The Resilient Buildings Project

Societal expectations for seismic performance of buildings

RESEARCH PAPER MARCH 2022

nzsee NEW ZEALAND SOCIETY FOR EARTHQUAKE ENGINEERING

EQC EARTHQUAKE COMMISSION Kōmihana Rūwhenua

Authors

Charlotte Brown, Resilient Organisations
Shannon Abeling, University of Auckland
Sophie Horsfall, Resilient Organisations
Helen Ferner, New Zealand Society for Earthquake Engineering
Hugh Cowan, Hugh Cowan Consulting

Acknowledgements

This research was initiated by the New Zealand Society for Earthquake Engineering with funding from Earthquake Commission (EQC). The research team was co-led by NZSEE and Resilient Organisations and supported by the University of Auckland. The authors gratefully acknowledge the contributions of the steering group to the design and delivery of this project: Sarah Beaven (University of Canterbury), Dave Brunsdon (Kestrel), Caleb Dunne (EQC), Ken Elwood (University of Auckland), Derek Gill (NZIER), John Hare (Holmes Consulting Group), Jo Horrocks (EQC), and Rob Jury (Beca).

We also gratefully acknowledge the contribution of our 32 interviewees and 27 focus group participants. In this project we deliberately sought diverse views of seismic resilience: we wanted to talk to people who are typical building users rather than those that think about seismic resilience every day. We are grateful, in particular, to those who agreed to talk to us despite thinking they had nothing to offer. Everyone we spoke to as a building user, owner, or representative of public interest contributed to our understanding of how society uses buildings and expects them to perform.

Supplementary reports

For more information on the data collection methods and detailed data collected during this research, please refer to the following supplementary report, available in April 2022.

> Abeling et al. (2022). Societal expectations for seismic performance of buildings: detailed report on interviews. The Resilient Buildings Project Report. NZSEE. April 2022.
>
> Horsfall et al. (2022). Societal expectations for seismic performance of buildings: detailed report on focus groups. The Resilient Buildings Project Report. NZSEE. April 2022.

Contents

Executive summary

Purpose

New Zealand has experienced its most sustained period of disruption caused by natural hazards since the mid-20th century. Foremost among these have been repeated damaging earthquakes, a volcanic eruption with mass casualties, severe weather impacts – coastal and inland – all since 2010. Overshadowing the local and regional impacts of those events is COVID-19 and its far-reaching disruption of social and economic routines.

This report responds to a challenge to take stock of current societal thinking related to earthquake risk, in light of recent earthquake events. The Resilient Buildings Project, through which we report our findings, sought to capture a snapshot of societal expectations and tolerance toward seismic risk to inform future performance objectives for new buildings. Historically, these objectives have been framed by technical experts in structural engineering and building science, and this project represents the first time in New Zealand researchers have set out to document from a community perspective nationwide societal expectations for the seismic performance of buildings.

Changes to disaster-risk insurance pricing and its availability in the New Zealand market and demand for improved engineering design and refitting of buildings have evolved rapidly during the past decade, whereas associated regulation and guidance for seismic design and construction has moved more slowly. Now for the first time in decades, there is an opportunity to revisit the philosophy behind our seismic engineering design practice to align it with current societal needs.

In 2021, we undertook 32 interviews and six geographically based focus groups to understand and map the variations of societal views on seismic risk. We set out to understand how performance expectations for buildings changed based on building use and geographical context, how and why risk tolerance varies across different community settings, and the importance of seismic risk relative to other demands on the built environment. The report summarises the views expressed with the intention of informing a wider process of review incorporating expert knowledge of current regulatory settings and technical options to meet future societal needs.

Life safety

Our findings show that peoples risk perceptions are diverse. Life safety remains of central importance in our built environment – both during an earthquake and in day-to-day life.

Priorities for life safety, however, are not necessarily linked to objective calculations of building occupancy. More common is consideration of the individuals that are likely to occupy a building. Protection of vulnerable persons and people with essential skills are both common expectations. Participants agreed that current requirements to prioritise buildings that have post-disaster functions are important but should be extended to buildings such as supermarkets and food production facilities, as well as multi-purpose spaces that can be used to support disaster recovery.

Participants also highlighted that large occupancy buildings or areas with the potential for panic or chaos post-earthquake should be designed to reduce risk of injuries and fatalities relating to human responses to events. Locations likely to experience or to attract large numbers of people immediately after an earthquake, such as schools or community centres, were also identified as locations where higher building performance is expected, due to dangers presented by aftershocks. Perceptions of safety, particularly for buildings housing vulnerable persons is also considered important for alleviating mental health strain post-event.

Social recovery

There is a growing need and expectation that the built environment should support social recovery following an earthquake through equitable access to essential goods and services, sustaining social connection, and restoring normalcy that supports cultural identity.

An initial priority following a major earthquake is the provision of services that support life – including emergency response services and healthcare. Linked to this is the provision of goods and services that support physiological health, such as shelter and provision of clean water, sanitation, food, and rubbish collection services. Telecommunications and power are also high priority to allow for communication and cooking. The preference is for shelter to be in peoples' own residences particularly in higher-density housing areas (e.g., cities) where significant numbers of people would otherwise be displaced, and communities dislocated.

An important element of social recovery, beyond essential services, is the capacity for community members to connect. The nature of the connection and their relationship with the built environment differs between communities. Across community types this includes places of worship, community centres and marae. In cities retail shops and restaurants are considered important locations for social connection. In towns, pubs, sports grounds/stadiums, and clubrooms are high priority gathering locations.

Restoration of effective governance is critical to social recovery for a number of reasons that change over time, from: provision of civil defence activities, in particular communication immediately post-event; to critical infrastructure provision (water and waste) within days to a week; to provision of regulatory and governance services that support the community in the medium term.

'Returning to normal' is considered a critical factor in social recovery. While 'normalcy' may look different for different communities it often involves the re-opening of schools, retail, and arts and recreation facilities, generally within 1-6 months. Access to buildings that support cultural wellbeing and identity are by this measure a key part of the return to normalcy, although it was noted that culture transcends buildings.

Having confidence in recovery time frames is also considered an important part of social recovery for some, particularly those with experience following the Canterbury and Kaikōura earthquakes[1]. Participants noted that the high degree of uncertainty associated

[1] Payne, B. A., Abeling, S. A., Becker, J. S., Elwood, K. J., Ferner, H., Brunsdon, D., & Johnston, D. M. (2021). Earthquake Stories: Experiences of Building Performance in Earthquakes to Inform Future Standards. Paper presented at the New Zealand Society for Earthquake Engineering Conference, Christchurch, New Zealand. repo.nzsee.org.nz/handle/nzsee/2348

with the settlement of insurance claims following the Canterbury earthquakes and the protracted recovery contributed to significant mental health challenges. It is believed that having clearer understanding of the likely timeframe for returning buildings to service will reduce the mental health impacts of a future earthquake event.

Economic recovery

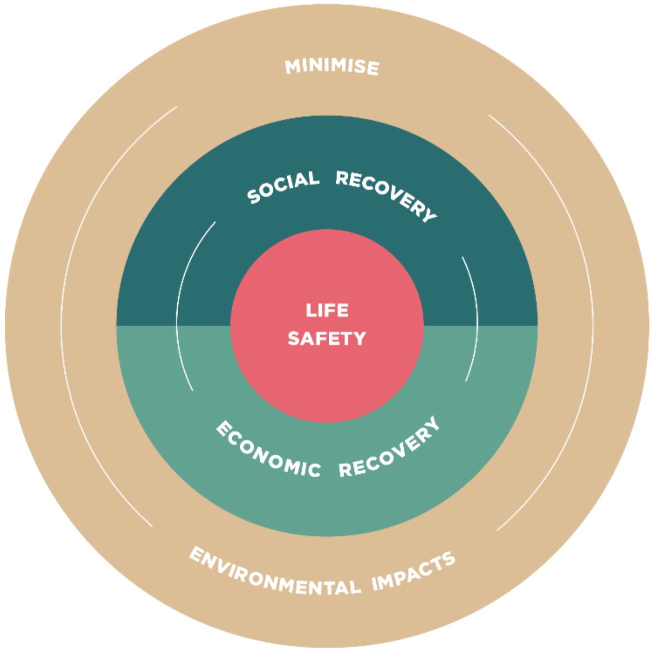
Buildings play a key role in economic recovery by supporting critical industries and enabling people to sustain their ways of life, including schooling, employment, and access to services. For many, economic recovery performance objectives are second only to life safety and social recovery priorities. However, it is evident that there are very strong synergies between economic and social recovery and many buildings support both. When considering economic recovery, many participants focused on the need to enable households to generate income, including the capacity to work from home. Confidence in recovery was also a key theme related to economic recovery, as was the connection between mental health and economic recovery due to potential impacts on individuals of unemployment.

Economic recovery priorities are strongly tied to place, for example agriculture in its various forms is more important in rural towns and districts than diversified metropolitan urban economies.

Environmental impact

Reducing impacts of earthquakes on the natural environment is an emerging priority. Many participants drew strong connections between impacts on the natural environment and community wellbeing, identifying the role that the environment plays in underpinning human existence. For many the potential impacts following an earthquake, particularly the presence of hazardous waste or waste volumes that exceed the capacity of current disposal facilities, are considered intolerable.

Intolerance of environmental impact appears to be primarily driven by the perceived public health consequences and the long-lasting or potentially irreversible impacts of waste on water and land quality for future generations. Consequently, reducing building waste from damage buildings following earthquakes is a priority for many.



1: LIFE SAFETY

Avoid mass casualty events
Protect vulnerable persons
Ensure safety at mass gathering points
Preserve high value skills and resources
Support immediate response activities
Maintain a perception of safety

2: SOCIAL RECOVERY

Ensure equitable access to essential goods and services
Enable effective governance
Have places to connect
Return sense of normalcy
Retain sense of place and cultural identity

3: ECONOMIC RECOVERY

Restore enabling services and industries
Enable people to work
Build business confidence

4: MINIMISE ENVIRONMENTAL IMPACT

Minimise waste generation
Avoid hazardous waste or potential public health risks
Reduce embodied carbon

Intolerable risks

A strong theme that emerged during the data collection is the intolerance of impacts that have permanent or long-term effects. For example, a mass exodus of residents/social dislocation, impacts on the natural environment, collapse of industry, and significant loss of trust in governance are all types of disruptions viewed as being potentially long-lasting or irreversible. Therefore, these types of disruption are intolerable regardless of earthquake likelihood.

This strong desire to avoid detrimental impacts on the social fabric of a community is underpinned by a desire to avoid multi-generational impacts and was a particularly strong view amongst Māori participants. Likely time to recover, consequently, is a key determinant of acceptability of a given impact. Intolerance of impacts significantly increase for events that are likely to affect two consecutive generations.

Acceptable risks

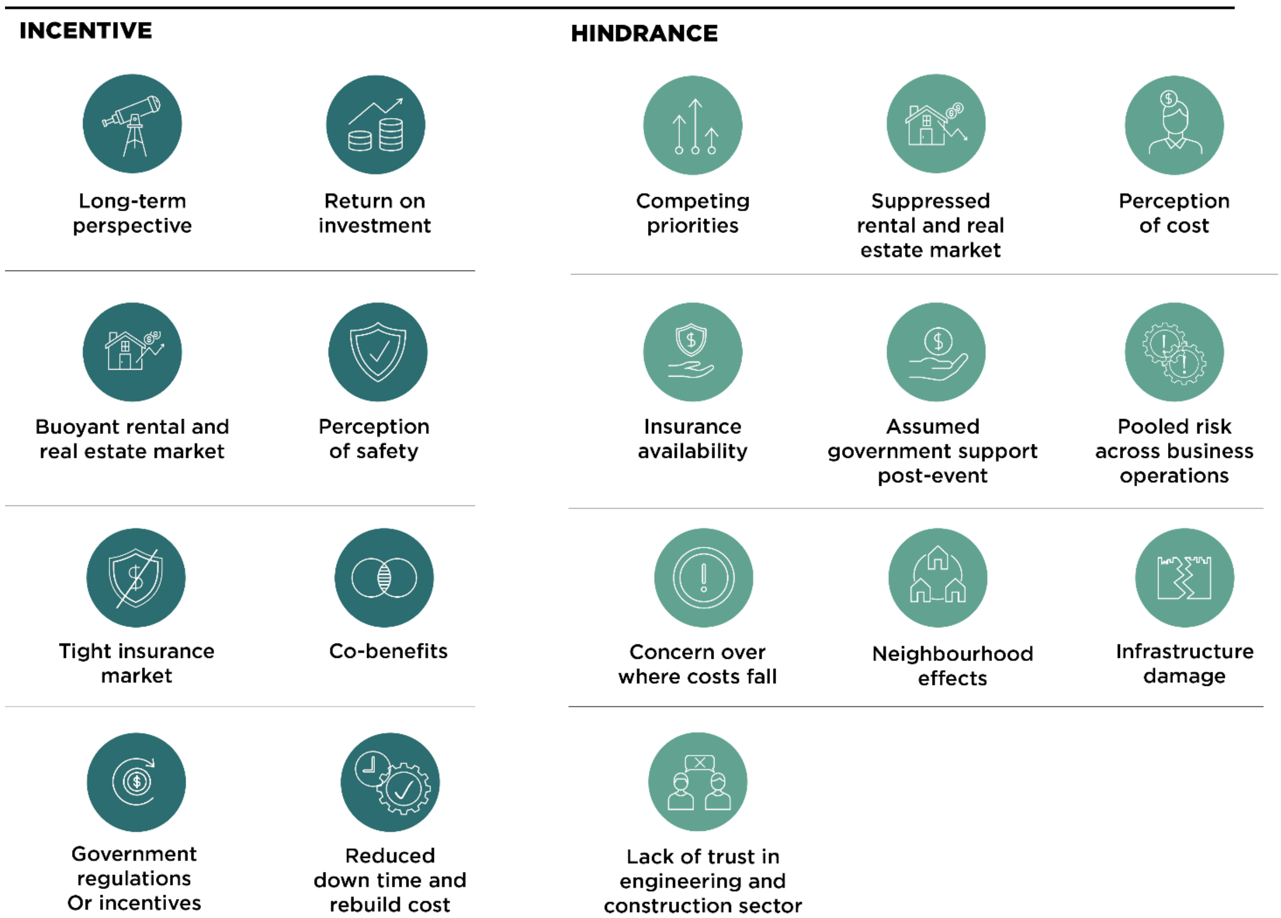
For more frequent events, being those perceived likely to occur several times during the life of a building, most people expect business/society to be able to continue as usual. However, minor, cosmetic damage is generally acceptable. For many private building owners or tenants, building maintenance and refurbishment is a regular part of a building's life cycle. Fixing minor damage every 5-10 years is acceptable, so long as the disruption to building tenants is minor (i.e., no displacement) particularly for tenants who are vulnerable to disruption.

Tolerable risks

Tolerable risks are those that people can live with but, given the opportunity or the right conditions, would like to reduce. This is essentially a trade-off zone between the benefits and costs of reducing the risk which need to be carefully considered.

Participants identified factors that might provide an opportunity or incentive to reduce tolerable risks. For example, building owners who take a long-term perspective are more likely to invest in reducing seismic risk to reduce whole-of-life costs, protect reputation, support local community, and attract tenants. Other incentives include insurance accessibility or affordability.

Conversely, many factors were presented as a deterrent or hindrance to enhanced risk mitigation. For example, issues such as housing affordability and climate change are placing, at times, conflicting demands on building owners and users and the limited resources available. Given earthquakes' uncertain timing and low frequency, seismic resilience is not always seen as the first priority. Other deterrents include perception of cost and return on the investment, insurance availability, reluctance to be a first mover in a community and lack of trust of the engineering and construction sector to mitigate seismic risk.



Throughout our data collection, place-based differences between seismic risk tolerance and recovery priorities were strongly evident. For example, focus groups with rural agricultural-based economies place greater importance on agricultural infrastructure (e.g., food production facilities and transport/logistics hubs) compared to focus groups with urban professional, service-based and manufacturing economies. The seismic performance of agricultural infrastructure is prioritised in these rural communities not only for economic reasons (e.g., export market reputation) but also for enabling employment, social interactions, and animal welfare. The community context deeply influences risk tolerance, restoration priorities, recovery timeframes and assets and industries that are considered most critical. This demonstrates the role of buildings in a broader system that supports community resilience.

The socioeconomic and geographic context of a community also influences the degree to which seismic risk is tolerated, including seismic hazard zone, geographic isolation, density of built environment and the perceived capacity of a community to recover from disruption. Communities that have access to resources (physical, financial, and human) are more accepting of seismic risk. Communities with fewer resources, those under stress or with significant social inequity issues are less risk-taking.

COMMUNITIES WITH LOWER TOLERANCE FOR RISK	COMMUNITIES WITH HIGHER TOLERANCE FOR RISK
LOW hazard zone	HIGH hazard zone
Geographically ISOLATED	NOT geographically ISOLATED
HIGH density built environment	LOW density built environment
LOW recovery capacity	HIGH recovery capacity

A community's capacity and willingness to cope with disruption will change over time. The influence of COVID-19 on the participants' risk preferences was evident. Many participants expressed how experiences with COVID-19-related disruptions had shifted their priorities – both in terms of their understanding of what impacts are tolerable or not, and where priorities for supporting social and economic wellbeing lie. Some also noted that the stress COVID-19 placed on individuals and communities had reduced their current capacity to cope with an earthquake.

These findings underscore a basic axiom that societal risk perspectives vary over time. Stressors (such as increased awareness and exposure to climate change risks), competing demands for limited resources (such as housing affordability), and trends such as technology change will positively and negatively impact a community's capacity to cope with disruption over time, as well as their desire to mitigate seismic risk.

Relative importance of seismic risk

Resilience to seismic events is just one of the performance outcomes we require from our buildings in the total risk environment. Relative to other priorities in the built environment, life safety during a seismic event is considered equally as important as other day-to-day safety measures. Social and economic recovery and minimisation of environmental impacts of earthquakes sit on par with the importance of day-to-day building objectives such as increased user wellbeing, environmental sustainability and building longevity.

Longevity, or improved lifespan of buildings, came up repeatedly as an important priority. It was noted that longevity has long-term environmental and cost benefits. Building material durability and adaptability of a building over time (e.g., changing its use) were often acknowledged as key contributors to improving the lifespan of buildings. Material durability, for example, contributes to better building performance, and potentially its function, through time. Participants noted the correlation between improved seismic performance and building longevity.

Key implications for building regulation and design practices

A clear finding of this study is the heterogeneity of people's risk tolerance. This diversity in risk tolerance and expectations of seismic performance expectations for new buildings arguably beckons a rethink of regulatory objectives. A rearticulation of the objectives of current regulatory settings would provide a useful starting point to test for gaps or ambiguities relative to contemporary expectations.

The strongest imperative for seismic resilience remains life safety, but economic and social recovery from disruption are strong emerging drivers of performance together with environmental sustainability. Enhanced performance of buildings in seismic events is expected to improve the longevity of the building stock and to reduce the likelihood of potential displacement following an earthquake or the disruption of operating in a damaged building.

However, the preferences revealed in this study indicate demand for more diverse performance objectives for buildings than currently mandated under existing regulatory settings, essentially unchanged since the early 1990s. This research does not address the scope of potential changes to the Building Act, Building Code, or relevant technical standards for seismic risk, but questions naturally arise from our findings, including:

- How can or should decision-makers balance local/community expectations with the need for national 'public good' outcomes?
- How might technical standards reconcile the range of perspectives concerning which buildings – and what functionality – may be prioritised at a local/community level?
- Where is the balance struck between regulated performance objectives (through codes and standards) and private actions (market incentives and co-benefits) to equitably improve seismic performance?
- What language is required to resolve existing ambiguities of purpose for seismic risk treatment in the building regulatory system (terms such as 'low probability', 'amenity' and 'sustainability')?
- If there is value in periodic tracking of shifts in broad societal expectations over time to feed into design practice and regulation, how might this be codified?

Beyond these conceptual challenges there are specific implications to consider. These include reviewing how building performance is articulated in the Building Act and Code and supporting documents, as it might pertain to seismic loadings, including:

- How might designs and technologies that limit the onset of damage at moderate levels of shaking be more strongly encouraged or mandated?

- Given the focus of building regulations on the treatment of risk within a lot boundary or single building footprint, how should the aggregate exposure of the neighbourhood and wider community be addressed?
- Should we specifically have criteria that relate to performance during aftershocks, to provide greater confidence for people to 'shelter in place' if required?
- How should the variance of societal expectations between individuals and communities be accounted for and balanced between regulated performance (through codes and standards) or market incentives and co-benefits, which may be better instruments for improving seismic performance amongst some building owners?
- How can confidence in the building profession, including architects, engineers, constructors, consenting authorities and building services consultants be enhanced to improve perceptions of seismic resilience of our building stock?

How the changing nature of urban centres influences design practice and regulation invites careful consideration. For example, increasing multi-unit and high-rise, inner-city housing is changing the concentration of risk in our urban communities. Increased expectations (since COVID-19) that individuals will be able to work from home during or following a disruptive event also means that the resilience of essential service connections and wider infrastructure need to be factored into design, much more so than for traditional housing and traditional work practices.

How building owners and investors make investment decisions in relation to seismic and other risks and how contingent protection mechanisms, such as insurance, influence decision making are also critical elements[2]. For this, a greater understanding of the expected costs and benefits of enhanced seismic resilience to reflect current expectations is needed. The interplay between seismic resilience and sustainability also needs to be understood to capture the relative benefits versus up-front costs of longer-lasting, more seismically resilient buildings

Last, we need to frame and measure building risk in the context of the wide range of risks facing our communities. This will ensure that seismic design and regulation advances consistently with other risks facing our communities.

[2] There is research currently underway within QuakeCORE to explore the seismic resilience incentives and insurance quakecore.nz/te-hiranga-ru-quakecore-funding-proposal-2021-2028/

Introduction

New Zealand has experienced its most sustained period of disruption caused by natural hazards since the mid-20th century. Foremost among these have been repeated damaging earthquakes, a volcanic eruption with mass casualties, severe weather impacts – coastal and inland – all since 2010. Overshadowing the local and regional impacts of those events is COVID-19 and its far-reaching disruption of social and economic routines.

This report responds to a challenge to take stock of current societal thinking about earthquakes to inform the design practices and regulation of risk in future buildings. Earthquakes since 2010 have resulted in loss of life and extensive property damage in affected communities. The scale of financial losses and the social trauma associated with these recent seismic events is unprecedented in New Zealand history. Not since the 1940s[3] have New Zealand communities experienced considerable earthquake-induced disruption to urban settings, and there are few alive with memories of such losses.

Throughout the second half of the 20th century, institutional treatment of seismic risk in New Zealand incorporated global progress in seismic design and construction practices, resulting in many buildings surviving levels of shaking that exceeded their design conditions, particularly in Christchurch in 2010-2011. Many buildings were also damaged, however, and subsequently deemed unfit for reoccupation even where the life-safety of the structure itself was not in question. This has led to steep increases in general insurance pricing in New Zealand, and in some cases, reduced availability of insurance[4]. There have been concerns about the seismic vulnerability of older buildings and some modern multi-storey buildings, which have translated into demands for urgent strengthening and greater oversight of design generally[5]. This has coincided with a growing awareness that fundamental linkages are missing between the regulatory treatment of risk within a lot boundary or a single building footprint and the aggregate exposure of the neighbourhood and wider community[6].

Currently buildings in New Zealand are designed with a focus on the protection of life safety for occupants. Damage that affects a building's capacity to function, and therefore its amenity, is regulated only at very low levels of earthquake shaking for most buildings. Only buildings with post-disaster functions, such as hospitals and emergency services, are required to consider their expected use in the aftermath of a major event and must be designed to withstand greater forces than those of lesser importance (Appendix 1). The frequent disruptive earthquakes since 2010 have shown how the impact of damage to the built environment by earthquakes goes well beyond life safety in an urban setting. The

---

[3] New Zealand had not experienced widespread urban damage since consecutive earthquakes of about magnitude 7 struck the lower North Island in June and August,1942, respectively. Approximately 10,000 chimneys toppled in Wellington and more than 5000 homes were damaged. There was considerable damage to buildings in Masterton and other towns throughout the Wairarapa, some of which took more than a decade to repair. teara.govt.nz/en/historic-earthquakes/page-9

[4] WCC 2019. Mayor's Insurance Taskforce, Discussion Document November 2019.

[5] MBIE 2017. Responses to the Canterbury Earthquakes Royal Commission recommendations. Ministry of Business Innovation and Employment, February 2017.

[6] Stannard, M. 2020. The New Zealand Building Code – a rethink? NZSEE Annual Conference 2020. Paper 155.

continuum of cascading impacts can be financial, economic, environmental, or social, and usually a combination of all these will be present once buildings and infrastructure experience major or prolonged disruption to services and function. Taken together, these impacts can significantly impact community wellbeing with prolonged consequences[7,8].

Project purpose

The updating of regulation and technical standards for building and construction in New Zealand has followed established norms. This has included reactions to crises[9,10] as well as gradual adjustments to changing technologies and practices[11]. The Resilient Buildings Project, through which we report our findings, seeks to provide a snapshot of societal expectations and tolerance toward seismic risk. It is the first time in New Zealand researchers have set out to document nationwide societal expectations of the seismic performance of buildings. Prior to this, the parameters for seismic design have principally been set by expert panels.

More than a decade has passed since the start of the Canterbury earthquake sequence, so a public discussion of the merits of damage avoidance for new buildings is timely. Of particular interest is whether tolerance for the impact of earthquakes has changed since the technical objectives for structural performance were last set in the 1970s[12].

To ensure our built environment effectively manages risk to building users, we need to understand societal objectives, risk attitudes, and tolerance toward seismic risk. This understanding is necessary if future building regulations and design standards are to evolve and meet these societal objectives.

This report details current societal expectations of new buildings during earthquakes. It aims to bridge a gap in communication between those who rely on the technical standards that facilitate society's functioning in the built environment and those called upon to write, revise and regulate them. Combined with expert knowledge, and technical analysis, the insights arising from this study will contribute to discussion about desired levels of seismic resilience and the design approaches, both mandatory and voluntary, available to achieve desired performance.

---

[7] See, for example, outcomes of the Public Inquiry into EQC, eqcinquiry.govt.nz/inquiry-reports/

[8] See, for example, Wellington City Council Mayor's Insurance Taskforce 2019 Discussion Document. wellington.govt.nz/-/media/news-and-events/news-and-information/news/files/2019/insurance-taskforce-recommendations.pdf?la=en&hash=3D635715B6F1D9CE4D713CD4BD3D71E9DCD373E0

[9] Hunn, D., Bond, I and D. Kernohan, 2002. Report of the Overview Group on the Weathertightness of Buildings to the Building Industry Authority, 31 August 2002.

[10] Searancke, G., Mumford, P., Simpson, K., and M. Steel 2014. Governing the Regulators – applying experience. Policy Quarterly, 10(1). Wellington.

[11] The historical role of expert standards development committees in creating and reviewing technical standards is acknowledged including their contribution to building technical consensus as a proxy for societal preferences. standards.govt.nz/develop-standards/standards-development-committees/

[12] The Building Code is a performance-based regulation (Appendix 1). Clause B1 – Structure sets out the objectives and performance objectives for the structure of.a building and has not changed since the early 1990s. legislation.govt.nz/regulation/public/1992/0150/latest/DLM162576.html#DLM164788

What we did

This explorative research set out to:

- Develop a clear language of desired performance objectives,
- Document how perceptions of risk and desired building performance vary in different building, geographical and community settings, and
- Evaluate the importance of seismic resilience relative to other demands on the built environment.

In 2021, we undertook a series of interviews and focus groups with diverse stakeholders across New Zealand to understand perspectives on the future seismic performance of buildings. The team interviewed 32 individuals who represented a range of experiences and interests across different seismic hazard zones, geographies, socioeconomic groups, and cultural contexts. The interviews focused on understanding each participant's current role, background, and earthquake experience and their expectations of building performance during a significant earthquake event and during minor earthquake events.

Then, a series of six geographically based focus groups were undertaken, covering three urban centres and three smaller towns with differing levels of seismic hazard. The focus groups comprised three to seven individuals who represented different community perspectives (local civil defence, business community, health sector, welfare sector, environmental interests, and Māori). Due to COVID-19 restrictions, each focus group was held over two 2-hour virtual sessions using video conferencing software and an online whiteboard application called Miro.

Participants took part in three activities that explored: 1) the importance of different types of buildings in a community; 2) risk tolerance to different types and frequencies of earthquake disruption, and; 3) how important seismic resilience is compared to other building performance priorities.

The first activity involved a generic town map on which participants were asked to work together to allocate a set number of counters across buildings within the imagined community (Figure 1), to illustrate the relative importance of a given building. The participants were asked to view the buildings through specific lenses and to prioritise accordingly. This included thinking about life safety, social recovery and economic recovery, and the time to return to functionality. They were then asked to consider how they would invest in buildings pre-event to prepare for a significant earthquake.

In the second activity, participants were asked to individually complete four risk matrices to indicate whether a given combination of likelihood (rare to frequent) and consequence (minor to significant) is acceptable, tolerable, or intolerable.

In a final activity, participants were presented with a table of building design requirements that included day-to-day building priorities plus those that would enhance the seismic resilience of a building. They were asked to individually rank the relative importance of each of the priorities and then discuss their choices as a group.

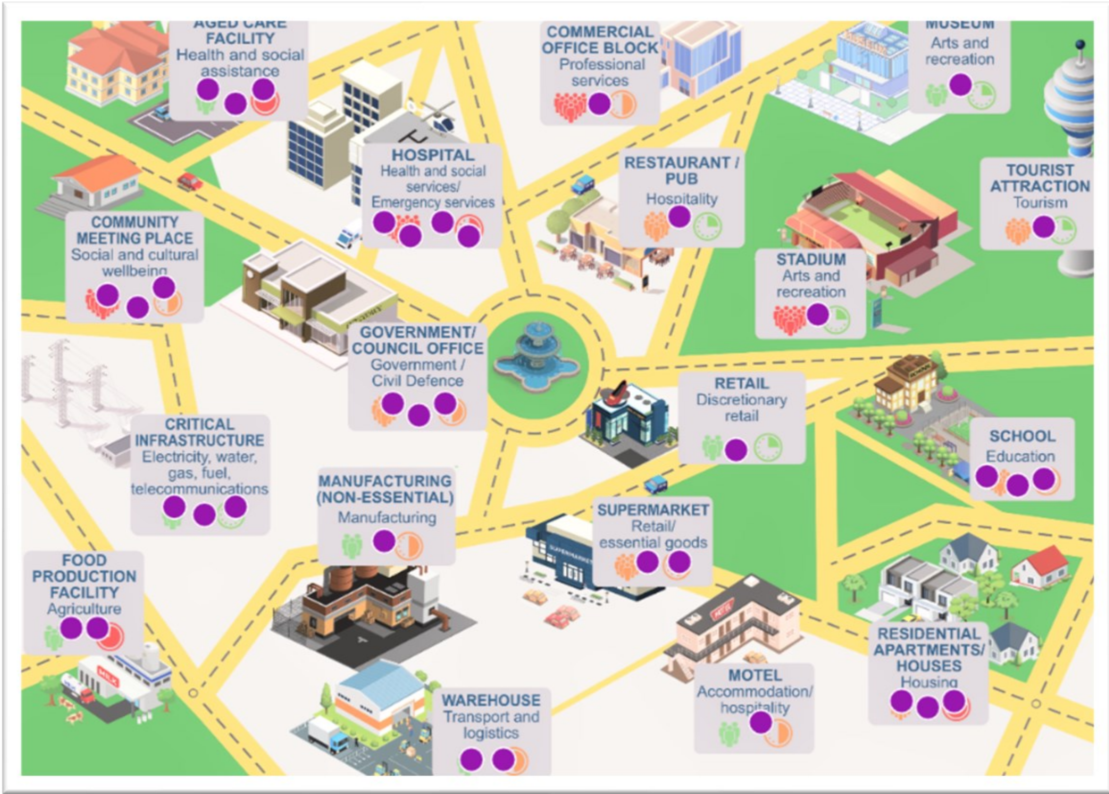


Figure 1: Example of town map activity with counters distributed to indicate pre-event investment priorities

The key findings from the interviews and focus groups are summarised in this report and offer insights to inform the development of technical standards and building regulations.

> The use of the term “risk” in this report aligns with the New Zealand Disaster Resilience Strategy (2019) being: the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined as a function of hazard, exposure, vulnerability and capacity[13].

13 National Disaster Resilience Strategy. civildefence.govt.nz/cdem-sector/plans-and-strategies/national-disaster-resilience-strategy/

Eliciting and incorporating societal perspectives in public policy

Internationally there is interest in incorporating societal perspectives and expectations into technical processes for seismic engineering code development[14]. However, eliciting societal tolerance for seismic risk to inform public policy is constrained by risk proximity in space or time[15]. Social norms evolve[16 17] and are influenced by proximity to adverse events[18]. Social norms are also influenced by current policy settings, community context and how hazard information is presented[19]. Risk preferences can vary significantly among individuals based on education, experiences and personal circumstances. This temporal and individual heterogeneity is a constant when contemplating the challenge to define and integrate social expectations into public policy.

There are a few examples, in New Zealand and internationally, where natural hazard risk management strategies have incorporated public opinion.[20 21 22] There is work currently underway by NIST and FEMA in the US exploring moving the US building codes (which also focus on life safety) toward 'functional recovery'[23 24]. They are undertaking a series of similar community engagement exercises to inform their work.

---

[14] Tanner, A., Chang, S. E., & Elwood, K. J. (2020). Incorporating societal expectations into seismic performance objectives in building codes. Earthquake Spectra, 36(4), 2165–2176. doi.org/10.1177/8755293020919417

15 May PJ. (2001). Societal Perspectives about Earthquake Performance: The Fallacy of "Acceptable Risk". Earthquake Spectra; 17 (4): 725–737. doi:10.1193/1.1423904

[16] Legros, S., & Cislaghi, B. (2020). Mapping the Social-Norms Literature: An Overview of Reviews. Perspectives on Psychological Science, 15(1), 62–80. https://doi.org/10.1177/1745691619866455

[17] Young HP. (2015). The Evolution of Social Norms. Annual Review of Economics; 7 (1): 359–387. doi:10.1146/annurev-economics-080614-115322

[18] McClure J, Ferrick M, Henrich L, Johnston D. (2019). Risk judgments and social norms: Do they relate to preparedness after the Kaikoura earthquake? Australasian Journal of Disaster and Trauma Studies; 23 (2): 41–51.

[19] Vinnell, L. J., Milfont, T. L., & McClure, J. (2019). Do Social Norms Affect Support for Earthquake-Strengthening Legislation? Comparing the Effects of Descriptive and Injunctive Norms. Environment and Behavior, 51(4), 376–400. https://doi.org/10.1177/0013916517752435

[20] Kilvington M, Saunders WSA. (2015). 'I can live with this'.' The Bay of Plenty Regional Council public engagement on acceptable risk (GNS Science Miscellaneous Series 86). Lower Hutt, New Zealand: GNS Science.

[21] Steentjes K, Demski C, Seabrook A, Corner A, Pidgeon N. (2020). British public perceptions of climate risk, adaptation options and resilience (RESiL RISK): topline findings of a GB survey conducted in October 2019 (Project Report). Cardiff: Cardiff University.

[22] Tappenden KM. (2014). The District of North Vancouver's landslide management strategy: Role of public involvement for determining tolerable risk and increasing community resilience. Natural Hazards; 72 (2): 481-501. doi: 10.1007/s11069-013-1016-0

[23] National Institute of Science and Technology and Federal Emergency Management Agency (2021). Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time. NIST_FEMA Special Publication FEMA P-2090/NIST SP-1254/January 2021.

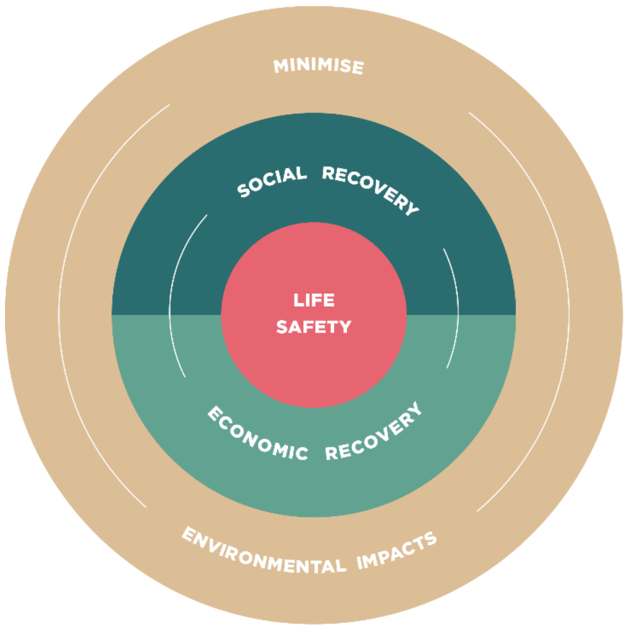
[24] National Institute of Science and Technology. (2021). NIST-FEMA Post-Earthquake functional recovery workshop report. NIST special publication 1269. July 2021. nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1269.pdf

Findings

Seismic resilience performance objectives

To effectively regulate the design of buildings for earthquakes, we need to understand societal priorities following a major shake: first in terms of reducing direct impacts and secondly through managing short-, medium-, and long-term impacts from social, economic, and environmental perspectives. For example, what type of disruption is most impactful? Which buildings are most important and why? How time critical is the return to partial or full functionality?

Generally, seismic resilience performance objectives fall into four categories, as shown in Figure 2[25] [26]. In this section we describe each of these objectives in detail, describing the common as well as the outlying perspectives and how they relate to each other. We also note where priorities significantly diverge, for example, between locations with different levels of seismic hazard and between urban and rural communities.



1: LIFE SAFETY

Avoid mass casualty events
Protect vulnerable persons
Ensure safety at mass gathering points
Preserve high value skills and resources
Support immediate response activities
Maintain a perception of safety

2: SOCIAL RECOVERY

Ensure equitable access to essential goods and services
Enable effective governance
Have places to connect
Return sense of normalcy
Retain sense of place and cultural identity

3: ECONOMIC RECOVERY

Restore enabling services and industries
Enable people to work
Build business confidence

4: MINIMISE ENVIRONMENTAL IMPACT

Minimise waste generation
Avoid hazardous waste or potential public health risks
Reduce embodied carbon

Figure 2: Seismic resilience performance objectives

[25] A multi-capital, wellbeing or environment framework is a common approach to understanding disaster preparedness and recovery. See for example, the Civil Defence and Emergency Management Recovery Preparedness and Management Directors' Guideline, civildefence.govt.nz/assets/Uploads/recovery/DGL24-20/Recovery-DGL24-20-Full-Version.pdf or the Guide to Disaster Recovery Capitals (ReCap) developed by New Zealand and Australian researchers, recoverycapitals.org.au/aotearoa-nz-recap-guide#c05c9196-1ec1-459d-8b9a-6218a967125c

[26] Recent research by Hoang et al. (2021) also identified safety, cultural and economic factors for prioritisation of seismic retrofitting in Wellington, New Zealand. Hoang, T., Noy, I., Filippova, O., and Elwood K., (2021), Prioritising earthquake retrofitting in Wellington, New Zealand. *Disasters,* 2021, 45(4): 968–995.

Life safety

Preserving life remains the minimum requirement for the seismic performance of buildings in New Zealand. There is a widely held expectation that everyone should be able to exit a building safely following a major earthquake. Those who thought fatalities and injuries were acceptable following a major earthquake generally believed that eliminating all risk is impossible given the seismically active setting of New Zealand.

> *"I expect my building to not kill or injure me. I expect it to withstand the kinds of quakes for which Wellington should be prepared, to not fall over if that quake brings a tsunami, and to allow me to eventually exit the building when it is safe to do so." – Interview Participant (Private sector, High seismic hazard zone, Tenant)*

> *"There's a certain base level of safety that people would expect." – Interview Participant (Private sector, National perspective)*

> *"I think probably the most important thing is that the building allows people to get out safely." – Interview Participant (Private sector, High seismic hazard zone, Owner-occupier)*

> *"Yes, so we kind of accept that there's going to be a level of damage there, but there's not going to be any ongoing risk to life safety" – Focus Group B participant (High seismic hazard zone, City)*

Reducing life safety risk to a low level is a key determinant of the way engineers design buildings. Such principles lie at the heart of current New Zealand regulatory design requirements, aimed at preventing sudden, catastrophic collapse of a building, allowing occupants to safely exit a building. For most buildings, these minimum requirements do not anticipate how the building's usual functions might be affected beyond very low levels of shaking.

Currently, in New Zealand, a new building's seismic resilience is determined based on its geographic location (seismic hazard region) and the size or use of the building. Buildings designed to withstand higher levels of earthquake shaking include buildings that contain large crowds or buildings with special post-disaster or emergency response functions, such as a hospitals, critical infrastructure assets or emergency or civil defence hubs. When asked about life safety, participants in our study added nuance to this established baseline.

First, priorities for life safety are not necessarily linked to objective calculations of building occupancy. The peak number of people potentially in a building, the duration people are likely to be in a building for or whether occupants are likely to be asleep in that building were all noted; however, they were not common in everyone's calculation. More common, was consideration of the individuals that were likely to occupy a building.

Protection of vulnerable persons and people with essential skills are both common expectations. Vulnerable occupants such as those with low mobility or reduced capacity to take life saving measures, such as young children or dependent elders, are deemed a higher priority to protect[27]. Not as strongly but commonly, participants felt that protection of people with skills essential to the response and recovery or vital to the economic recovery of a region should also be prioritised.

Second, and related to the nature of the occupants, is the importance of knowing a building is safe – before, during and after an event. A perception of safety is particularly important for buildings that house vulnerable persons. Knowing loved ones are in a safe building during an earthquake may reduce the urgency to check on them following an event. It may also reduce ongoing anxiety (and related mental health impacts) after an event for those who continue to occupy earthquake-affected buildings[28].

Third, participants often noted that buildings that act as natural gathering points should be prioritised for the protection of life safety. For example, following an earthquake, parents will descend upon schools to collect children. Buildings in close proximity to these natural gathering points were also identified for prioritisation to reduce risk to those near these locations, particularly during aftershocks. Community centres, maraes, hospitals and civil defence gathering points all potentially fall into this category.

Fourth, buildings or situations with the potential for panic or chaos post-earthquake should be designed to reduce the risk of injuries and fatalities relating to human responses to events. For example, participants emphasised the need for safe evacuation routes from buildings and areas that housed large numbers of people to encourage safe, calm, and quick egress from a building.

Last, participants agreed that facilities that can sustain life and support response activities are important. Examples included civil defence hubs and hospitals (which already attract high designations under existing design standards) as well as supermarkets and food production facilities (which currently do not). Participants also highlighted the importance of facilities that, if severely damaged, would create significant pressure on other critical facilities (for example, damage to aged care facilities could create pressure on hospitals). And the importance of prioritising multi-purpose spaces was noted to support emergency response and recovery in a number of ways, including temporary accommodation if needed.

Beyond the common life safety priorities described above, some other views were shared that attracted less consensus but provide useful insight. In particular, contrasting views were shared over whether the agency of the person using the building should be considered. In other words, are higher standards warranted for buildings where users have less choice over whether they enter the building or not (e.g., a prison, school or hospital, versus a retail shop)?

---

[27] Research is underway in New Zealand to develop an Earthquake Casualty Model for New Zealand. The research will look at the key drivers for earthquake injury and fatality. See for example, Horspool, N., Elwood, K., Johnston, D., Ardagh, M. (2020). Factors influencing casualty risk in the 14th November 2016 Mw7.8 Kaikōura, New Zealand earthquake. International Journal of Disaster Risk Reduction. Vol51, 2020, 101917, ISSN 2212-4209, doi.org/10.1016/j.ijdrr.2020.101917.

[28] Perception of safety was an important factor in the self-evacuation of inner-city residents following the 2016 Kaikōura earthquake. Blake, D., Becker, JS, Hodgetts, D., Hope, A. (in review), The 2016 Kaikōura Earthquake: Experiences of safety, evacuation and return for apartment dwellers in Te Whanganui-a-Tara (Wellington), Aotearoa New Zealand. International Journal of Mass Emergencies and Disasters.

> *"If you are asking people to rely on a community facility, then that has to be to a higher code than something that's private." – Interview Participant (Public sector, National perspective, Environmental expert)*

Related, some believed that building users' familiarity with the building and seismic risks (or lack thereof) should be considered to recognise the high anxiety that visitors to a town or location may feel during a seismic event and the lack of means to self-care post-event. This approach would prioritise buildings such as motels, hotels or some tourist attractions. Conversely, some believed priority should be on buildings that housed residents of a community rather than visitors given their likely duration of exposure. These distinctions, although not always explicit, highlight the challenge of differentiating 'what when' (impact and consequence) from 'what if' (frequency and likelihood).

Social recovery

Beyond protection of life safety, there are high expectations that our future buildings can effectively support community recovery following a major earthquake. Effectively this means providing equitable access to essential goods and services, opportunity for social connection and restoring a sense of normalcy through access to assets that support cultural identity.

Access to essential goods and services such as critical infrastructure (telecommunications, water, electricity for heating etc) and food consistently emerged as critical elements to support social recovery. These elements all support the physiological health, safety, and wellbeing of our communities. Typically, communities expect these basic services to be functional within days and over time these services need the support of transport and logistics to continue supply of goods.

Restoration of effective governance is also critical to social recovery for a number of reasons that change over time from: provision of civil defence activities, in particular communication immediately post-event; to critical infrastructure provision (water and waste) within days to a week; to provision of regulatory and governance services that support the community in the medium term. Provision of these services have varying degrees of reliance on local government buildings due to increased capacity to work from home, but are critical in maintaining social order, cohesion and trust in governance.

Participants noted that equitable access to services and assets is important for successful social recovery. Understanding how recovery priorities can exacerbate inequities is important. For example, closure of schools can not only affect educational outcomes but disrupts food in school programmes and puts increased pressures on families to feed children within constrained household budgets. Earthquake impacts can also exacerbate housing issues/ homelessness.

> *"There are some communities that are quite resilient, others less so. So there are different consequences on different people. And stating the obvious, depending on particular economic circumstance, you've got greater ability to respond than people with lesser means. And also, stating the obvious, people with disabilities and older people find it particularly traumatizing" – Interview Participant (Private sector, National perspective, Expert in building sector)*

An important element of social recovery, beyond essential services, is the capacity for community members to connect. The nature of the connection and relationship with the built environment differed between different communities. Across community types this includes places of worship, community centres and marae. In cities retail shops and restaurants were considered important locations for social connection. In towns pubs, sports grounds/stadiums and clubrooms were high priority gathering locations.

> *"Then I suppose on a lesser level, loss of things like suburban centres, irrecoverable loss of sporting facilities would strike at the heart of a community. So, I think that there are things here where the community gathers for a sausage sizzle, or school fairs and all those sorts of things. If they were all gone, then the community would certainly be in much worse health" – Interview Participant (Private sector, High seismic hazard zone, Owner-occupier)*

Buildings that have both physical and social infrastructure to support the community, that is, buildings that can feed and house large groups of people, as well as providing for established social networks (maraes, community centres, sporting and country clubs, religious centres), are higher priority for supporting social recovery in the short term. Other venues that support social connections were lower priority with a desired return in the medium-term.

Several participants noted that the ability to connect post-earthquake is particularly difficult for some groups within a community. There was particular concern about older people, people with disabilities, and/or mental health issues. One interviewee from the social housing sector mentioned that they go door to door after major earthquakes to check on tenants. The extent to which buildings can sustain these social connections, particularly for vulnerable or isolated groups, is unclear. Some participants noted that social connections are adaptable and are not dependent on built infrastructure[29], but the inability to 'shelter in place', and forced dislocation of communities can create significant physical barriers to social connection.

A return to a sense of normalcy is desired around 3-6 months post-earthquake. 'Normalcy' looks different for different people and urban settings but often involves re-opening schools (within 1 month), retail, and arts and recreation facilities (within 3 months). A return to routine activities is particularly important for some vulnerable groups such as older persons and those suffering dementia. A return to physical workplaces is also included here as an important step in returning to normalcy and a sense of personal fulfilment – particularly for those that cannot work from home (within 3-6 months).

Access to buildings that support cultural wellbeing and identity is a key part of the return to normalcy. As above, what comprises cultural assets differs significantly across communities. For some urban settings this includes restaurants and pubs and economic activity hubs. For

[29] International research shows the importance of social capital to support disaster recovery and demonstrates that recovery pathways and outcomes are more heavily influenced by social connections than physical damage. For example, see Aldrich, D. P., & Meyer, M. A. (2015). Social Capital and Community Resilience. American Behavioral Scientist, 59(2), 254–269, doi.org/10.1177/0002764214550299

others it includes sports grounds and stadiums or access to cultural taonga that are housed in museums. It was noted that culture transcends buildings.

> *"Tikanga and reo are more than just marae" "As long as there is somewhere, tikanga processes can be moved [they are] bound to people not a building" Focus Group A participant (Low seismic hazard zone, Town)*

> *"Culture is more than museums and art, it is the ability to walk between restaurants and pubs etc and that is hard to restore" Focus Group B participant (High seismic hazard zone, City)*

A less common sentiment, but noted in some rural settings, is the need to ensure the community is empowered to support their own recovery. This means protecting or quickly restoring built assets that house equipment that can support the community to be active participants, and potentially lead, in their own recovery.

Also evident in rural economies is the key role agri-business plays in social interactions and networks in small towns. The social recovery of a rural community is tightly coupled with the economic recovery as business activity ensures regular interaction between potentially isolated community members. Consequently, the timely restoration and return to function of agri-business assets play a key role in social recovery.

Having confidence in recovery time frames is also considered an important part of social recovery for some, particularly those with experience following the Canterbury earthquakes. Participants noted that the high degree of uncertainty following the Canterbury earthquakes and prolonged recovery contributed to significant mental health challenges. It is believed that having clearer expectations of the return to service of buildings will reduce the mental health impacts of a future earthquake event.

> *"It will be a combination of the duration of [the recovery] and the certainty. So a longer period that is certain and fixed is better than one that's shorter but with a lot of uncertainty about whether [the recovery] will extend out for years beyond." – Interview Participant (Private sector, High seismic hazard zone, Tenant)*

> *"It's unacceptable to have a really drawn-out recovery that is just too long... So Christchurch has been unacceptable in many ways... People's houses, homes down there, and the crap people have had to go through with insurance. It's just unacceptable... This prolonged chronic stress of trying to recover." – Interview Participant (Private sector, National perspective, Building user)*

Economic recovery

Economic recovery is critical following an earthquake. Buildings play a key role in economic recovery by supporting critical industries and enabling people to go back to work.

For many, economic recovery performance objectives are secondary to life safety and social recovery priorities. However, it is evident that there are very strong synergies between economic and social recovery, and there are a number of built assets that support both economic and social recovery. Below are the key economic recovery priorities identified by participants.

Economic wellbeing and corresponding recovery priorities are highly dependent on the nature of the economy. Thus, they vary widely between communities. However, common priorities are built assets and services that enable economic activity. These include critical infrastructure and transport and logistics, both of which should ideally be at least partially operational within days and fully operational within the first few weeks. Other key economic enablers are services that enable people to go to work; this includes having schools and aged care facilities open such that dependents are cared for. It also includes functional and healthy homes that people can live in without affecting their physiological or mental health. In some cases, this includes homes that enable people to work effectively from home. Having access to healthcare services is also important for enabling economic recovery.

For many participants, the drive to support economic recovery is founded on a desire to enable households to generate income. More than minor job losses are felt by many to be an unacceptable consequence of an earthquake, and there is an expectation that most people could return to work between 1-3 months. This means that some place-based workplaces, such as manufacturing, are prioritised over commercial office blocks where most users can work from home.

For some communities, tourism is a key economic sector, and the restoration of facilities such as motels, stadiums, museums, retail, and hospitality is considered key to stimulating economic recovery. While a priority for some, a return to operation of around 3 months is considered reasonable.

Connection between economic recovery and mental health

Within our focus groups, discussions around economic impacts/recovery quickly looped back to social impacts and impacts on mental health for individuals, families, and communities. For many participants capital loss or reduced industry production were less tangible, and arguably less impactful, than the potential for job loss. Job loss, on an individual level, could impact the health and wellbeing of family and their capacity to pay for essential goods and services (food, healthcare, schooling). Beyond that job loss can contribute to mental health issues. At community level, job loss at high levels is likely to create social issues such as increased occurrences of vandalism, assaults, theft, and family violence.

Alongside job loss, increase in debt levels, and loss of capital value (particularly houses) could negatively affect individuals' financial positions and, depending on their individual circumstances, this could adversely impact mental health. In severe circumstances this could also result in increased suicide rates.

> *"The rollout from the mental health issues [since the Canterbury earthquakes] has impacted a generation. So, you've got mums and dads who have been dealing with earthquake issues, raising kids who have not been raised correctly. The teachers are looking after things that they shouldn't be looking after, the kids soiling themselves because they haven't been trained to get to the toilet. And it just goes on and on when ignored. So, you know, there is a wave of a generation that's coming through that has particular earthquake-related mental health." – Interview Participant (Private, High seismic hazard zone, Tenant)*

As noted above, economic recovery priorities are strongly tied to place. For some communities, priority lies in fast restoration of large employment industries or sectors, for example a milk or meat processing plant. For others, priority lies in buildings that are not immediately obvious. For example, rugby clubs and pubs play a key role in some rural communities as they are locations where many agri-business deals are done.

Other less common sentiments included prioritising efforts around industries that are time sensitive, such as agricultural businesses that, if disrupted at the wrong time of year, could lose a whole year's worth of production.

> *"Farming is cyclic as well. If you don't do something at certain time of the year, you have nothing at the end too." – Focus Group F participant (Medium seismic hazard zone, Town)*

Confidence in recovery also emerged as a key theme related to economic recovery. Business confidence is considered an enabler of investment and innovation: both internal and external. Poor business confidence or a perception that the affected region is not safe or able to assure quality could significantly impact export markets, which could take years to recover from. It could also affect investment in areas with potential growth (e.g., aged care, tech-sector).

> *"So probably the worst economic impacts – they are many and varied really – I mean, there is the impact of the loss of an asset, whether that's an individual or business… [and] there is loss of confidence over time, so some people might choose not to rebuild." – Interview Participant (Private sector, National perspective, User)*

> *"Complete loss of confidence in the area. It's not totally irreversible, but you're talking decades for it to get back, which is almost irreversible. But it's just a really long, hard process, getting people to come back." – Interview Participant (Private sector, High seismic hazard zone, Tenant)*

Natural environment

Impacts on the natural environment were not generally the initial focus for participants when considering the performance of buildings during earthquakes. However, when prompted to consider the potential impacts of the general and hazardous waste from an earthquake event, as well as the embodied carbon in disaster waste and rebuild materials, it became apparent that these are emerging priorities for many.

Many participants drew strong connections between impacts on the natural environment and social and human wellbeing, and the role that the environment plays in underpinning human existence. For many, the potential impacts following an earthquake, particularly the presence of hazardous waste or waste volumes that exceed the capacity of a current waste management facilities, are considered intolerable.

> *"It doesn't matter what happens, if we don't look after the environment we have nowhere to live full stop." … "The environment doesn't come before people, but it's pretty high up there." Focus Group F participant (Medium seismic hazard zone, Town)*

> *"In my philosophy…wellbeing is that high-level goal, and then sustaining that is environmental sustainability. There is no point in having wellbeing in a temporary*

sense while the system is falling apart, you know. So, wellbeing and sustainability are the sort of top and bottom of your… view of the world." – Interview Participant (Private sector, National perspective, Environmental expert)

Intolerance of environmental impacts is driven by the perceived direct impact on public health, long-lasting or potentially irreversible impacts of the waste, and the subsequent impact on future generations. Some also note the potential impact on waterways. Consequently, reducing building waste following earthquakes is a priority for many.

"We've been very much focusing on low impact design, so ensuring that the building is actually operational and doesn't need to be knocked down as a consequence of the earthquake. So clearly, the embodied emissions is really raising up the profile at the moment. We don't want to waste millions or thousands of tons of embodied carbon as a result of the earthquake. So that's probably the longer-term priority." – Interview Participant (Private, National perspective, Sustainable construction expert)

A less common counterpoint to this view is that building waste has to be dealt with at some point so is not a major concern or priority specific to earthquakes.

"The expectation is that buildings … would last maybe 100 years. The building is going to get pulled down, probably …we have to deal with that waste regardless within that time frame." Focus Group E participant (Low seismic hazard zone, City)

"There's always going to be environmental impacts. I mean, dust and asbestosis, petrol falling out of tanks and going into the water and stuff like that. To my mind,… I think that a lot of that stuff is probably pretty minor in this scheme of things." – Interview Participant (Private sector, National perspective, Tenant)

The carbon cost of earthquakes was discussed by some participants but was not a universally understood concept. For those that understood the concept, there was concern over the potential loss of embodied carbon through building demolition and disposal and the embodied and operational carbon required to replace damaged buildings. However, the relative impact of this was not generally well understood. There is research underway to investigate the relative carbon benefits or costs of more seismically resilient buildings[30] [31].

One participant noted the opportunity for future technology and building materials to significantly reduce the impact of damaged buildings including more readily recyclable materials.

[30] mbie.govt.nz/building-and-energy/building/building-for-climate-change/

[31] PhD candidate Rosa Gonzalez is undertaking research funded by BRANZ and QuakeCoRE to understand the carbon case for building resilient buildings wiki.canterbury.ac.nz/display/QuakeCore/IP1%3A+Functional+Recovery+with+Repairable+Multi-storey+Buildings

Recovery progression

As part of our focus groups, using our imagined community maps, we discussed recovery priorities in terms of the speed at which certain types of buildings (and the functions those buildings deliver) should return following a major earthquake. The sequence and speed of the return of services differed across the focus group locations, but the average response is shown in Figure 3. Below we have charted a sequence of recovery across four stages, spanning the initial weeks of response to the period beyond six months.

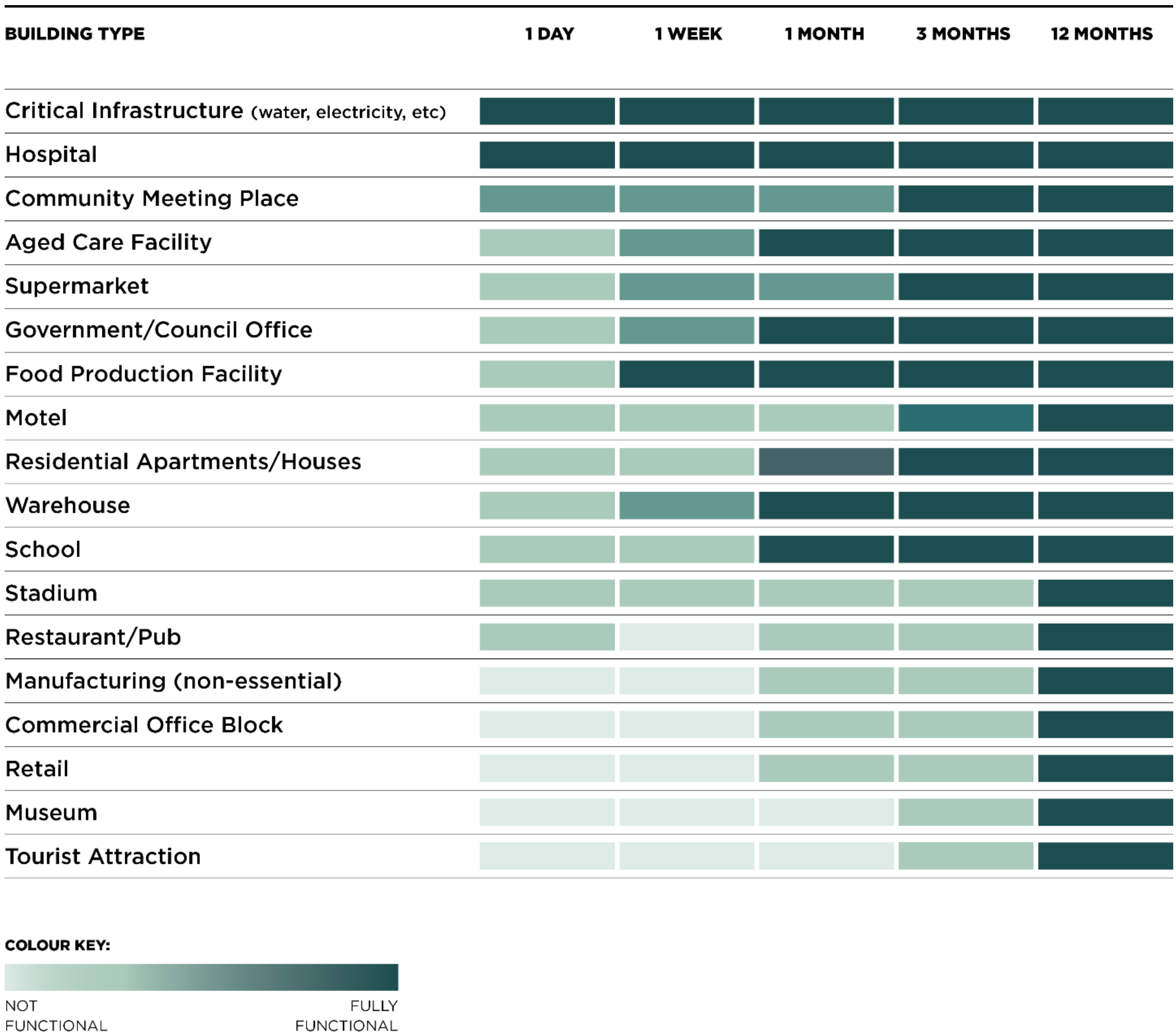


Figure 3: Time to restore building function

Early response priorities (up to 30 days)

An initial priority following a major earthquake is the provision of services that support life – including emergency response services and healthcare. Linked to this is the provision of goods and services that support physiological health, such as shelter and provision of clean water, sanitation, and rubbish collection services. Telecommunications and power are also high priority to allow for communication and cooking. The preference is for people to shelter in their own residence particularly in higher-density housing areas (e.g., cities) where significant numbers of people would otherwise be displaced[32]. Having alternative facilities such as maraes, community centres, motels, schools, or stadiums is advantageous. These versatile spaces also act as safe gathering points for communities needing emotional and practical support. People are reasonably amenable in the first few weeks to temporary or emergency provision of water, and sanitation services. Having food available from supermarkets and access to cash/banking facilities is also considered an early priority.

Underpinning these early priorities is the need to have facilities operational that, were they not, could have a cascading impact on the recovery. These include critical infrastructure services, and (basic) transport and warehousing services. This can also include aged care facilities that, if disrupted, could severely impact on healthcare facilities as some high dependency residents may need to be cared for in hospital.

Basic infrastructure and building-based services that support animal welfare is a priority in rural areas.

Recovery 1- 3 months

Once individuals' basic survival needs are met, the focus shifts to ensuring safe or healthy living conditions – this includes the availability of electricity to heat homes and allow for cooking.

During this phase, basic needs for businesses are also a priority to ensure as many people can be employed as possible. This includes enabling access to business premises to allow retrieval of essential business materials, and sufficient electricity and internet services to allow working from home; or having place-based workplaces (such as essential manufacturing facilities) open. Availability of childcare for essential workers is, consequently. a priority.

Government services, such as welfare payments and regulatory services, are also becoming time critical and need to be operational but can generally be carried out without dependence on access to the government building itself.

Local food production is considered an important industry to operate during this phase, particularly in rural towns, due to the time sensitive nature of industry and the potential to both support the local communities supply needs and bring in export revenue. To support local food production and connection with export markets, as well as supply of essential goods (such as baby clothes), support is needed from the transport and logistics sector.

[32] Recent research by Becker et al. argues that targeted preparedness measures are needed to specifically address the needs of inner-city dwellers. Blake, D., Becker, JS, Hodgetts, D., Hope, A. (in review), The 2016 Kaikōura Earthquake: Experiences of safety, evacuation and return for apartment dwellers in Te Whanganui-a-Tara (Wellington), Aotearoa New Zealand, International Journal of Mass Emergencies and Disasters.

Recovery 3-6 months

During this phase economic activity and employment are prioritised. It is expected that most local economic activity has resumed and ideally is being done on premises – particularly those non-essential, placed-based services like manufacturing, hospitality and retail.

At this stage building a sense of normalcy through social and cultural connections is becoming time critical. This includes a return to normal routines such as attending a workplace or school, attending religious services, discretionary retail, going to the pub/cafe, or participating in social sport. This reduces the adverse impacts of disruption to mental health. Stadiums were particularly important for this purpose in smaller community settings.

Recovery after 6 months

After six months the built environment is expected to underpin the ongoing recovery and rebuild process (e.g., motels to house rebuild workers, community spaces and social networks such as churches to support individuals).

For some communities, return of domestic tourism is important. Generally, towns want infrastructure that supports domestic tourism to be open sooner than cities to support economic recovery. This includes the re-opening of motels, museums, stadiums, and tourist attractions.

Management of perceptions of disruption and recovery was an issue commonly raised by participants. Being able to signal to those outside the affected region that you are open for business is an important step towards full recovery.

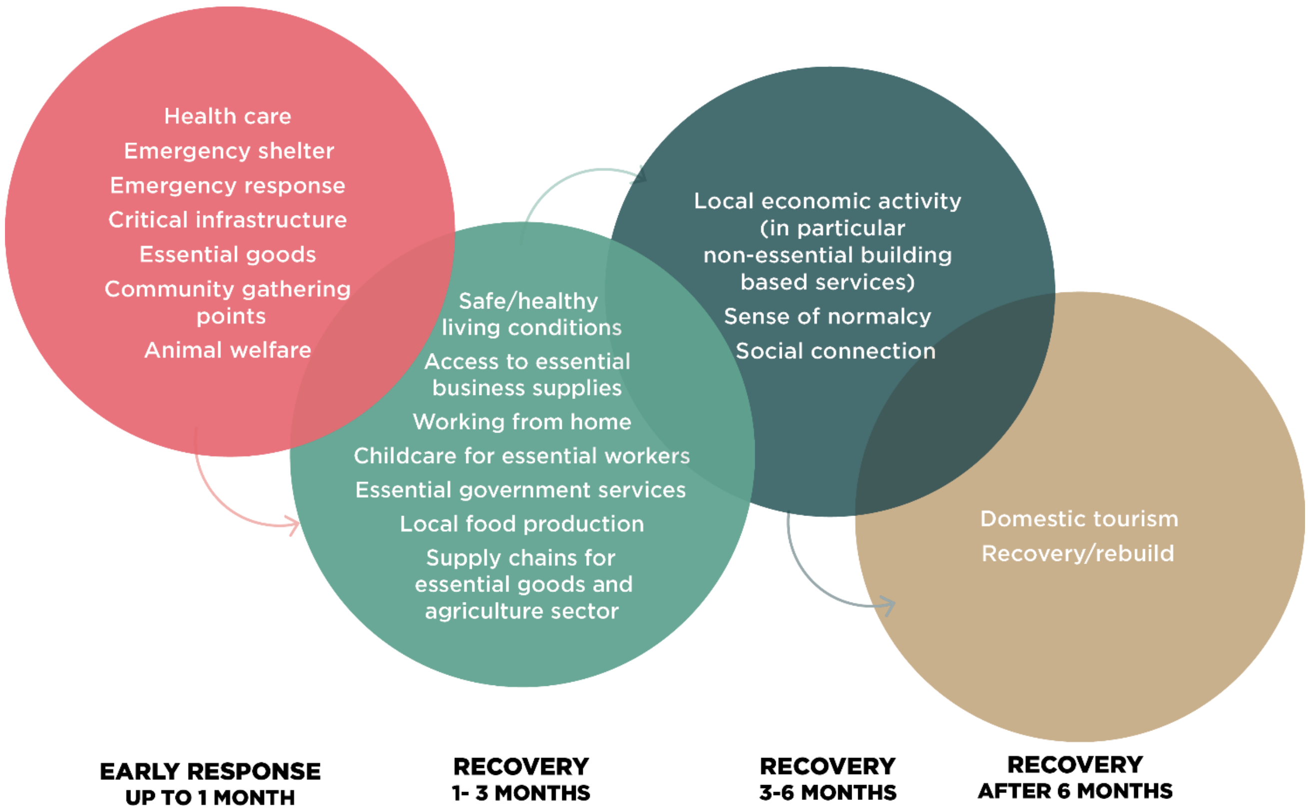


Figure 4: Recovery priorities for built environment over time

Risk tolerance

Overall

Communities are exposed to a range of potential earthquakes: minor events that may be experienced several times during any decade, or major earthquakes that occur rarely but could reasonably be expected to occur once or more often during any century. The frequency of these events and the likelihood a community will experience different earthquake impacts depends on the level of seismic hazard of the community, which varies geographically throughout New Zealand.

A key outcome of our project is to understand how people's expectations for seismic performance of buildings change with different sized earthquakes. For example, are people more willing to accept large scale disruption from a very rare event? Or are individuals willing to accept damage from small earthquake events? And what contextual factors influence an individual's seismic risk tolerance?

Typically risks fall into three categories: acceptable, tolerable, and intolerable, depending on the expected frequency or likelihood of an event occurring and the expected impacts. As shown in Figure 5, risks associated with low impact or rare events tend to be considered acceptable. Conversely, intolerable risks tend to be associated with high impact or high frequency events. Between these two zones is a tolerable zone within which risks involve more complex trade-offs related to the perceived costs and benefits of managing the risk.

This high-level map of risk tolerance is common to many different types of risks; however, it is important to understand what factors contribute to a risk being classified as acceptable, tolerable, or intolerable. In the following section we explore what is considered an acceptable or intolerable risk in an earthquake context, what considerations apply to a risk in the 'tolerable risk' zone and what influences risk tolerance.

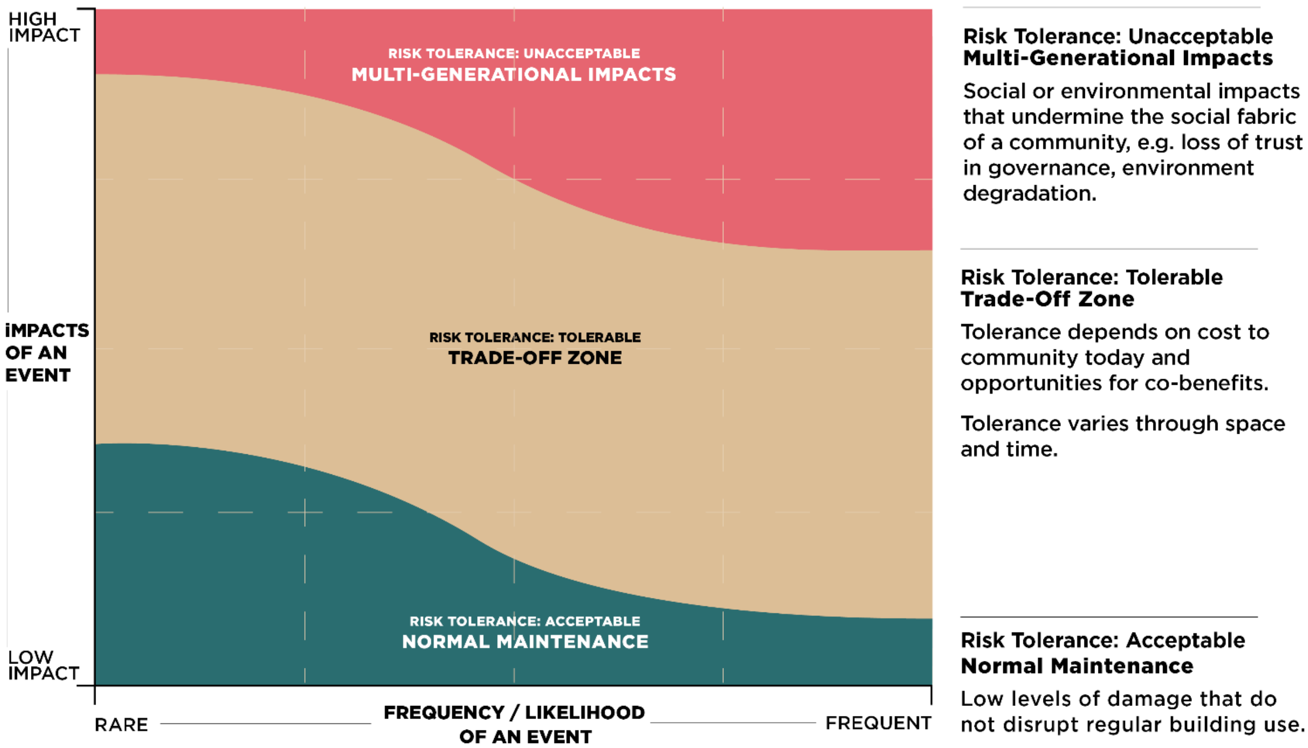


Figure 5: Acceptable impacts/risk tolerance

Acceptable risks

Participants used a mix of heuristics to determine risk tolerance: some were led by likelihood or frequency (i.e., how often the impacts are likely to be experienced), some by consequence (i.e., by the impact the community will feel) and some by a combination of the likelihood and consequence.

Generally, participants accept that major earthquakes will be damaging and disruptive. In major (less frequent) earthquakes there is an acceptance that some buildings may be unusable, people may be temporarily displaced, and some key services disrupted.

For more frequent events, that are likely to occur several times during the life of a building, most people expect business/society to continue as usual. Minor, cosmetic damage is considered generally acceptable. For many private building owners or tenants, building maintenance and refurbishment is a regular part of a building's life cycle. Fixing minor damage every 5-10 years is acceptable, so long as the disruption to building tenants is minor (i.e., no displacement), particularly for tenants who are vulnerable to disruption. Moderate damage is considered acceptable for many once every 10-20 years, but tolerance depends on disruption to building tenants.

> *"Minor damage...I think you should be looking at having a maintenance schedule in place from sort of seven years. Yeah, I think minor levels of damage are acceptable. You've got cracking. You might have facades that you might need to check for water tightness, those sorts of things." – Interview Participant (Private sector, National perspective, Owner long term investment interest)*

> *"Well, it kind of depends on who you are, doesn't it? So, if you're that very vulnerable solo parent family, I don't think a lot is going to be tolerable at all. And depending on if you're a commercial property, with businesses that can't survive as we've just seen with the pandemic, many businesses don't have sufficient liquidity to last more than a couple of months at the most without government support. So, if those are the sorts of indicators of survivability of a business, it's tenanting a commercial property, or for individuals and families needing somewhere to live, I think the tolerance level [for minor damage] is going to be extremely low." – Interview Participant (Private sector, National perspective, Multiple / Expert)*

Intolerable risks

A strong theme that emerged during the data collection is the intolerance to impacts that have permanent or long-term effects. For example, a mass exodus of residents/social dislocation, impacts on the natural environment, industry collapse and loss of trust. All these types of disruptions are viewed as long-lasting or irreversible and therefore intolerable regardless of earthquake likelihood.

This strong desire to avoid disruption to the social fabric is underpinned by a desire to avoid multi-generational impacts and while shared between a range of participants was a particularly strong view among Māori participants. Participants were careful to consider the likely time to recover from different types of impacts and let that determine its acceptability.

> *"Spend a little bit more time to think about things so that it's not a problem in 200 years...it's still going to be our family's problem... we work in 100-year planning blocks [to ensure inter-generational wellbeing]" - Focus Group F participant (Medium seismic hazard zone, Town)*

> *"...I was also looking at generational interruption of evolution .... one generation getting a trauma event can be managed better than when you've got multiple generational [impacts]" Focus Group F participant (Medium seismic hazard zone, Town)*

When considering intolerance for certain impacts, many participants also factored in the likelihood of the impacts occurring. Here again, the potential for events to affect multiple generations was highlighted. For example, a set of impacts with an assumed average return period of less than 250 years tended to be less tolerable than the same set of impacts with a longer (i.e., rarer) expected occurrence. 250 years was a common benchmark for likely impact on consecutive generations. This risk tolerance 'tipping point' varied significantly across participants and depended on the type of impacts being discussed (ranging from 50 to 2500 years).

Tolerable risks: managing trade-offs

Between acceptable and intolerable risk is a large spectrum of tolerable risks. These are risks that people think they can live with but, given the opportunity or the right conditions to intervene, could be reduced. This spectrum is a realm of potential trade-offs between perceived benefits and costs and how these may be allocated or distributed over time.

Below are a series of factors that can reduce risk tolerance (act as incentives to reduce risk) or increase risk tolerance (hinder or retard risk reduction) for an individual (building developer or owner) or community.

Incentives

Participants identified a number of factors that might provide an opportunity or incentive to reduce risks in this 'tolerable' zone.

First, is a long-term investment interest in a property. The longer someone intends to hold equity in a property, the more likely that individual is to invest in reducing seismic risk. There are a number of motivations, including: reducing whole-of-life costs, preserving reputation within community, supporting local community, and attracting or retaining tenants.

> *"[Our decision to strengthen a building] wasn't driven by tenants. It was driven by us and the fact that we're spending quite a significant amount on a key downtown position. So we wanted to make sure that it performed. And, yeah, and given its position in town, and its name and all the rest of it, it's a highly recognized building." – Interview Participant (Private sector, Moderate seismic hazard zone, Owner-occupier)*

> *"There's an expectation as [company] as a reasonably major player in town, or certainly one of the big three anyway, that, you know, we're putting investment back*

into town in a proper way. So I'll call that reputation." – Interview Participant (Private sector, Moderate seismic hazard zone, Owner-occupier)

Second, is investment in seismic resilience that will improve financial return. This could be through increased market value (resale or rental), often influenced by perceptions of safety or greater likelihood of post-earthquake building functionality, reduced business downtime, and reduced cost to rebuild (particularly where uninsured). The availability and cost of insurance can also influence property owners' return on investment thinking.

"I think the resilience of buildings will become far more important. And you can absolutely see that already from occupiers having the ability to re-enter a workspace more freely and quickly following a moderate or severe earthquake will be hugely valued by occupiers. And that's where you've got to really think about … what the occupier wants, not necessarily what the investor wants, because they are the people that are using the assets. I think that will become more and more important in having resilient buildings." – Interview Participant (Private sector, Low seismic hazard zone, Owner (long term investment interest))

Last, motivation can come from non-monetary benefits or co-benefits. Businesses are increasingly measuring performance across a range of performance metrics. Sustainability, climate change mitigation, staff and community wellbeing are all decision factors in reducing seismic risk, through buildings that last longer and provide safety and security for building users.

Hindrance

Conversely, there were many factors presented as a deterrent or hindrance to enhanced risk mitigation. First, building owners, developers and communities have a number of competing priorities. Issues such as housing affordability and climate change implications for construction practices pose conflicting demands on building owners and users. Finite resources have to be allocated. Given the rarity of major earthquakes, seismic resilience generally will not be the first priority that comes to mind.

"Over the long haul, there's some really big environmental issues. And impacts on biodiversity and climate change are the two biggest. And then there's, of course, a whole range of economic and social issues, which I won't try and sort of make a comparative comment about. But yeah, in terms of what I get my knickers in a twist about, it certainly wouldn't be earthquakes" – Interview Participant (Public sector, National perspective, Environmental expert)

Second, a perceived low return on investment can also be identified as a barrier to more seismically resilient buildings. There is a perception that higher building standards are/will be prohibitively expensive and that benefits, given the low likelihood of a major earthquake, may not match or exceed the costs over typical debt repayment periods of 20 years or so. In parallel, a suppressed rental or real estate market may not compensate for the increased costs: that is, building users, existing and future, might not value or be willing to pay for the enhanced levels of building performance. There is concern that the market may not understand or be able to adequately value the benefits of seismic resilience[33].

> *"Well, interestingly, … an overseas anchor tenant has taken 85% of that building. They never asked once what the seismic strength of that building was. Does that surprise you? I guess perhaps that's confidence in our [building] stock then, isn't it? " – Interview Participant (Private sector, Moderate seismic hazard zone, Owner-occupier)*

The availability and affordability of insurance plays a role in return-on-investment calculations as many building owners will rely on insurance to cover catastrophic losses. A number of interviewees also indicated that they believed the government would step in as an insurer of last resort in a large event, if insurers failed or there was evidence of significant under-insurance.

However, not all businesses rely on insurance. Many larger businesses self-insure and rely on redundancy in their business operations, as well as business continuity planning to reduce the risks. These large, often national, businesses have calculated that a disruption in one region, or the loss of one site, will be compensated for in other parts of their operations. Similar logic, of pooling risks, applies to investors with portfolios of properties.

> *"Because the advantage for us is that we are distributed across the country. So, if for example, we can collect [raw product] at one point, then even if our manufacturing site is down, we can potentially transfer it elsewhere if the logistic routes are open." – Interview Participant (Private, Moderate seismic hazard zone, Owner-occupier)*

> *"The biggest thing that I probably learnt [during Canterbury earthquakes] is having options up your sleeve. There's no such thing as a perfect earthquake. So there's a way in which, if you've got a lot of options up your sleeve, and you've got a plan B or Plan C, then effectively you can look to adapt to any situation." – Interview Participant (Private sector, High seismic hazard zone, Owner-occupier)*

Third, some participants were concerned about on whom increased costs of seismic resilience would fall. Recent experience with the costs of earthquake strengthening of earthquake-prone buildings across the country, as well as the rising cost of housing, was a concern expressed by some participants. Their concern was that the costs of implementing higher standards will inevitably fall on those least able to afford it: largely tenants. And increased costs could impact the diversity of economic activity in new buildings: as one participant put it, "inhibiting interesting things from happening".

> *"What I want to convey is, when we go through this [building standard/regulation update] process, again, what is the return on investment that we should be considering? And what is the unintended flow-on effect to communities who are stuck with these new building codes? And we can get into these kinds of theoretical debates [about whether] everything should be great and resilient. But somebody's got to bear the cost. And that's what I work with at the coalface of communities. And*

[33] Recent research by Hoang et al (2021) indicated that market forces typically ignore life safety and socio-cultural significance of buildings. Hoang, T., Noy, I., Filippova, O., and Elwood K., (2021), Prioritising earthquake retrofitting in Wellington, New Zealand, *Disasters,* 2021, 45(4): 968–995.

> *when it gets too hard for them, they won't participate in the conversation." – Interview Participant (Public sector, High seismic hazard zone, Community Recovery Expert)*

Fourth, the expected performance of neighbouring buildings is a significant concern and inhibitor. There is some reluctance from buildings owners to be the first mover: concerned that they may not be able to realise the benefits of a seismically enhanced building due to damage associated with neighbourhood properties, including the presence of a cordon, reduction in foot traffic, or perception of safety of an area.

> *"There's not much point being the strongest building and the most resilient building in a pile of rubble for kilometres around. So you're not going to build the most incredibly resilient building in terms of economic rather than life safety point of view if nobody else is doing it... There's going to be a lag time before you actually get sufficient critical mass of implementation of the new codes. So there'll be a risky period where the people who are the first movers are going to be disadvantaged to a certain extent". – Interview Participant (Private sector, National perspective, Tenant)*

Relatedly, infrastructure damage came up repeatedly as a concern and a hindrance to improved building performance. Individuals were concerned about the capacity to use a resilient building if services were not available to make the building habitable or fully functional[34].

A strong thread in our data collection indicated a lack of trust in engineers and the construction sector. Influenced by events such as damage to relatively modern buildings following the 2016 Kaikōura/Hurunui earthquake and personal experiences dealing with engineers offering conflicting opinions, some individuals did not believe buildings could be designed or built to withstand earthquakes. This sentiment included a lack of trust in engineers to design a building to a given standard, to manage building sites and to ensure what is designed is actually built, and for contractors to build quality products.

> *"We all know that engineers, you put two of them in a room and you get an argument, right? So based on engineering opinions, you know, one says you should do this, another one says you should do that, then, you know, what's the fashion of the day?... It's more unacceptable to me that there are buildings being built here that are subject to shoddy shortcuts and people not following the plans, very good plans, because they're trying to save money, because the engineers aren't watching the construction process. Because that sort of stuff is going on."– Interview Participant (Private sector, National perspective, User)*

> *"I think one of the things ... is understanding our technical capability. And I'm not talking about the design side. I'm talking about the building side, where the technical capability of the builder, I think, is often underappreciated and underestimated. And we see that particularly with the larger, more complex commercial buildings where*

[34] Expected recovery timeframes for infrastructure services has also been identified by NIST-FEMA as a significant challenge in their work toward functional recovery. NIST-FEMA (2021). Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time, NIST_FMEA Special Publication FEMA P-2090/NIST SP-1254/January 2021.

the builder is expected … to have capability or have access to the capability that understands some of the engineering requirements." – Interview Participant (Private sector, National perspective, Expert from building sector)

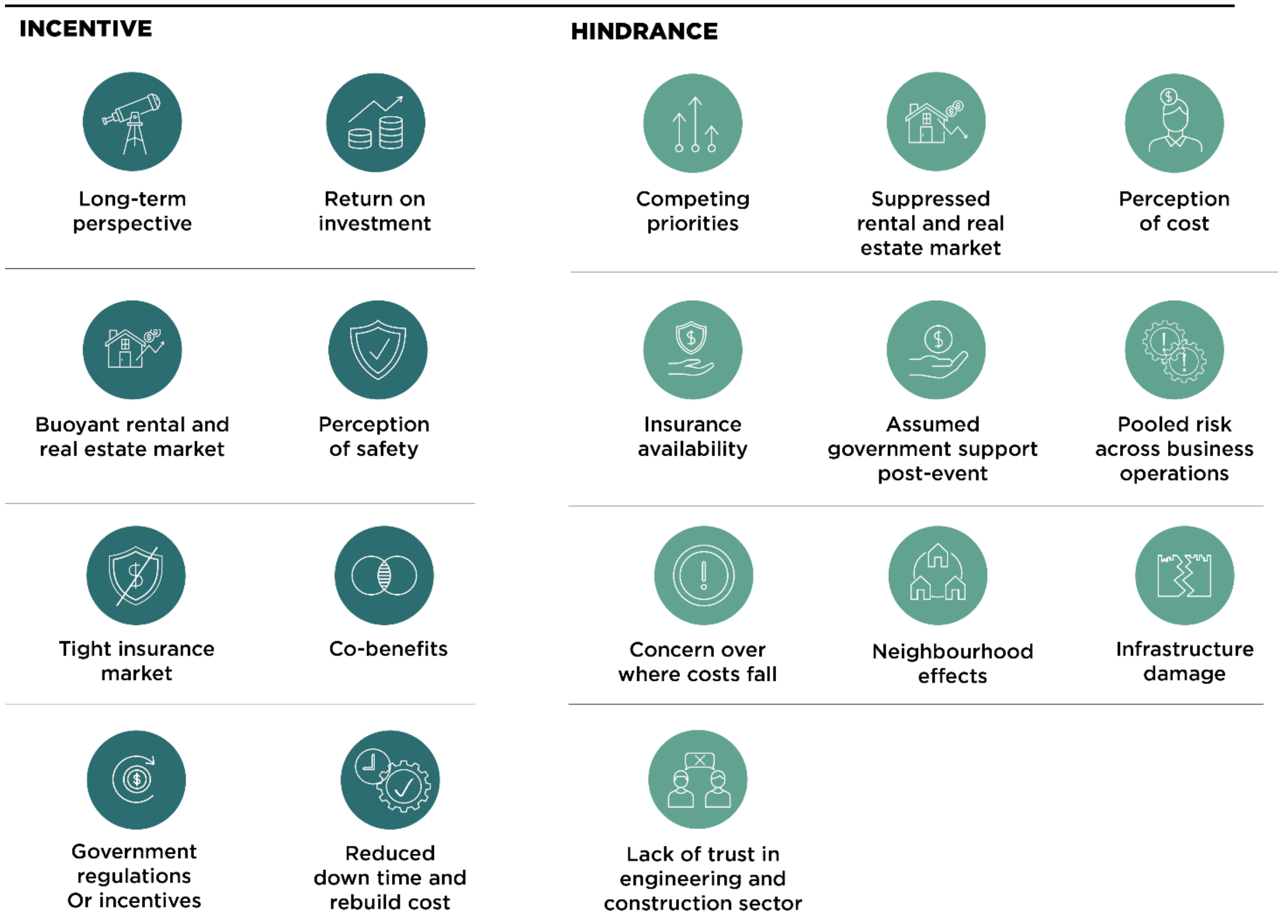


Figure 6: Incentives and hindrances to managing tolerable risks

Influences of risk tolerance

Above we have discussed the general risk tolerance of our participants. However, a clear finding of this study is the heterogeneity of people's risk tolerance. This is not a novel finding; there is significant research on how individuals perceive and assess risk. But a recognition of the diversity in risk tolerance and how this affects a community's needs and expectations from its buildings is an important point to reflect on when establishing building performance objectives and standards. In this study we have not focussed on individual factors affecting personal risk preference but rather focused on societal context that can influence risk tolerance at a community level, specifically the importance of place and time.

Importance of place

Throughout our data collection place-based differences between seismic resilience priorities were strongly evident. For example, focus groups with rural agricultural-based economies placed greater importance on agricultural infrastructure (e.g., food production facilities and transport/logistics hubs) than focus groups based in diverse urban economies. The seismic performance of agricultural infrastructure is prioritised in rural communities not only for economic reasons (e.g., export market reputation) but also for enabling employment, social interactions, and animal welfare.

Beyond these differences in resilience priorities, community socioeconomic and geographic context also influenced the degree to which seismic risk is tolerated.

First, we noticed a difference in risk tolerance based on the seismic hazard of the community. New Zealand's earthquake hazard varies and communities in high seismic hazard zones tend to be more accepting of risks associated with earthquake events. They expect and accept higher levels of disruption to buildings and longer recovery periods than other communities.

Second, those communities who believe they will be geographically isolated following an earthquake are less accepting of earthquake risk and want their buildings to perform better than others. Isolation is generally due to the geographical setting and the limited number of access routes into a community (e.g., due to mountain ranges and river crossings).

Third, the density of the built environment plays into how individuals and communities view seismic risk. This manifests in a number of ways. For example, denser built environments are more likely to experience neighbourhood disruption effects, where one damaged building will affect other buildings, cultural assets, critical infrastructure assets, or access routes[35]. This has implications both for the immediate recovery and for the complexity of the recovery.

> *"I think [planning has traditionally] been around the response aspect of it more than the longer-term rebuild or mitigation measures that would go beyond simply individual buildings not killing people. There's quite a lot of work that needs to go into that if we're going to have quality sustainable cities and towns" – Interview Participant (Private sector, National perspective, User)*

Density of the built environment is particularly important when considering impacts on residents. Dense urban communities place more importance on housing resilience than smaller communities. Urban communities are concerned that high-density multi-storey apartment complexes will be unable to provide basic services to residents after a major earthquake, resulting in displacement of people, potentially beyond what emergency services can reasonably be expected to manage. As noted earlier, large-scale or prolonged displacement of people from a region following an event is considered unacceptable for many.

---

[35] Recent research by Hoang et al. (2021) identified proximity to roads and built-up areas an important factor in prioritisation of seismic retrofitting of buildings. Hoang, T., Noy, I., Filippova, O., and Elwood K., (2021), Prioritising earthquake retrofitting in Wellington, New Zealand. *Disasters,* 2021, 45(4): 968–995.

Fourth, the capacity of a community to absorb the earthquake impact and recover plays into how communities assess their risk tolerance. Communities that have access to abundant resources (physical, financial, and human) are more accepting of seismic risk. Communities with fewer resources, under economic stress or perceiving significant social inequity issues are less inclined to contemplate risk taking.

Most communities will have a mix of the above attributes, summarised in Figure 7: some will tend toward risk taking and others toward risk avoidance. The overall risk preference of communities will be a combination of these factors. It is also likely that there will be different risk preferences within communities as well – with micro communities (e.g., a CBD vs a suburb) having different risk-taking tendencies. Individual interests within those communities are also likely to have different approaches to risk. For example, some of those with purely financial interests tend to be more risk taking and their risk horizon proportionally shorter than those contemplating community or public interests across generations.

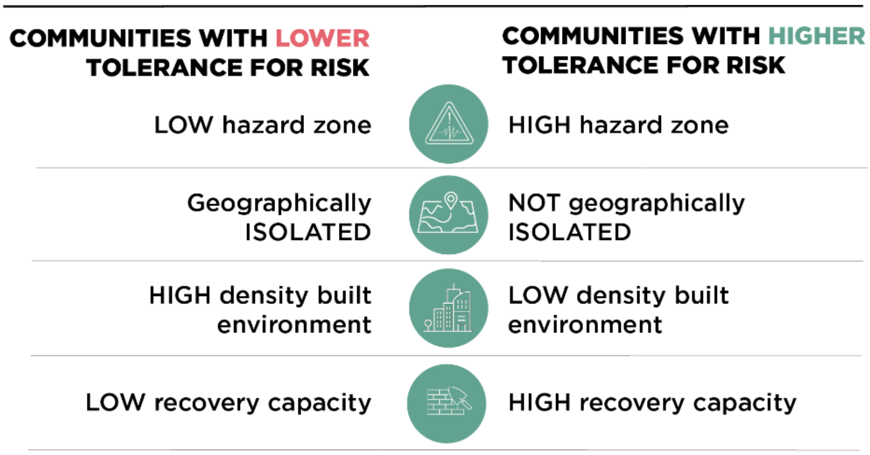


Figure 7: Factors affecting risk tolerance of communities

Importance of time

Individual and community perceptions of risk and associated risk tolerance are temporal. Availability bias and recency bias can change how communities perceive and accept risks over time. Throughout the data collection phase, a number of current societal issues were identified that significantly impact how people currently perceive seismic risk and, subsequently, influences their tolerance for seismic risk. In particular, COVID-19, climate change, and housing affordability were mentioned.

The influence of COVID-19 on the participants' risk preferences was clearly evident. Many participants expressed how experiences with COVID-19 related disruptions had shifted their priorities – both in terms of their understanding of what impacts are tolerable or not, and where priorities for supporting social and economic wellbeing lie. For example, COVID-19 has highlighted the importance of food supply chains (e.g., food production facilities, warehouses, logistics hubs, and supermarkets). Additionally, the ability for most office-based employees to now work from home resulted in decreased importance attributed to commercial office blocks and increased desire for immediate restoration of power and telecommunications in homes. COVID-19 has also reduced the prominence of tourism as an enabler for economic recovery following a seismic event.

Increased awareness of long-term trends such as climate change also impacted how people perceive seismic risk and the relative importance they place on mitigation of seismic risk. For some, seismic resilience is seen as a 'blip' relative to the long-term impacts of climate change. For those people, seismic risk is largely acceptable, except where it exacerbates impacts of climate change, for example impacts on embodied carbon.

Housing affordability is another current issue that featured in participants risk assessments. Some participants were prompted to accept seismic risks where they perceived the cost of mitigation as too high. The participants were concerned about the immediate impact of seismic resilience on housing affordability and the welfare of people affected by the rising cost of housing. For climate change and housing affordability, participants were struck by the need to reduce the immediate impacts on current communities.

> *"I'm doubtful that we should be investing a whole lot more in infrastructure that prevents death or minimizes damage. You know, just because I think there are so many other important claims. This is a typical set of economists' views; you've got to think of the opportunity costs and then the investment in it. And, I would much rather see the government investing in things that mitigate climate change, for example, at the moment. I think the returns are much, much higher" – Interview Participant (Public sector, National perspective, Environmental expert)*

Some participants also raised concerns about the timing of an earthquake event and how a community's capacity to cope with an earthquake will be affected by recent crises a community has experienced. COVID-19, climate change impacts, and housing affordability are all currently placing stresses on individuals and communities. Natural hazards, economic shocks, equity issues, loss of trust in governance are just some of the other stressors that are likely to erode a community's capacity to cope with an earthquake over time. Changes to how we manage earthquakes and access to insurance will also impact how readily we accept earthquake risks. Conversely, some future lifestyle and technology trends may also reduce the impact of damage to the built environment on communities – such as a rise in working from home practices and a shift in our reliance on commercial office accommodation.

> *"As we have many other modern pressures being placed upon our citizenry, you know, you think about the Auckland housing crisis and issues around ensuring employment, there are probably a lot of people who are already fairly stretched in terms of their personal psychological resilience. So, if you then add a major disaster on top of that, how many people are going to effectively just snap?" – Interview Participant (Public sector, Low seismic hazard zone, Community Expert)*

All of the above illustrates the temporal nature of societal perceptions and risk preferences.

Seismic resilience in context

Resilience to seismic events is just one of the performance outcomes we require of our buildings. To understand risk we need to understand the total risk environment. Moreover, as discussed above, the costs, risks and benefits of seismic resilience are being traded against other pressing issues such as housing affordability and climate change adaptations.

As a first step in putting seismic resilience in a wider context, we sought to understand how important seismic risk is relative to other key performance objectives in the built environment. We asked participants in both interviews and focus groups to rate the importance of a list of building performance objectives such as durability, architectural value, capital cost, accessibility etc. The list also included items directly relating to seismic resilience, such as life safety during an earthquake or impacts to the natural environment from earthquake building damage.

The results indicated where the highest values were perceived (Figure 8). It also demonstrated the opportunity for complementarity: that is where there is strong alignment between multiple performance objectives and initiatives, and improvements to one area will have flow-on effects to other objectives.

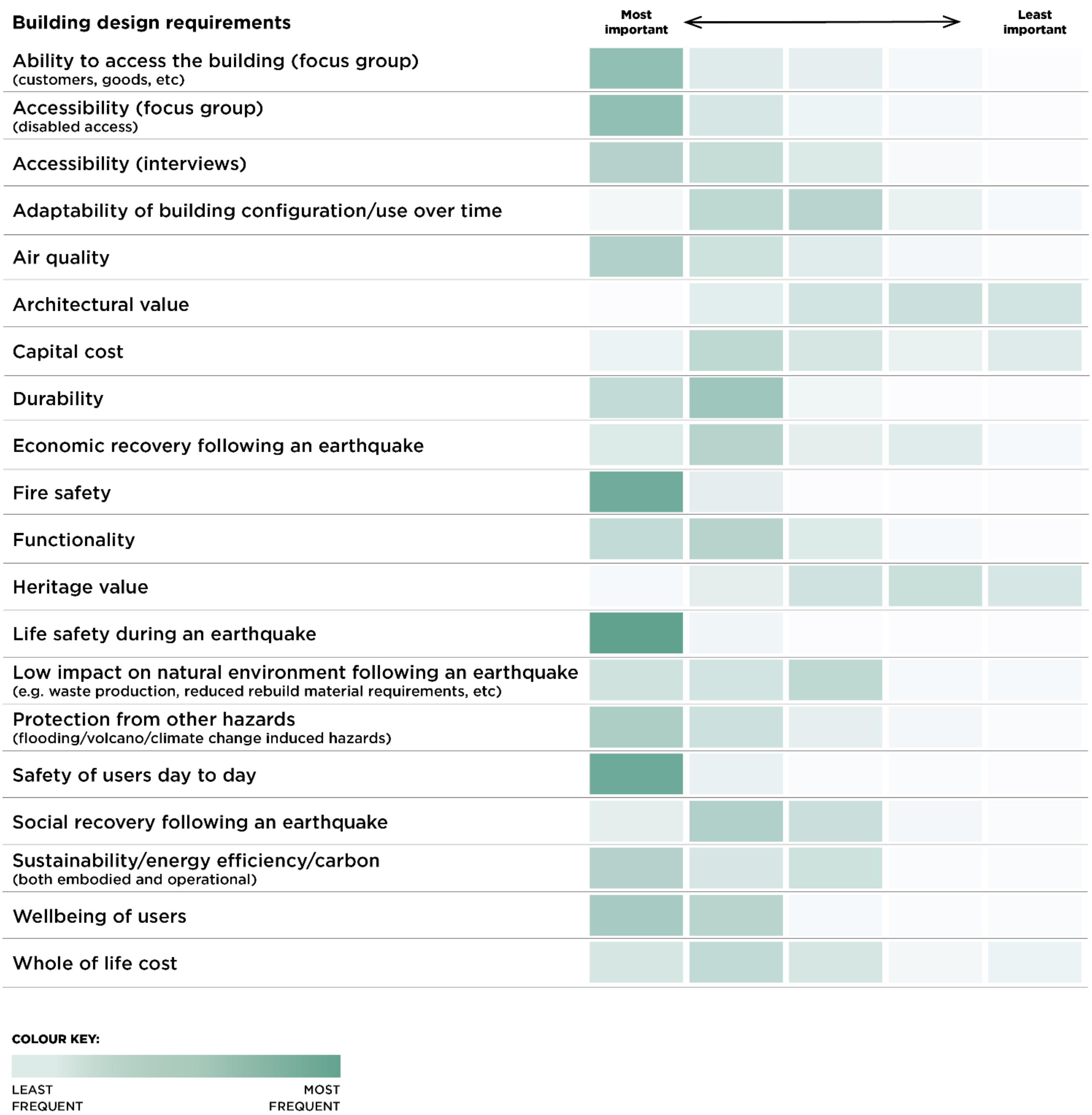


Figure 8 Relative importance of building design requirements

Almost without exception, safety is considered the most important performance objective. Safety includes safety of building users day-to-day, fire safety, and life safety during an earthquake. Provision of safety appears to be a non-negotiable item and is not, within reason, influenced by cost. This is consistent with research that shows that earthquake safety is a key influencer in rental and purchase decisions of residential apartments.[36]

Beyond safety, the health and wellbeing of building users is considered very important. Wellbeing of users is deemed by many as a catch-all for the experience of people using the building (acoustics, lighting, temperature, access to amenities) and as such a high priority. One specific element of user wellbeing that resonated with participants is air quality. Many participants noted how much more prominent air quality, and good ventilation have become since the COVID-19 pandemic.

> *"I will admit to air quality becoming a little more important given COVID -19 … and good air movement and a safe environment is pretty important" - Focus group D participant (High seismic hazard zone, Town).*

Accessibility is another component of wellbeing that came through strongly, particularly the need to facilitate access to disabled and low mobility users. Good access not only has benefits for the daily wellbeing of users but also supports safe and efficient evacuation during a fire, earthquake, or other hazard event. Accessibility is also desirable from a business perspective – for easy customer access and operations.

In a post-earthquake context, user wellbeing can be affected if buildings are damaged. Damage can impact the indoor environment (ventilation, temperature, etc.) and can also affect the mental health of users if there is concern for user safety. There is a strong connection between user wellbeing post-earthquake and social recovery.

Another strong theme that emerged is the importance of building longevity. Throughout the interviews and focus groups, participants were surprised that the assumed exposure time to earthquakes for the seismic design considerations of a building is only 50 years. Many thought buildings should (and do already) last much longer than 50 years and that earthquake-related design should contemplate longer timeframes. Building material durability and the adaptability of a building over time, such that its use might change, were acknowledged as key drivers for improving the life span of buildings. It was also noted that durability contributes to better building performance, and potentially its function through time. Reduced damage of buildings during earthquakes will support economic recovery through reduced recovery costs and reduced business disruption. Improved longevity is also perceived to serve environmental goals in terms of sustainability and whole-of-life cycle costs Environmental sustainability has been growing in importance in recent years. The Zero Carbon Act[37] and initiatives such as the MBIE Building for Climate Change programme[38] are highlighting the need to reduce carbon in the built environment. A number of participants believe that reducing embodied and operational carbon in buildings (including minimising the disposal of damaged buildings following an earthquake) is a

---

[36] Blake,D.;Becker,J. S.; Hodgetts, D.; Elwood, K.J. The Impact of Earthquakes on Apartment Owners and Renters in Te Whanganui-a-Tara (Wellington) Aotearoa New Zealand. *Appl. Sci.* **2021**,*11*,6818. doi.org/10.3390/app11156818.

[37] environment.govt.nz/acts-and-regulations/acts/climate-change-response-amendment-act-2019/

[38] mbie.govt.nz/building-and-energy/building/building-for-climate-change/

critical priority. Improving the life span of the building stock (through adaptability, durability, and repairable buildings) is part of enhancing these outcomes.

The importance of cost differed significantly between participants. Those with strong commercial interests tend to rate cost considerations more highly if they are factoring in return on investment on short time frames. Those answering from a public, long-term interest, or purely building user perspective are much less likely to rate capital or whole of life cost as important. However, the connection between cost and longevity of buildings was noted, in that longer life buildings (likely with higher initial capital cost) often have reduced whole of life costs.

The architectural value of buildings scored quite low in terms of importance. However, it was noted that effective architectural design is a key component of performance if it provides functional and aesthetically pleasing space that supports the wellbeing of users; and if material and design detailing supports building durability and longevity through adaptable design. Environmental sustainability is enhanced through choice of materials and the return on investment will be higher for buildings that are attractive to tenants. It was also noted that today's architecture provides value to the community that will become part of future heritage.

These results show us that the strongest imperative for seismic resilience remains life safety. However, it also shows us that emerging drivers such as wellbeing of users, longevity and environmental sustainability have strong links to seismic resilience.

Cultural heritage in buildings

While this project focussed on the design of new buildings, views on the cultural heritage value of buildings were sought and offered.

It was clear from our interviews and focus groups that heritage is individualistic: what people think of as important and how important it is, is very personal. Perceived heritage value is often based on a person's connection to a place. For many this goes beyond the physical building and is more closely tied to the history of the land and its people. As such, heritage is not always about the age of a site or building.

"I think I'd be confident enough to say that, again, from those experiences, that it wouldn't all be catastrophic or it all wouldn't be lost. There'd be some things, no matter what the [earthquake] magnitude was, [that] would be able to be retained. The one thing that absolutely can be retained for everything, no matter what its final stage is, is its story." – Interview Participant (Private, National perspective, Cultural heritage expert).

Heritage considerations are important when defining the performance standards of new buildings because building standards not only help to preserve the built cultural heritage of the past but can also to enable and enhance cultural heritage for the future.

SAFETY
Fire safety
Safety day to day *(🔗 Wellbeing)*
Earthquake life safety

WELLBEING
Acoustics
Lighting
Temperature
Access to amenities
Indoor air quality *(🔗 Safety)*
Accessibility *(🔗 Functionality)*

FUNCTIONALITY
Usability
Accessibility *(🔗 Wellbeing)*
Adaptability *(🔗 Longevity)*

LONGEVITY
Durability *(🔗 Sustainability)*
Adaptability *(🔗 Functionality)*
Repairability

ENVIRONMENTAL SUSTAINABILITY
Embodied carbon
Operational carbon
Material choice
Durability *(🔗 Longevity)*

AESTHETIC AND CULTURAL VALUE
Architectural design
(🔗 Functionality and Wellbeing)
Heritage *(🔗 Longevity)*

COST
Capital cost
Whole of life cost
(🔗 Sustainability and Longevity)
Return on investment

Figure 9: Seismic resilience in context

Future research

We gathered a diverse range of perspectives in this research, and we are aware that the results do not necessarily present a fully representative view. There are also some perspectives that we are aware are missing. In addition, some elements important to discussions around seismic resilience policy, such as willingness to pay, were not explicitly addressed in the scope of this project. Key areas for further investigation are included below:

Mātauranga Māori perspective

While our study included some Māori voices, the majority of views gathered were of a western world view. A complementary study with Mātauranaga Māori principles at the core would provide balance to this work and ensure policy outcomes are aligned with Te Tiriti o Waitangi.

Large scale survey

To validate and gain a better understanding of the representativeness of these results, a survey could be undertaken with a wider cross section of New Zealand society. The survey could further test how risk preferences vary across different interest groups (e.g., public, private, developers, owner-occupiers) and geographic settings (rural and urban) and how important buildings are in supporting these recovery objectives.

Economic analysis

Changes to building codes that raise standards if well implemented, will deliver better outcomes to those regulated. Understanding where the benefits of adjustment may lie and where costs are likely to fall will help define the efficiency of enhanced seismic resilience and its long-run benefits.

As part of this, the financial services sector (banking and insurance) needs to manage its exposure to seismic risk and how this is currently accounted for and distributed, so there are shared imperatives related to how this might be mitigated sustainably for all parties affected.

Willingness to pay or stated preferences study

To effectively achieve increased seismic resilience, understanding the willingness of different stakeholders (developers, owners, tenants and users) to pay for seismic resilience benefits is critical. Such inquiry would logically follow on from the economic analysis above.

Sensitivity analysis for priority setting

Participants in this study would be considering seismic resilience within their experience. To better understand how societal expectations might change over time and under varying conditions, a sensitivity analysis would be beneficial. Testing expectations under a range of future conditions would help to identify potential tipping points in risk tolerance and how critical the built environment could be for certain outcomes.

Specific analyses of societal expectations

This work has highlighted several specific areas that would benefit further investigation, including: understanding relative tolerance for earthquake-induced injuries versus fatalities; how social and economic recovery are impacted by temporary relocation; societal understanding of building standards and seismic risk, and how this influences risk perception; how individuals perceive the safety of a building; and the role buildings play in impacts that have multi-generational impacts, such as mass exodus of people from a neighbourhood or community.

Seismic resilience in context

Within this research we looked at how seismic resilience compares to other priorities and performance objectives in the built environment. But seismic resiliience sits within an even wider context of risks facing New Zealand. During the study concerns were raised over the comparative effort that is taken to mitigate seismic risks in New Zealand versus other risks facing society, such as public health risks or climate change risks. Understanding where seismic risk sits within these wider priorities, and having a common language, standard and/or metrics that can be applied across a range of diverse risks would be a useful tool for setting codes and standards.

Conclusions

Making sense of sentiments

This research charts societal expectations for the seismic performance of new buildings in New Zealand, coinciding with a period in which multiple severe earthquakes have followed a long (70 year) period of quiescence. The findings represent a qualitative 'snapshot' of a point-in-time baseline concerning expectations of seismic performance expressed by a range of building users.

Like all social norms, expectations are dynamic and change in response to broader social trends and events. So, unlike the physical evidence of recent earthquake impacts there is no way to definitively quantify them. But the following key sentiments are apparent in our findings:

- Life safety remains a top priority for building performance, but priorities for life safety commonly reflect consideration of the individuals that are likely to occupy a building. Protection of vulnerable persons and people with essential skills are both common expectations.
- Swift social and economic recovery and minimising the environmental impacts of earthquakes now sit on a par with day-to-day building performance objectives such as increased sustainability and longevity. These reflect diverse expectations of the need for buildings to remain functional or repairable swiftly after an earthquake
- There is a growing perceived need and expectation that the built environment should support social recovery following an earthquake through equitable access to essential goods and services, sustaining social connection, and restoring normalcy that supports cultural identity.
- There is a strong influence of community context on seismic risk tolerance and priorities and near-unanimous intolerance of impacts with multi-generational impacts
- Awareness of constraining issues like costs and the availability of insurance are among factors that inform risk tolerance in some communities.

The findings highlight the central importance of life safety to our built environment but there are growing expectations that the built environment should support social and economic recovery following an earthquake, through the delivery of essential goods and services, places to connect and restoration of a sense of normalcy to support mental health and community well-being.

Density of the built environment is particularly important when considering impacts on residents. Dense urban communities place more importance on housing resilience than smaller communities. Urban communities are concerned that high-density multi-storey apartment complexes will be unable to provide basic services to residents after a major earthquake, resulting in displacement of people, potentially beyond the capacity of emergency services to manage. Large-scale or prolonged displacement of people from a region following an event is considered unacceptable for many.

Economic recovery is critical following an earthquake, so the continued function or swift repairability of damaged buildings is material to enabling people to maintain employment and to fulfil other community needs.

While there is a growing desire for enhanced seismic performance of buildings, there are also factors that contribute to a tolerance of seismic risk, including perceived cost, competing priorities on limited societal resources, and neighbourhood and system constraints related to expected critical infrastructure performance. The time horizon and the individual or community that evaluates a risk is also influential, as is insurance availability and trust of the engineering and construction sector to mitigate seismic risk.

Beyond these tolerable risks individuals are generally accepting of minor damage from smaller earthquakes, although this can depend on the vulnerability of building users to disruption. There is strong sentiment that impacts that have multi-generational impacts are unacceptable, as these are the types of consequences that may lead to irrecoverable or irreversible damage to communities.

A general finding is that priorities vary with geography and community. The context deeply influences restoration priorities and timelines, in particular the community assets and industries considered most critical for recovery. This demonstrates the role of buildings in a wider system that supports community resilience. These findings also underscore a sense that societal risk perspectives vary over time and are influenced by contemporary factors such as recent earthquake events and COVID-19. Stressors and trends, such as technology change, will positively and negatively impact a community's capacity to cope with disruption over time, as well as their desire to mitigate seismic risk.

Are changes to building regulation and design practices required?

The direct elicitation and integration of societal expectations into technical standards for seismic performance is novel here and abroad[39]. However, the preferences revealed in this study indicate demand for more encompassing performance objectives for buildings than currently mandated under existing regulatory settings, essentially unchanged since the early 1990s.

This research does not address the scope of potential changes to the Building Act, Building Code, or relevant technical standards for seismic risk, but our findings suggest that a rethink of current regulatory objectives may be warranted.

A number of questions arise:

- How can or should decision-makers balance local/community expectations with the need for national 'public good' outcomes?
- How might technical standards reconcile the range of perspectives concerning which buildings – and what functionality – may be prioritised at a local/community level?
- Where is the balance struck between regulated performance objectives (through codes and standards) and private actions (market incentives and co-benefits) to equitably improve seismic performance?

[39] Tanner, A., Chang, S. E., & Elwood, K. J. (2020). Incorporating societal expectations into seismic performance objectives in building codes. *Earthquake Spectra*, *36*(4), 2165–2176. doi.org/10.1177/8755293020919417

- What language is required to resolve existing ambiguities of purpose for seismic risk treatment in the building regulatory system (terms such as 'low probability', 'amenity' and 'sustainability')?
- If there is value in periodic tracking of shifts in broad societal expectations over time to feed into design practice and regulation, how might this be codified?

The changing nature of our communities and urban landscapes have implications for future design practice and associated regulation. As noted earlier, increasing multi-storey, inner-city housing is changing the concentration of risk in our urban communities, and there are increased expectations (since COVID-19) that individuals will be able to work from home during or following a disruptive event. This means that the resilience of essential service connections and wider infrastructure must be contemplated in the setting of design objectives.

Beyond these conceptual challenges, there are specific implications to consider. These include reviewing how building performance is articulated in the Building Act and Code and supporting documents, as it might pertain to seismic loadings, including:

- How might designs and technologies that limit the onset of damage at moderate levels of shaking be more strongly encouraged or mandated?
- Given the focus of building regulations on the treatment of risk within a lot boundary or single building footprint, how should the aggregate exposure of the neighbourhood and wider community be addressed?
- Should we specifically have criteria that relate to performance during aftershocks, to provide greater confidence for people to 'shelter in place' if required?
- How should the variance of societal expectations between individuals and communities be accounted for and balanced between regulated performance (through codes and standards) or market incentives and co-benefits, which may be better instruments for improving seismic performance amongst some building owners?
- How can confidence in the building profession, including architects, engineers, constructors, consenting authorities and building services consultants, be enhanced to improve perceptions of seismic resilience of our building stock?

How building owners and investors make investment decisions in relation to seismic and other risks and how contingent protection mechanisms, such as insurance, influence decision making are also critical elements[40]. For this, a greater understanding of the expected costs and benefits of enhanced seismic resilience to reflect current expectations is needed. The interplay between seismic resilience and sustainability also needs to be understood to capture the relative benefits versus up-front costs of longer-lasting, more seismically resilient buildings.

Last, we need to frame and measure building risk in the context of the wide range of risks facing our communities. This will ensure that seismic design and regulation advances consistently with other risks facing our communities.

---

[40] There is research currently underway within QuakeCORE to explore the seismic resilience incentives and insurance quakecore.nz/te-hiranga-ru-quakecore-funding-proposal-2021-2028/

Appendix 1.

The Building Control System in New Zealand

The building regulatory system in New Zealand provides for the regulation of buildings, building work, and various occupational groups in the building industry, as well as the setting of building performance standards. All building work in New Zealand must meet certain requirements, which are set out in legislation and regulations that determine how work can be done, who can do it, and ensure the system has checks and consumer protection in place[41]. The legislation and regulations work together as the building regulatory system:

> *Building Act 2004* – the primary legislation governing the building and construction industry
>
> *Building Code* – contained in Schedule 1 of the Building Regulations 1992, sets the minimum performance standards buildings must meet

The Building Code describes performance requirements for the outcome of building work aspects including, structure, durability, fire safety, access, moisture, safety of users, services and facilities, and energy efficiency. Being performance-based, the Building Code states how a building must perform in its intended use rather than describing how the building must be designed and constructed. It is important to note that while you cannot design to less than the minimum standards, owners and designers can choose to exceed them in order to meet their own requirements.

Any systems, materials and methods can be used provided the building owner or designer can demonstrate that the performance criteria are met. This allows for innovation and design flexibility. For many buildings and building work, traditional or empirical methods are all that are required. To reduce compliance costs and time for both designer and consenting authority, the regulator Ministry for Business, Innovation & Employment (MBIE) publishes deemed-to-comply Acceptable Solutions (AS) and Verification Methods (VMs) for the various Building Code clauses. Guidance may also be issued by MBIE under s175 of the Building Act to achieve the desired performance, particularly when assessing Alternative Solutions (Figure A1).

These prescriptive documents are collectively often referred to as 'code-supporting documents'. If they are followed, the building consenting authority (usually the Territorial Authority) is required to issue a building consent for the work. If the consenting authority contests the approach, MBIE may issue a Determination which is legally binding.

The performance of a building in an earthquake is the physical manner in which it responds to shaking (or the displacement of its foundation). Building performance is often described by the extent of damage it has suffered, and the impacts of this damage in terms of functionality or potential casualties. The relevant performance requirements for Clause B1 (Structure) of the Building Code are:

---

41 building.govt.nz/building-code-compliance/

> B1.3.1 Buildings, building elements and sitework shall have a low probability of rupturing, becoming unstable, losing equilibrium, or collapsing during construction or alteration and throughout their lives.
>
> B1.3.4 Due allowance shall be made for: a) the consequences of failure; b) the intended use of the building.

For seismic design, the loadings Standard NZS 1170.5 is the most relevant document[42]. The Standard NZS 1170.5 provides procedures for the determination of earthquake actions on structures in New Zealand. It gives the requirements for verification procedures, site hazard determination, the evaluation of structural characteristics, structural analysis for earthquake action effects, the determination of and limits for, deformations and the seismic design of parts of structures.

The AS/NZS 1170 series uses importance levels, among other factors, to determine the loadings for earthquake, snow and wind that a building needs to be designed for. The importance level classifications in AS/NZS 1170 are from 1 (lowest) to 5 (highest) and are determined in accordance with a building's occupancy and use, the potential consequences of failure in terms of loss of human life, and the economic, social, and environmental effects of structural failure. A building with a higher importance level is required to be designed for stronger forces than a building designed to a lower importance level[43].

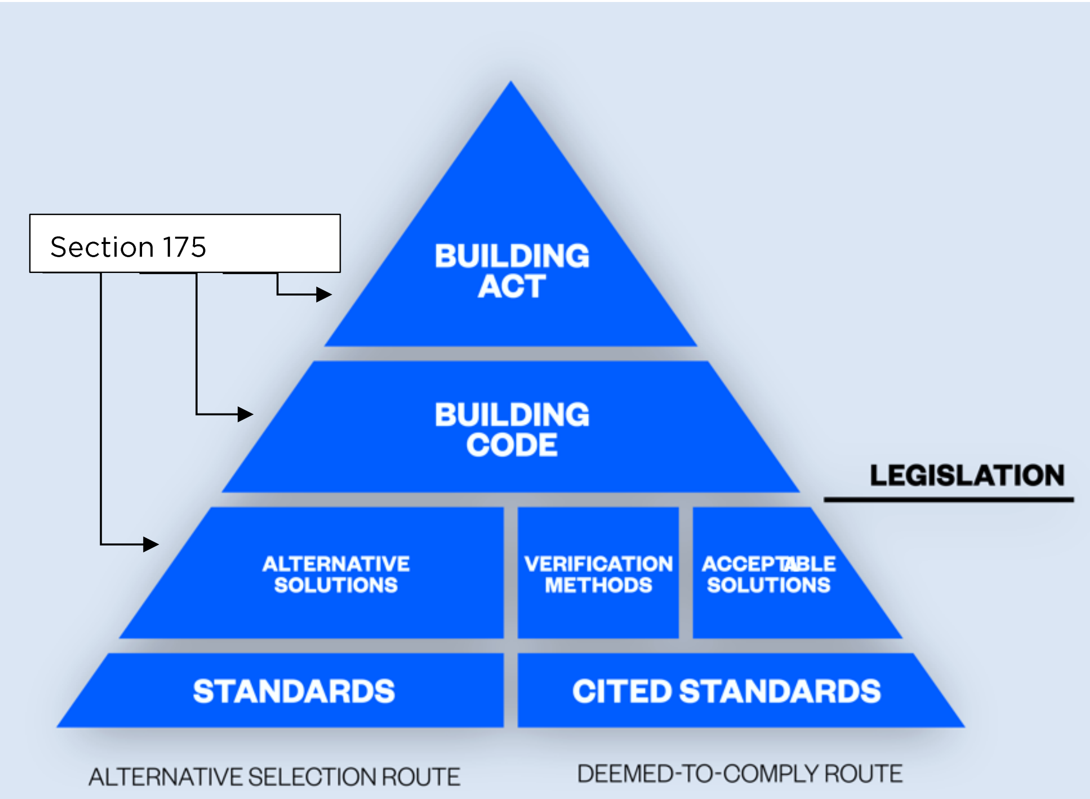


Figure A1 New Zealand Building Control System (schematic). Adapted from MBIE (2020)[44]

---

[42] codehub.building.govt.nz/resources/nzs-1170-52004-a1-excl/

[43] Importance levels are also found in Clause A3 of the Building Code, but the reference pertains to the C-Clauses of the Code relating to fire safety, not earthquakes.

[44] Seismic Risk and Building Regulation in New Zealand. Findings of the Seismic Risk Working Group, November 2020, Ministry of Business Innovation and Employment, New Zealand Government.