, local authorities must take the interests of both current and future communities into account when making decisions (Local Government Act 2002, (s14(1)(c)(ii)). Such interests would need to include the seismic resilience of such assets but also, potentially, the community impacts of closing such assets.

Local authorities must also take into account other factors in their decision-making process, including the economic and cultural well-being of the communities they represent (Local Government Act 2002, s14(d)). This indicates that the management of risk in public buildings must therefore be made in the context of economic and cultural interests. If a TA determines through relevant evidence and assessment that a public building poses too great a risk to safety to remain open, the legal framework requires that they must also consider the economic and cultural impacts of such a closure, and, potentially, mitigate the impacts.

Local governments are also mandated to consider views and perspectives of persons likely to be impacted by the decision and the need to consider and balance all available options when agreeing on a decision (Local Government Act 2002, s77–79). A decision to close a public building, without any consideration of the impacts or other possible options, would thus appear open to challenge.

3 METHOD

To understand how TAs translate engineering advice and community impacts into public policy decisions about EQP public buildings, a series of recorded interviews with eight staff representing five TAs across New Zealand was carried out. To ensure our research obtained a range of perspectives, interviewees represented both the property owner and regulatory arms of councils and were from local authorities of varying sizes and degrees of internal resourcing and located within different seismic zones.

Each interview involved providing participants with three hypothetical scenarios about public buildings categorised as EQP. The scenarios and the associated questions were designed to enable interviewees to talk

through their respective decision-making processes, in particular: who makes decisions; what the key decision drivers are; and how seismic risk information is assessed alongside other risk information (e.g., in relation to liability, reputation, legislative responsibility, insurance, social impact, and public sentiment).

Based on the interviews the authors developed a 'strawman' decision-making framework reflecting a possible best practice approach to seismic risk management in public buildings that also considers community impacts. This 'straw-man' framework was tested and refined through two on-line workshops with representatives from nine TAs. During the workshops, the strawman framework was presented and feedback on its potential utility was obtained. This instigated a process of refinement, leading to the creation of the decision framework introduced in this paper.

4 INTERVIEW FINDINGS

Interviews with TAs identified clear variance in how policy decisions about buildings categorised as EQP or assessed as less than 34%NBS are made. Each of the five TAs interviewed used a different process for making decisions around occupancy of EQP buildings. The commonalities and differences are summarised below.

Policies and decision makers

Three of the five TAs interviewed had an internal policy that governed occupancy (and ongoing management) of EQP buildings. The majority of the policies emerged from the property management arm of the TA, in conjunction with the building regulation team. Those that had policies found that they were invaluable for effectively managing council-owned building risk and making defendable decisions.

For all TAs, there was a clear and conscious delineation between building safety and the function or role of the building in the community. Property or building managers tended to make a decision about building safety before consulting with the corresponding service manager. The decision to close ultimately lay with the council Chief Executive, or their delegate, as a PCBU under HSWA. Two of the five councils, however, expected elected officials to sign off on closure decisions because of expected public interest in the decision.

Closure decision criteria

%NBS was used by four of the five TAs to guide closure decisions, with one TA having a rigid rule to close any buildings assessed as less than 34%NBS. The other TAs were more nuanced, considering failure mechanisms and mitigation options. The fifth council used to have a rigid policy based on %NBS, however, they realised they needed a policy that gave engineers an opportunity to look at behaviour and performance (beyond %NBS) to take into account buildings that rate above 34%NBS but have vulnerabilities that could lead to a brittle or sudden collapse in larger earthquakes (such as those identified in Chapter 5 of the Engineering Assessment Guidelines 2017 (the "Yellow Chapter") (Technical Proposal to Revise the Engineering Assessment Guidelines, 2018). Their policy now centres on the potential for brittle catastrophic collapse under any earthquake loading.

The primary (and in most cases the only) driver behind EQP building decisions for all five councils was staff and public safety. However, minimum legal obligations such as HSWA and the Building (EQP amendment) Act were also a factor. With one interviewee noting *"[Decisions] need to be black and white based on law so it is defensible…I have a job to do, it is all about life safety"*.

Across each case study organisation there appeared to be little internal discussion around risk tolerance. Much of the decision making of these TAs accordingly appears to rest on the potential consequence of an

earthquake event rather than its likelihood. None of the TAs we interviewed explicitly considered and assessed the life safety risk against the impacts of closing a building on the community.

This is a significant finding in the context of this study because it suggests that the likely community impacts of pre-emptive building closure are overshadowed by concerns about the potential scale of a hypothetical risk, as predicted in the behavioural science literature (Eiser et al., 2012; Mcclure et al., 2009; Joslyn and Nichols, 2009; Patt and Dessai, 2005; Bruine De Bruin et al., 2000; Windschitl and Weber, 1999). In other words, the likelihood and immediacy of an event (i.e. the socioeconomic impacts of a building closure on a community) is outweighed by the theoretical possibility of a catastrophe (involving life safety risks) over an extended geological timeframe. Without a robust process that seeks to balance risk consequence and likelihood, TAs may be inadvertently and inappropriately allocating resources, and adversely impacting their communities. This points to a clear need for a standardised process that assists TAs to balance risk likelihood more deftly with the possible consequences of public policy decisions.

5 DECISION FRAMEWORK

5.1 Purpose

A core output of this research project is a co-designed decision process that will support TAs to make robust building occupancy decisions. The aim of the guide is to help councils as building owners understand and more confidently balance the potential effects of building damage should an earthquake occur against the impacts that follow directly from a decision to close a building. The five steps in the decision framework are shown in Figure 1. The steps largely align with the ISO31000 risk management process, stepping users through the risk identification, assessment and treatment phases of risk management. The framework sets out the information needed and process for decision makers to make robust and considered decisions. The framework is set out in a way that allows territorial authorities to adjust the parameters to match their own risk management processes and risk tolerance.

In the following sections, we qualitatively describe each step of the assessment process as well as the rationale behind each step. The full framework and guide will be publicly available in mid-2021.

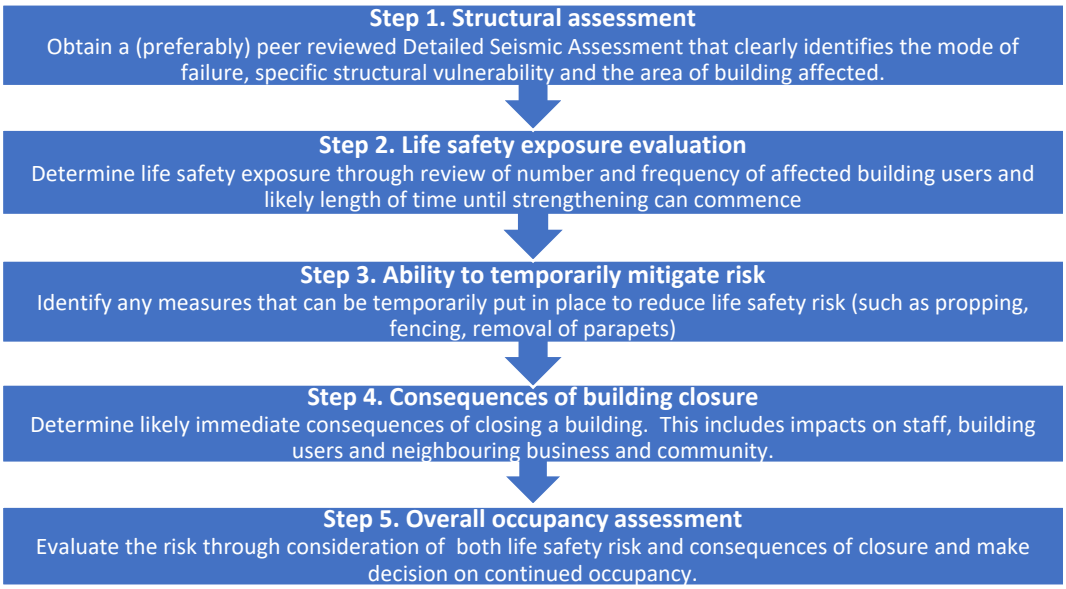

Figure 1: Steps in earthquake-prone public building decision framework

5.2 Step 1: Structural assessment

Step one of the framework describes the process of engaging a qualified engineer to assess the building. The step sounds simple, however, our interviewees noted a number of challenges in this step around quality and interpretation of engineering assessments and the framework provides some guidance on this.

Decisions to change the occupancy of buildings should be based on sound engineering advice and a clear understanding of the likely behaviour of the building under a range of earthquake actions. Usually this requires a Detailed Seismic Assessment from an experienced Chartered Professional Engineer who has not only assessed the %NBS rating but are confident they understand the likely vulnerability, mode of failure and physical consequences of failure. The assessment should include any adjoining structures that might affect building safety (e.g. shared structural roof or wall elements). For any buildings rating less than 34%NBS, the DSA should be critically reviewed internally or externally (through a panel or via a peer review) to ensure confidence in the technical advice provided and that life safety risks are identified and managed appropriately.

Given the very low probability of a significant earthquake occurring in the short term, and the potential immediate adverse consequences of closing a building on the community, it is important that decisions to change occupancy are made on a peer reviewed Detailed Seismic Assessment, rather than upon the receipt of only an Initial Seismic Assessment or draft Detailed Seismic Assessment. Draft assessments should be appropriately reviewed, along with an equally considered review of the impacts of closure. This process can take a period of weeks and months. The only exception to this is if an ISA has indicated a critical and urgent deficiency that must be addressed immediately, which would result in the building being be classed as a *Dangerous building* under Section 121-124 of the Building Act 2004. It is important to note that earthquake is specifically excluded from the scope of dangerous buildings, unless damaged directly by an earthquake such that an aftershock could give rise to a life safety hazard.

We recommend all buildings with structural vulnerabilities that could lead to a brittle or sudden collapse in larger earthquakes should be subject to a review of continued occupancy, regardless of their %NBS rating. They may not be designated 'Earthquake Prone' under the Building Act, but they may pose a significant enough risk to pose a liability under the HSWA.

5.3 Step 2: Life safety exposure

In Step 2, users of the framework are guided through a series of tables to ascertain the likely life safety exposure of a particular building. To fulfil obligations as a PCBU under the Health and Safety at Work Act 2015, the life safety exposure of EQP buildings must be considered: this includes consideration of the failure mechanism and part of building affected (Step 1); and how many people use that part of the building and how frequently they use the building. It also includes exposure to those outside the building. This helps decision makers understand the likelihood that someone will be in the building at the time of an earthquake.

TAs also need to consider the length of time it will take to design and fund the remediation of an EQP building and people will, therefore, be using the building while EQP. This is because risk is a function of time: the longer we are exposed to a risk, the more chance we have of the event occurring. In the case of seismic performance of buildings this risk is exacerbated by the natural deterioration of buildings over time contributing to lower seismic performance and the increasing stress in earthquake fault systems over time.

Building Act earthquake prone building provisions since 1991 have always recognised that it is impractical and impossible to mitigate all seismic risk immediately. The 2016 amendments define statutory time frames that give building owners between 7.5 years (for priority buildings in high seismic hazard zones) and 35

years (for non-priority buildings in low seismic hazard zones). The decision framework provides some added nuance to the MBIE time frames and encourages TAs to think about the time it will take to design and fund seismic remediation projects and compare that against the life safety exposure to occupants.

Figure 2 illustrates how the risk of occupying an EQP building increases over time. Total life safety risk is a combination of the life safety exposure at any time and the duration people are exposed to the risk (i.e. the area under the graph). You could have a building that has high life safety exposure, but if you can remediate it quickly the building occupants are only exposed for a short period and the overall risk to occupants is reduced. Conversely if you have a building with low life safety exposure you could leave it occupied for a longer period and have the same overall life safety exposure risk.

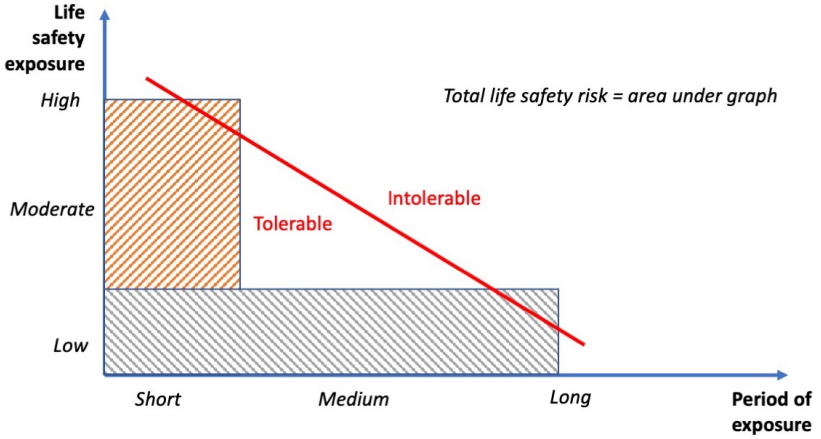

Figure 2: Total life safety risk is a combination of the life safety exposure at any time and the duration people are exposed to the risk.

If the building poses a high life safety risk, local authorities need to either: work to reduce that risk more quickly; mitigate the risk (see Step 3); or have a sound reason for keeping the building open (see Step 4). Conversely, if the risk is low, then local authorities can take more time to remediate the risk. Buildings that pose a higher life safety risk, and remain occupied, should be prioritised for remediation.

5.4 Step 3: Ability to temporarily mitigate risk

In step three, TAs are encouraged to consider ways to temporarily mitigate life safety risk, particularly in cases where there may be a long time before earthquake strengthening can occur. Any measure that can reduce life safety risk should be considered: including physical works to remove or secure high risk building elements (parapet ties or props, removal of chimneys), and closing parts of the building/moving some services to reduce building occupancy.

5.5 Step 4: Consequences of immediate building closure

Step 4 is an evaluation of the consequences of closing a building while seismic strengthening or other alternative plans are made for the building. Under the Local Government Act 2002, local authorities must take into account the interests of both current and future communities when making decisions (s14(1)(c)(ii)). This includes the seismic resilience of assets as well as the economic, social, and cultural impacts of closing such assets. Specifically the framework suggests TAs evaluate the 1) ability to deliver services by other means, 2) impact on vulnerable communities, 3) impact on neighbouring buildings, and 4) impact on staff. During this assessment we suggest reviewing options for alternative service delivery. This includes ability to move services to another location or to deliver it by alternative means (e.g. online).

5.6 Step 5: Overall occupant assessment

The final step is to combine and evaluate both the life safety exposure and the consequences of closure. This step is critical to ensure that local authorities are balancing both their roles as PCBU under HSWA and their duties under the Local Government Act. In the framework, users give buildings a rating of A, B or C based on the combination of life safety exposure and consequences of closure. The aim of this step is to minimise significant disruption to communities from closure of high importance buildings and also minimise unnecessary exposure of occupants to life safety risk in a low importance building.

Before a final decision is made, the framework prompts users to do a 'sense check'on the final decision. The decision framework is designed to ensure all relevant information is considered in a logical and robust way. However, there will always be situations where the complexity of the building, or community, will mean that the process does not derive the best solution. The framework should be used as a starting point, and a basis for gathering and considering all relevant information.

In particular, there may be other factors that influence a closure decision including building condition (ie extent of any deterioration not specifically adressed in the engineering assessment), the presence of other hazards like hazardous substances or asbestos in the building, or geological hazards adjacent to the building (e.g. unstable ground) that might create an additional life safety and human health risk during an earthquake.

Also the demographics of the people using the building could also be considered – are they young, elderly, physically impaired, or vulnerable in any way? Does this vunerability put them in an unacceptably risky situation; for example, users are unable to safely exit a damaged building following an earthquake?

The framework also provides guidance around mitigating the risk to occupants while they occupy an EQP building, including: erecting signage, isolating any dangerous building elements, creating and practicing emergency plans, and training staff.

For any closure decision, the framework suggests a reasonable time period is allowed to vacate the premises and relocate services, unless there is imminent danger to building users. This is to help mitigate and reduce the impact on the health and wellbeing of building service users.

6 CONCLUSION

Our research shows that TAs as building owners are obligated to consider both life safety and community impact of closure of earthquake prone public buildings. The framework we have developed steps TAs through a robust and thorough risk assessment process that looks beyond %NBS to consider all aspects relating to life safety exposure, and then balances this against the socio-economic impacts of building closure. Once finalised, this framework will become a resource for TAs to more confidently and robustly assess decisions around occupancy of EQP buildings.

The challenge of managing earthquake prone buildings extends beyond TAs as owners of public buildings; the process and theory behind the framework developed here will be applicable to all building ownership situations.

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