The Resilient Buildings Project

Societal expectations for seismic performance of buildings

DETAILED REPORT ON INTERVIEWS

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We also gratefully acknowledge the contribution of our 32 interviews 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.

This is a supplementary report to Brown et al., 2022. Societal expectation for seismic performance of Buildings. The Resilient Buildings Project Research Paper.

Contents

1. Introduction

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.

The Resilient Buildings Project set out to:

- Explore whether there is a social license to redefine statutory performance objectives.
- Develop a clear and shared language of desired performance objectives.
- Map the pluralities of societal risk perception and define how performance objectives shift relative to building and geographical context.
- Understand the importance of seismic resilience relative to other demands on built environment.

In 2021, we interviewed 32 individuals across a range of backgrounds and sectors, as well as 27 individuals in 6 geographically based focus groups, to capture a snapshot of expectations for seismic performance of buildings. The purpose of this report is to highlight the findings from the 32 interviews. This is a data report and is intended as a fully documented account of the interview methodology and data collected. A comprehensive analysis and synthesis of these findings, alongside the focus group findings, can be found in: *Brown et al., 2022. Societal expectation for seismic performance of Buildings. The Resilient Buildings Project Research Paper*[1].

The specific research questions we sought to address in the project were:

1. What are the desired performance outcomes for buildings following earthquakes of varying scales, this could include
    - human outcomes (e.g. life safety, availability of critical infrastructure services)
    - economic outcomes (e.g. cost, business disruption impacts)
    - social (e.g. social connectivity, heritage, cultural impacts)
    - natural (e.g. sustainability, carbon emissions, waste)
2. How does the desired performance outcome change for different:
    - geographic settings (rural, urban, geographically confined, seismic hazard risk, economic importance of community, other?)
    - building setting (proximity to roads, footpaths, critical infrastructure etc)
    - levels of insurance/societies ability to pay/recover availability
    - types/uses/occupancy/design life of buildings (e.g. critical infrastructure, health, stadiums, office, residential units)
3. How does earthquake resilience or the above desired performance outcomes compare against day-to-day building priorities (e.g. embodied carbon, architectural value, fire safety etc)?

The insights arising from this study will contribute to debate about desired levels of resilience to the impacts of earthquakes, and the design approaches and options available to achieve desired performance.

[1] Full report available at https://www.eqc.govt.nz/resilience-and-research/research/search-all-research-reports/societal-expectations-for-seismic-performance-of-buildings-march-2022/

2. Method

2.1 Overview

To support the overall project outcome, 32 interviews were undertaken between July and September 2021. The interviews were approximately one hour long and were conducted in person or virtually using video conferencing software. All interviews were recorded and transcribed for analysis.

The interviews followed a set of structured questions intended to gain an understanding of the interviewee's current role, background, and earthquake experience; expectations during a significant earthquake event; expectations during a minor earthquake event; and prioritisation of seismic resilience relative to day-to-day building design requirements. Interview questions are presented throughout the 'Findings' section as they are relevant to the discussion and provided in entirety in Appendix A.

2.2 Perspectives

Purposive sampling was used to select interviewees that represented a wide range of perspectives, including wellbeing (human, social, economic, or natural perspectives), building ownership (owner with short or long term investment interest, owner-occupier, tenant, user, or multiple/expert), sector (private, public, public interest or research), geographic (national, low, moderate, or high seismic hazard zones[2]), and industry perspectives. Figures 1-5 show the distribution of interviewees across these perspectives. Several interviewees represented more than one perspective, but a post hoc critical review was taken to assign each interviewee to their dominant categories.

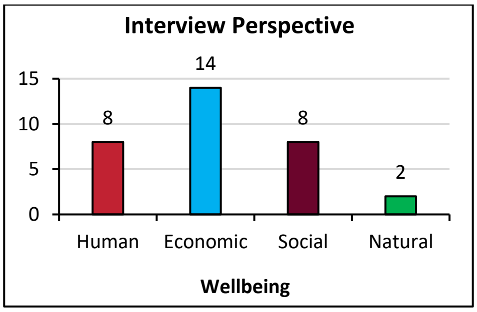

Figure 1. Primary wellbeing perspective of interviewees

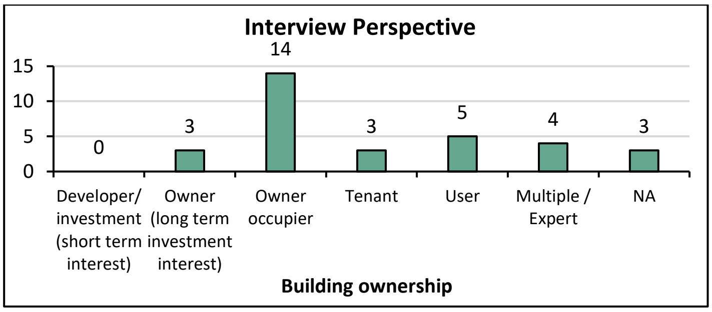

Figure 2. Primary building ownership perspective of interviewees

[2] The Building Act 2004 divides New Zealand into three seismic risk areas (high, medium, and low) based on the 'Z' factor, which is the seismic hazard factor for each area of New Zealand. High seismic risk areas have a Z factor greater than 0.3, medium seismic risk areas have a Z factor between 0.15 and 0.3, and low seismic risk areas have a Z factor lass than 0.15.

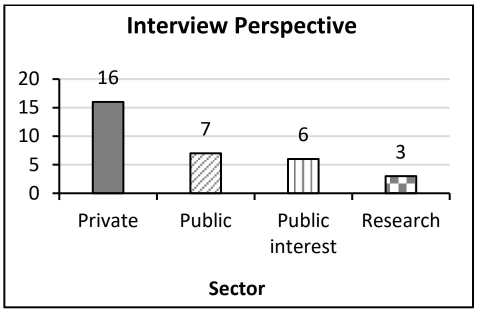

Figure 3. Sector perspective of interviewees

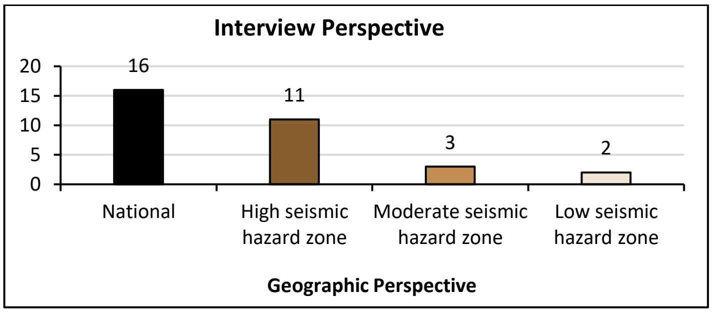

Figure 4. Geographic perspective of interviewees

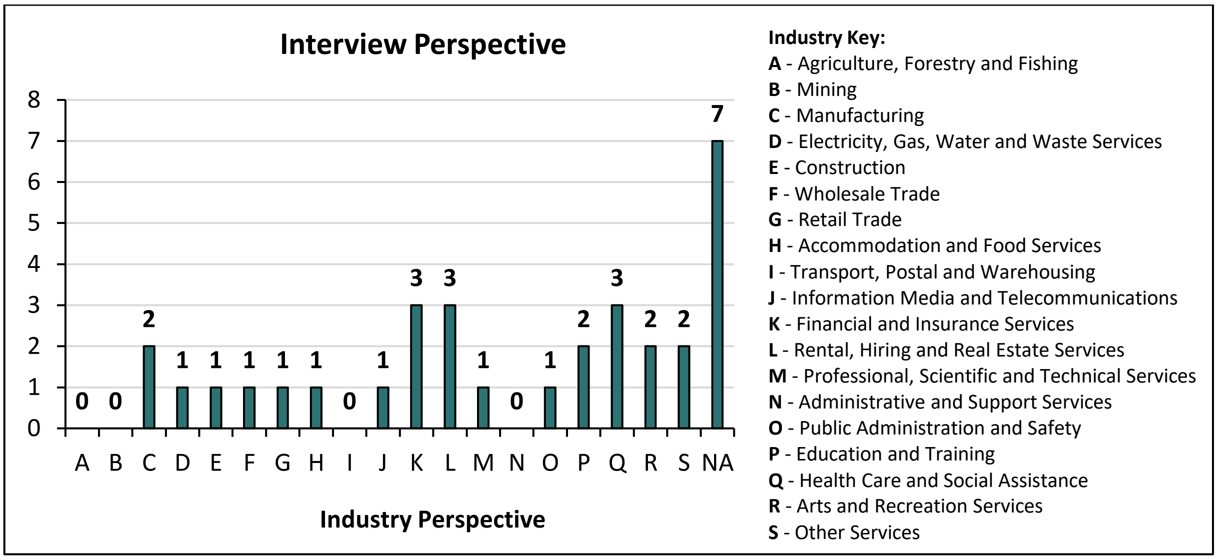

Figure 5. Industry perspective of interviewees. Note that each interviewee was only assigned to one industry, but the interview may have covered multiple perspectives (e.g., a major supermarket chain was assigned to F – Wholesale trading, but the interview also covered warehousing (I) and retail (G) perspectives). NA indicates the interviewee did not represent any of the listed industries.

2.3 Overview of report and analysis

This report documents the discussions from the 32 interviews. The interview data was predominately evaluated using qualitative thematic analysis, which is a 'method for identifying, analysing and reporting patterns (themes) within data', where the theme captures important aspects of the data and meaning within the data set[3]. Unless noted otherwise, the themes presented are in the authors words and aim to summarise sentiments raised by interviewees.

Quantitative analysis methods were also utilised and are presented throughout the report. Frequency, which is denoted as '(n=*x*)" following a statement, was often used as a means to understand whether opinions were common or unique among interviewees. However, the presented frequency counts do not necessarily indicate that other interviewees do not share the same opinion. They only show that '*x*' number of interviewees stated that opinion during the interview process. The frequency count was used in conjunction with data on the interviewee perspectives (as presented in Figures 2-4) as a means of identifying emerging trends or factors that may influence risk tolerance.

[3] Braun V & Clarke V. (2006). "Using Thematic Analysis in Psychology." *Qualitative Research in Psychology* 3 (2): 77–101.

It is important to note that interviewees were selected to demonstrate a breadth of expectations, and not as a representative sample of the population or sectoral perspectives. Therefore, the analysis in this report is not intended to serve as a statistical representation of the population. Readers should focus on the nature of the sentiments raised by interviewees and general patterns of views. Useful patterns include the frequency with which a view is raised, and whether views are similar or differ between different perspectives.

Overall, eliciting societal tolerance for seismic risk is influenced by several dynamic factors[4]. Social norms evolve[5, 6] and are influenced by proximity to adverse events[7]. Social norms are also influenced by current policy settings, community context and how hazard information is presented[8]. Risk preferences can vary significantly among individuals based on education, experiences, and personal circumstances. This temporal and individual heterogeneity needs to be acknowledged and reflected in the interpretation of data on societal risk expectations. Hence this analysis is designed to show a snapshot of perspectives, in time, across a diverse range of individuals. It is not intended to be representative of all views across New Zealand but rather demonstrate the breadth and trends in expectations.

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

[5] 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

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

[7] 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.

[8] Vinnell LJ, Milfont TL, & 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

3. Findings

3.1 Expectations during a major earthquake

In an effort to understand the expected impacts of a major earthquake as well as the response and recovery needs of affected individuals and communities, interviewees were presented with the following prompt:

> *Imagine, 20 years from now, that your community has been hit by a rare and significant earthquake. The prolonged and severe shaking is frightening to most people. Physical damage causes considerable and prolonged disruption to normal life.*

The focus of the Resilient Buildings Project is about how buildings should perform in the future. Therefore, the purpose of establishing that the hypothetical earthquake takes place in the future (20 years from now) was to encourage the interviewees not to be limited by their understanding of the building code performance objectives and the current risk environment, nor constrained by their experiences of recent earthquake events. Instead, interviewees had the freedom to define what the built environment might look like in the future to support their recovery needs.

The interviewees were asked a series of questions that aimed to establish 1) the most important aspects of the built environment, 2) aspects of the built environment that the community could live without, and 3) secondary impacts (i.e., consequences) from failures in the built environment that would be unacceptable.

In terms of overall performance, all interviewees expect new buildings should withstand a major earthquake without creating a significant threat to the life safety of building occupants or passers-by. Significant structural failures, including total building collapse, are unacceptable (n=7). Damage to non-structural systems (e.g., cosmetic cracks to plaster board, damage to ceiling tiles or mechanical ducts) is expected to occur in most buildings. The extent to which damage to non-structural systems affects building functionality will vary building to building.

Outside of individual building performance, interviewees understood that external factors in the built environment have the ability to impact the post-earthquake functionality of their buildings. Most buildings are reliant on the performance of critical infrastructure to ensure access to utilities such as power, water, sewer, gas, and telecommunication. Damage to these systems will impact building usage. Damage to transportation infrastructure (e.g., roads and bridges) may impact one's ability to access their building, as would damage to neighbouring buildings that result in cordoned areas.

Potential consequences of failures in the built environment from earthquake damage as well as priorities for the response and recovery process are discussed in the following sections.

3.1.1 Life safety

All interviewees discussed life safety during earthquakes, with most interviewees (n=24) explicitly stating that safety would be their first consideration following a major earthquake. It is generally expected that buildings should protect lives in earthquakes and building occupants should be able to safely evacuate a building following a major earthquake (n=9). Five interviewees also discussed the risks that buildings could pose to passers-by or evacuated occupants, with falling glass cited as a particularly concerning hazard in urban areas.

> *"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." – Interviewee (private sector, high seismic hazard zone, tenant)*

Following an earthquake, fire safety was a concern for some interviewees (n=3). Earthquake shaking could damage reticulated gas lines and fire protection systems (e.g., fire wall barriers and sprinkler systems). Damage to these systems could result in a conflagration that spreads to adjacent buildings. There was concern that fires would be particularly challenging to contain if there is damage to the surrounding water supply or transport routes.

Three interviewees expressed a belief that deaths following a significant earthquake are inevitable. This primarily stemmed from a belief that eliminating all risk is impossible given the seismically active setting of New Zealand.

> *"I think we've got to accept the possibility of some loss of life, just as we accept the possibility of loss of life on our roads, and in the event of landslides, and flooding, and all those things. – Interviewee (public sector, national perspective, environmental expert)*

In addition to being safe during an earthquake, interviewees expressed a desire to have reassurances of their buildings' safety. People look to authority figures (e.g., engineers or building managers) to provide confidence that their building is safe to re-occupy after a large earthquake (n=11). This confidence is crucial for making decisions during the response and recovery processes.

> *"So from a safety perspective, it's important to have that reassurance from our structural engineers that [they] are comfortable that we can be inside this building." – Interviewee (private sector, national perspective, owner occupier)*

> *"The first thing we're looking for from our buildings is certainty. Can we go back in? Are we allowed to? Health and safety? What's that crack mean? Certainty is the thing you need, because to make decisions, you need information." – Interviewee (private sector, national perspective, tenant)*

3.1.2 Response priorities

The immediate concern of most interviewees following a major earthquake was for the safety of themselves, building occupants that they were responsible for, and their loved ones. Correspondingly, an early response priority is the ongoing provision of services that support life – including emergency response services and healthcare.

It is generally expected that emergency services will continue to function after a major earthquake so that those who need help are able to receive it. Buildings identified as critical in the early response phase included hospitals or other medical centres (n=14), emergency operations centres (i.e., buildings that host civil defence and search and rescue operations) (n=13), fire stations (n=6), police stations (n=5), and ambulance depots (n=3). Interviewees also spoke about the need to keep key arterial routes open (i.e., clear of building debris or land damage) to ensure that ambulances and other emergency vehicles are able to be dispatched to areas in need and return any injured persons to emergency medical centres (n=7).

The ability to move people and supplies into and out of the affected area was also a common topic (n=15). Ensuring that critical routes remain open allows people to return to their homes after an earthquake (n=10). This was a particular concern for Wellington, where thousands of people are likely to be stranded in the Central Business District if a major earthquake occurs during a workday and cuts off transport routes to surrounding suburbs. Roads also allow for emergency supplies (e.g., food, water, medication) to be delivered to the affected area (n=8). However, it was noted that there are alternative means of delivering supplies (e.g., by ships or helicopter) in an emergency (n=2).

The ability to communicate with others was identified as critical to the early response, and therefore maintaining telecommunication networks (i.e., cell phone coverage) is a key priority (n=14). Communication is important for the coordination of emergency services. It also allows people to connect with loved ones to enquire about their safety and wellbeing. Some interviewees were concerned about cell networks being overloaded immediately after an earthquake, which was an issue after the Kaikoura earthquake, and suggested that even reduced coverage (e.g., texting only) would be acceptable.

After the acute health and safety and access concerns are attended to, the basic needs of individuals must be met. This includes access to shelter (n=15), water (n=19), food (n=14), and medication (n=3). A suitable shelter would be a warm, dry, safe and secure location with access to facilities for food, water, and sanitation. The ideal place for most people to take shelter is in their own homes. It was noted as particularly important that medium to high-density housing continues to provide shelter after a major earthquake, preventing large numbers of people from being displaced (n=5). Temporary housing needs to be provided for stranded visitors or locals with damaged houses (n=9).

> *"Within a day, you need as much as possible to give people the necessities of life: food, shelter, water" – Interviewee (private sector, national perspective, expert in building sector)*

> *"We need to … find ways that we can get people from wherever the problem is to somewhere safe, and then from there back to their homes." – Interviewee (private sector, national perspective, owner occupier)*

Interviewees were generally accepting of disruptions to utilities (e.g., water and sewage) in their homes for days, weeks or even months after a major earthquake, as long as basic needs could be provided for with temporary measures (e.g., community water points and portaloos) (n=8). Power was noted as being more time-critical to return to function, particularly in the winter months when people need to use heaters (n=12).

Interviewees were also accepting of community buildings taking on post-disaster functions after a major earthquake (n=11). Schools, halls, gymnasiums, stadiums, maraes, churches, libraries, and community centres were all suggested as buildings that could be repurposed as civil defence centres or temporary accommodation. Many interviewees (n=12) also spoke about the need for a 'community hub' to be established after a major earthquake. The purpose of this hub would be to provide a central location for people to gather and share information about the response.

In fact, clear communication and information sharing were identified as one of the primary community needs during the response phase (n=13). The information that people seek after an earthquake includes the status of neighbours and the locations of supplies, mental health services, and other support networks. It was noted that methods of communication (e.g., text, radio, calls, in-person hubs) should be utilised in order to ensure that vulnerable individuals and communities (e.g., disabled, elderly, non-English speaking) have access to pertinent information.

In order to reduce ongoing burden on emergency services, it is important to enable individuals to look after themselves and others as much as possible. As previously mentioned, keeping people in their own homes reduces the need for temporary housing. Other buildings in the community identified as helpful for individuals to retain independence after a major earthquake include essential retail such as supermarkets and pharmacies (n=4), petrol stations (n=3), and banks (for ATM/cash access) (n=3).

3.1.3 Recovery priorities

After a rare and significant earthquake, people are generally tolerant of disruption during the recovery process at least in the early aftermath. However, this tolerance for disruption after an earthquake is finite, and people need to see progress towards normalcy in order to recover confidence about the future (n=8).

The interviewees identified a range of recovery priorities relating to mental health, social recovery, economic recovery, and the natural environment. The nature of these priorities and how they relate to recovery of the built environment are discussed in the following sections.

Two priorities, in particular, seemed to provide a foundation for other aspects of recovery. These were (1) the provision of safe, secure, and healthy housing and (2) a desire for certainty and confidence in the recovery process.

Overall, the ability to keep people in their homes after an earthquake (or provide adequate housing alternatives) was identified as one of the most vital aspects of recovery (n=7). Ensuring that people can continue to live in safe and healthy homes is essential for mental well-being and enables individuals to contribute to the social and economic recovery of their community.

> *"I think that a key to our resilience, in so many ways, comes back to our housing and the key lifelines associated with enabling people to stay in their homes. If they can work from home and have the basic amenities, they can keep their job, they can keep sending their kids to school, they can keep their biggest financial investment if they're homeowners" – Interviewee (public sector, high seismic hazard zone, community recovery expert)*

The interviewees that spoke about a desire for certainty and confidence in the recovery process often reiterated the idea several times throughout their interview. Having confidence that their building(s) are safe and their community can bounce back in a timely manner was key to achieving positive recovery outcomes. Uncertainty in the recovery process could lead to poor mental health, encumbered social and economic recovery, and, ultimately, the retreat of people and businesses from the affected area.

> *"[The success of the recovery] 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." – Interviewee (public sector, high seismic hazard zone, tenant)*

Recovery progression

The interviewees were asked several questions related to their needs after a major earthquake and what they could live without. While these needs varied based on circumstance, there were general trends in how interviewees expected recovery to progress.

It was noted that interviewees were most comfortable talking about short term recovery priorities (i.e., the first several months after the event). Longer timelines were generally difficult to discuss in detail because of the varying possible levels of disruption and the many interdependencies and uncertainties in the recovery process.

The earliest part of the recovery process is about enabling people to get back into buildings or start the repair or rebuild process. Most larger buildings will need to be inspected by an engineer to allow for re-occupancy after an earthquake. It was generally expected that this inspection would occur within the first day to week following an earthquake, depending on the size of the earthquake and the supply of engineers in the area (n=4).

For buildings determined to be structurally sound by the engineer but not fit for continued use (e.g., severe non-structural damage), the collection of essential belongings was an early priority (n=4). This could include allowing people to return to their apartments to collect important documents or their workplaces to collect essential business supplies. The collection of these types of belongings enables individuals or businesses to make alternative arrangements while their building is closed for regular use.

Some interviewees discussed the importance of getting cash into the community quickly after a major earthquake (n=3). Quick financial support from banks or insurers can fund recovery or relocation efforts of individuals and businesses. Cash gives people the flexibility to take action that suits their needs, whether that be starting repairs or relocating.

Within the short term (i.e., the first few months of the recovery process), people may still be adaptable but are looking for more stability and certainty than they may have experienced in the first few weeks of the earthquake. This stability can come from having a safe/secure/sanitary home, being able to earn a living, and starting to return to normal activities.

Interviewees noted that people living in damaged homes should be able to maintain safe and sanitary living conditions. Buildings should be weather tight, power and telecommunication (i.e., internet) available, and councils should be collecting rubbish. There was still some tolerance for disruptions to normal water and sewerage systems (n=2). This tolerance was primarily based on the Christchurch experience, where many households went months without indoor plumbing. Other interviewees (n=4) expressed that homes, especially relatively new ones, should not have to go months without indoor plumbing.

Temporary sewerage measures were considered unsustainable for large apartment buildings.

Schools opening in the short term (i.e., less than eight weeks) was a priority for many (n=5). Schools assist students to regain a sense of normalcy by attending class and seeing their peers (n=1). Schools also enable parents to return to work and/or attend to repairs (n=5).

> *"The focus [following the Canterbury earthquakes] was on how to get kids back to school. How do you normalize life? Maybe it was an unrealistic expectation because we couldn't normalize it but getting kids back into school gave everybody a bit more breathing space. You now had a population who were being cared for. Because it was quite difficult [for parents], you know, when you're living in a damaged home, and have all that stress of EQC, and just living in that [post-earthquake] environment. When you take away one problem, the kids being educated, it was a huge, I think, a huge relief for a lot of parents" – Interviewee (public sector, national perspective, owner occupier)*

Getting people back to work within months of an earthquake was also a priority identified by interviewees (n=2). People need to be able to generate an income to support themselves and their families. Many interviewees discussed the importance of having access to information technology (IT) to enable businesses to continue running remotely and people to work from home (n=11). For many people, reliable internet connections to enable virtual meetings and access to cloud or web-based services were viewed as a suitable alternative to needing a physical building in the short to medium term. This sentiment was primarily based on recent experience with COVID-19. However, it was noted that people would need to have a reliable living environment to work or attend school from home, which is not a guarantee after a major earthquake.

> *"In the economic space, COVID has certainly driven us to be able to work from home in a more effective way. But if telecommunications are down, that's obviously a challenge. That becomes a bit of an … existential question, … 'If we don't have jobs here in the short to medium term, where do those people go and what does the future look like?'" – Interviewee (public sector, high seismic hazard zone, community recovery expert)*

> *"Commercial space itself, you can do without for a certain amount of time, because these days most organizations… have pretty good resilience strategies for weeks - weeks to months. You can work from home and stuff like that, assuming you've got power at home and the necessities of life. I think if you get beyond months - and this is what happened in Christchurch - if you get beyond months, people go, 'Well [obscenity], we need a Plan B.' Like you're not going to go back to Plan A" – Interviewee (private sector, national perspective, tenant)*

Also in the short term (within first few months), people expressed desire to participate in normal social activities such as going out to eat or playing sports (n=2). There was acceptance that these normal activities may take place in temporary facilities (e.g., food trucks instead of restaurants and fields instead of stadiums).

It was noted that if people aren't seeing progress in their communities within the first few months following an earthquake, they will lose confidence in the recovery (n=8). This lack of confidence in the short term could have long term consequences if people start to move themselves and/or their business out of the affected area.

In the medium to long term (several months to years following a major earthquake), interviewees generally spoke about wanting more 'normal' social and economic activity to resume over time. This included the reopening of restaurants, pubs, and cafes as well as other workplaces opening and operating from permanent facilities. The return of office-based workers was noted as being particularly important in city centres because these workers provide the customer base for many retail and hospitality businesses (n=3). People also want more permanent community spaces to open (e.g., libraries (n=3) and pools or other sporting facilities (n=4)). Finally, opening public assets for events (e.g., stadiums and convention centres) will attract tourists, bringing new customers to local businesses (n=1).

Hindrances to recovery

Several interviewees expressed intolerance for a long, drawn-out recovery (n=6) and identified factors that would impede progress for individuals and communities. These hindrances to the recovery process included damage to critical infrastructure, damage to surrounding buildings, 'red tape' in the building consent process, and protracted insurance settlements.

> *"I think what's unacceptable is delayed recovery. Unnecessarily delayed recovery, for a whole range of reasons." – Interviewee (private sector, national perspective, expert in building sector)*

Re-establishing key critical infrastructure was a noted early recovery priority because progress is often dependent on this infrastructure being operational (n=3). Major arterial routes to and from the affected area enable the transportation of people and essential supplies, including building supplies. Roads within the affected town or city also need to be functional to allow for the delivery of supplies and for contactors to access buildings. A functioning power supply also helps to enable repair or rebuild efforts. In terms of economic recovery, functional critical infrastructure is required because most businesses will not be able to operate from premises that do not have reliable road access or utilities such as power, telecommunication, and water.

Damage to surrounding buildings can also hinder an individual or business's ability to recover (n=10). The damage to adjacent buildings may cause a safety hazard that prevents access to other buildings in the area, delaying repairs and ultimately the return to function of those buildings.

> *"Even if you had a highly resilient, base-isolated building in the CBD, you might be surrounded by buildings that are vulnerable…. You may not be able to access [your] building for months, if not a year or two, simply because of the dangers that those adjacent buildings pose to your highly resilient building." – Interviewee (private sector, national perspective, expert in insurance sector)*

The Government was also identified as a potential inhibitor of recovery efforts (n=3). It was noted that flexible and expedited consenting is necessary to enable quick repairs or temporary solutions that facilitate the reoccupation of homes and businesses. Some interviewees drew on their experience following the Canterbury earthquakes to explain that uncertainty and indecision related to proposed changes to land use zoning in the CBD and suburbs following an earthquake slowed the rebuild[9].

> *"Having sufficient flexibility in zoning and consenting to let people get on with things after the event and getting more housing so that [people] aren't reduced to living in cars and shacks and sheds, that matters to me." – Interviewee (public sector, high seismic hazard zone, tenant)*

> *"The regime uncertainty that is introduced by [the government's] inability to make decisions about what the plan might be.... Frustrates individuals' efforts to form their own recovery, whether it's in their home or in their business." – Interviewee (public sector, high seismic hazard zone, tenant)*

Delays in access to financial resources can severely inhibit recovery progress and outcomes. For example, some interviewees spoke about how changes to the seismic design standard following the Canterbury earthquakes[10] complicated insurance claims and delayed settlements (n=2). Overall, delays to the settlement of insurance claims, for any reason, is costly both in terms of monetary expense and social harm (e.g. stress and anxiety) for individuals seeking payments to fund their recovery efforts. An interviewee from the insurance sector explained these costs:

> *"One of the ... lessons learned ... in Canterbury is that the longer it takes to settle a claim, the more expensive it gets. And the more uncertainty around what the insurance liability is." – Interviewee (private sector, national perspective, expert in insurance sector)*

> *"If the government is taking actions that prevent the insurance company from providing support immediately, then the result will be social harm to that family, because they will be unable to progress their lives if they want to move elsewhere, buy another property, and put themselves in a safe place. So, lots of things follow when you don't have those payments come through." – Interviewee (private sector, national perspective, expert in insurance sector)*

Addressing these potential hindrances before a future event can support effective and timely recovery.

Mental health

Mental health and well-being following an earthquake were a concern for most of the interviewees (n=18). A post-earthquake environment is full of stressors of many forms, including visual reminders of the earthquake (i.e., building damage), aftershocks, degraded infrastructure including closure of schools, places of worship, and recreation facilities, prolonged insurance settlements, and in some cases financial uncertainty. In general, the best way to alleviate adverse effects on mental health, identified by the interviewees, was

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[9] According to Chang et al (2014), the three most significant decisions in recovery were the establishment of the Canterbury Earthquake Recovery Authority (CERA), the residential red zoning, and the cordoning of the CBD. Chang, SE, Taylor, JE, Elwood, KJ, Seville, E, Brunsdon, D, Gartner, M (2014) Urban disaster recovery in Christchurch: The central business district cordon and other critical decisions. Earthquake Spectra 30(1): 513–532. https://doi.org/10.1193/022413EQS050M

[10] The seismic hazard factor (aka Z-factor) is a fundamental value used to determine the design seismic actions for buildings. Following the 2010/11 Canterbury earthquakes, the Z factor in Christchurch increased from 0.22 to 0.30 to account for the greater seismicity in the region. https://canterbury.royalcommission.govt.nz/vwluResources/Final-Report-docx-Vol-2-S7/$file/Vol-2-S7.docx

to prevent a lengthy recovery process and facilitate a return to normalcy as quick as possible.

Individuals may be traumatised by the ground shaking and poor performance (perceived or actual) of buildings to the extent that they are wary of entering certain types of buildings (e.g., tall buildings) (n=2). Visible earthquake damage to buildings (even non-structural damage) may trigger anxiety and undermine confidence in the safety of a building (n=3).

The chronic stress related to having an unstable living environment, employment uncertainty, and/or having a lengthy insurance settlement or dispute can negatively affect personal and professional relationships. The stress of an earthquake and the recovery process may impact an individual's ability to perform at their job if that stress makes them distracted and tired (n=4). Dealing with issues related to the earthquake and recovery process can also result in a lack of spare time and time spent with loved ones (n=2). These mental health-related issues can have a multi-generational impact if parents are unable to provide adequate care for their children, who may also be traumatised by the earthquake (n=3).

> *"The people who were the most affected with serious mental health problems were not actually the people who lost spouses, but the people whose homes were in really terrible condition" - Interviewee (public sector, national perspective, building user)*

> *"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." – Interviewee (private sector, national perspective, building user)*

> *"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." – Interviewee (private sector, high seismic hazard zone, tenant)*

People who have had their homes, businesses and communities impacted may feel as if they have lost control over their environment, which can adversely affect their mental health (n=8). This feeling of losing control is heightened by long and drawn-out insurance settlements or other hindrances to the recovery process (e.g., a difficult consenting process or a safety hazard from a neighbouring building restricting site access) that make individuals feel as if they are at the mercy of others. Overall, the ability of an individual to be resilient to the mental health impacts of an earthquake largely depends on their personal circumstances prior to the earthquake. The stress of an earthquake has the potential to exacerbate existing mental health conditions (n=1). It also may be the tipping point for someone already dealing with multiple or significant hardships in their everyday life (e.g., COVID-19 impacts, securing housing and/or employment).

> *"[The earthquake] puts [individuals] completely out of the control. They have no control over what's happening around them. They have no control over what's*

happening to their families… [They] are subject to that EQC Act [National Government Insurance Scheme] and to [their] insurance company. So there's other people in control of [their] destiny." – Interviewee (public sector, high seismic hazard zone, owner occupier)

"We have many other modern pressures being placed upon our citizenry, [such as] 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?" – Interviewee (public sector, low seismic hazard zone, community expert)

Social and economic recovery

Further to the recovery priorities already described, the interviewees mentioned additional topics related to social and economic recovery. Table 1 and Table 2 outline themes related to social recovery and economic recovery, respectively, that were discussed during the interviews.

Table 1. Additional themes related to social recovery

Theme	Description
Communities are adaptable.	All interviewees described ways that their communities could adjust to survive in a post-earthquake environment because, as one interviewee explained, *"Communities have the instinct and resilience to readapt."* For example, micro-communities (e.g., church congregations) that typically gather in buildings can adapt and move post-event if necessary, as the community is built of individuals, not just buildings (n=3).
Communities should be empowered to help manage their recovery.	Community members will be most aware of their community's specific needs after an earthquake and are best placed to determine how response and recovery efforts should be prioritised (n=3). Therefore, community leaders should work with civil defence and other non-local relief organisations to allocate services and resources to accurately reflect the needs and wants of the community. *"How do you support communities to do what they need to do, rather than just trying to provide services? Because you'll never have the capacity to do it all, and you'll never do it right" – Interviewee (public sector, high seismic hazard zone, owner occupier)*
Individuals should be empowered to help with community recovery.	It is important to provide individuals with a sense of purpose after a major life-disrupting event (n=2). Identifying ways of empowering individual community members to assist in the recovery process may help alleviate mental health impacts and build a stronger community.
There needs to be an equitable distribution of resources in the recovery process.	Less affluent communities are likely to be disproportionately affected by the impacts of a major earthquake (n=3). These communities tend to have older buildings that are more likely to be damaged and community members that work more service-based jobs that will be disrupted if commercial buildings are not functioning. They may also have community members whose financial status makes them more vulnerable to disruptions. Government assistance should be equitably distributed such that these communities receive adequate resources to enable recovery.
Vulnerable people may have additional needs in the recovery process.	Vulnerable members of society (e.g., elderly and physically or mentally disabled) have a high risk of becoming isolated if damage to their home and surrounding environment results in disruption to their regular social routines

Theme	Description
	and/or dislocation from their community (n=3). Special care needs to be taken by community members to prevent the isolation of these vulnerable individuals. The post-earthquake environment presents significant barriers to the mobility of physically disabled individuals (n=3). Temporary access paths provided during the response and recovery efforts should be suited to people with different levels of mobility.
The preservation of heritage is important for future generations.	While it was generally acknowledged that the preservation of heritage buildings is not an immediate priority in the recovery process, many still find it important to maintain some heritage sites as touchstones to a shared history (n=6). It was noted by a heritage expert that there is no appropriate timeline for repairing heritage buildings; communities can work to a timetable that fits their resources and needs. Regardless of the state of a heritage building – be it open, closed for repairs, or demolished – the cultural identity of a community or heritage site can be maintained through stories (n=1). *"The one thing that absolutely can be retained for everything, no matter what its final stages, is its story." – Interviewee (public sector, national perspective, cultural heritage expert)*
Heritage buildings pose an unacceptable risk to safety and recovery.	Some interviewees explained that they do not feel a social or cultural connection to heritage buildings (n=3). Rather, they view earthquake-prone heritage buildings as safety hazards that may hinder future recovery efforts. These interviewees would rather have old, damaged buildings pulled down, regardless of heritage status, to expedite recovery following a major earthquake. *"Heritage buildings are stagnating. You can't use them because they're seismically prone, and you can't fix them because they're heritage enabled. If a few of them got knocked over [in an earthquake], a lot of people would probably cheer if there were nobody in them." – Interviewee (private sector, national perspective, tenant)*
Business and population loss impact sense of place.	Loss of a critical mass of buildings, business or population can impact the vibe of a city, how it looks and feels, and disruption to this could negatively impact people's sense of place in a community (n=4).

Table 2. Additional themes related to economic recovery

Theme	Description
Business confidence is necessary to stimulate recovery.	Economic agents in a community need to be perceived by others as being safe, secure, and of high quality to minimise reputational damage and prevent investors from fleeing an area (n=4).
Schools enable parents to return to work.	Having schools open enables parents and guardians to go to work by ensuring their children are cared for (n=5).
A stable home life enables people to return to work and be productive.	Living in an unstable home environment, such as a quake-damaged house, can affect people's physiological and/or psychological health, resulting in reduced productivity at work (n=4).
Maintaining infrastructure that supports the supply chain is critical to economic recovery.	Ports and roads need to be functional to maintain supply chains for both essential and non-essential goods (n= 3). Storage facilities are also critical to the supply and distribution of goods (n=3). A representative from a national supermarket chain stressed the criticality of ensuring the ongoing operation of supermarket distribution centres, as the supply of goods in a region (i.e., up to 50+ stores) is dependent upon deliveries from these centres.
Businesses are often interdependent such that the economic recovery of one relies on others.	Most businesses cannot function independently; they are reliant on the ongoing operations of complementary companies in their area and those in their supply chain. For example, tourism-based businesses rely on hotels and cafes/restaurants to be operating to ensure that potential customers can comfortably visit an area (n=2). Similarly, manufacturing companies will be affected if their suppliers or distributors are impacted by earthquake-related disruptions (n=2).
Hospitality and retail jobs are especially vulnerable to disruptions from building damage	Many jobs in the service, manufacturing and primary production industries are dependent upon having a physical place of operations. If the buildings that house these types of businesses are damaged or destroyed in the earthquake, the employees will be out of work (n=2). *"You have those direct employment types of businesses, which require a physical presence within a space and interaction with the public, such as retail, hospitality. If [the buildings] are completely written off, all the people who work in those industries are instantly going to be out of a job" – Interviewee (private sector, high seismic hazard zone, owner occupier)* Additionally, many service-based industries (e.g., hospitality and retail) are dependent on having a reliable customer base. Businesses may be forced to close if they no longer have customers because they have moved away, no longer work in the area or there is neighbourhood disruption (n=4).

Theme	Description
Economic recovery is about prioritising and rationalising business resources.	Businesses will need to adapt to the disruptions caused by a major earthquake. In doing so, they may need to make tough decisions about their business model to stay afloat (e.g., the range of products they can offer or the number of staff they can employ) (n=1). *"But the reality is that you have to prioritize your return because you can't fix everything straight away. You have to prioritize where your major focus and growth is. You then have to rationalize some of the less popular and less attractive options … because to keep your areas of strength, you may have to reduce your total offerings." - Interviewee (public sector, high seismic hazard zone, owner occupier)*
The recovery process can introduce new job opportunities.	The recovery process may generate new job opportunities for people in the construction sector or those willing to work jobs related to the repair or rebuild (n=1).

Natural environment

The natural environment was not typically top of mind for interviewees when considering the potential impacts of failures in the built environment following a major earthquake. However, when prompted to consider topics such as sustainability, carbon emissions, and waste, it became apparent that these are emerging priorities for many.

One of the most common concerns was managing the waste generated from demolished buildings (n=6). The Christchurch earthquake was often cited as an example of an earthquake that resulted in widespread building demolition, which required innovative approaches to waste management[11]. Interviewees were concerned that the uncontrolled demolition of buildings would result in ground contamination from hazardous building materials (e.g., asbestos) and a lost opportunity to re-use or recycle building materials.

A less common counterpoint to this view is that building waste has to be dealt with at some point, so it is not a significant concern or priority specific to earthquakes (n=1).

> *"There's always going to be environmental impacts. I mean, dust and asbestos, petrol falling out of tanks and going into the water and stuff like that… I think that a lot of that stuff is probably pretty minor in the scheme of things." –Interviewee (private sector, national perspective, tenant)*

The carbon cost of demolishing a building due to earthquake damage was also discussed by some interviewees (n=4). Reducing carbon emissions is an emerging priority for many individuals and organisations. The untimely demolition of a building would counteract environmental sustainability objectives. Several interviewees observed that fixing a building is more sustainable than demolishing and rebuilding it (n=2).

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

Containing other potential pollutants (not from building demolition waste) was also a priority. Some interviewees thought it was important to take precautions prior to an earthquake to ensure buildings that hold hazardous materials (e.g., acids) are not damaged in a way that would cause containment issues (n=3). Sewage was also identified as a potential pollutant if there is damage to underground piping or wastewater treatment facilities (n=3).

One interviewee noted that there might be some environmental benefits to the widespread demolition of buildings in an area, citing the renewal of plant and animal life in the Ōtākaro

[11] Brown C, & Milke M. (2012). Case study report: 2010 Canterbury and 2011 Christchurch Earthquakes – Demolition and Disaster Waste Management. https://www.resorgs.org.nz/wp-content/uploads/2017/07/appendix-k.cbrown.pdf

Avon River Corridor (an area that was declared a residential red zone) following the Canterbury earthquakes[12].

> *"When people moved out [of the Christchurch residential red zones], nature re-established itself, which was a bonus" – Interviewee (public sector, national perspective, owner occupier)*

Irrecoverable damage

Interviewees were asked to identify types of disruption that might cause irreversible or irrecoverable damage to a community. Interviewees considered either the community in which they lived (e.g., Wellington) or the micro-community they represented (i.e., an individual business).

Most interviewees discussed their belief that the flow-on effects of widespread damage to the built environment (city or town) would be irrecoverable. Extensive damage to buildings and infrastructure would require a long and disruptive recovery, with limited assurance that the community could return to pre-earthquake levels of social and economic activity. The extent of the disruptions, duration of the recovery, and the uncertainty associated with both may be beyond what individuals and businesses are able to tolerate, and in the worst case this could lead to a mass exodus.

Examples of disruptions considered irrecoverable are presented Table 3 and Table 4. In residential areas irrecoverable disruption arises when residents cannot secure safe, sanitary and secure housing in a reasonable timeframe after an earthquake, or if their social ties within the community begin to fracture. For businesses, irrecoverable disruption could result from a breakdown in their supply chain and/or a loss of part or all of their customer base. Uncertainty about the duration of these disruptions could lead to a lack of confidence in the area, driving businesses to close or relocate.

Some interviewees identified the likely physical causes of the socio-economic disruption noted in Table 3 and Table 4 such as severe land damage and environmental destruction. Damage from liquefaction, fault scarps or a tsunami could result in the land being declared unfit for reoccupation (as was the case for the Christchurch residential red zone following the 2010-2011 earthquake sequence) (n=4). Earthquake damage that leads to environmental destruction (e.g., soil or waterway contamination from wastewater or other hazardous waste) could also make affected areas uninhabitable (n=1).

The capacity of individuals and communities to recover was also discussed. When multiple destructive earthquakes occur in a short timeframe, the stress and disruption caused by these successive events can be irreversibly detrimental to individuals and to the social and economic fabric of a community (n=1).

[12] See details of the Ōtākaro Avon River Corridor Regeneration Plan at https://dpmc.govt.nz/our-programmes/greater-christchurch-recovery-and-regeneration/recovery-and-regeneration-plans/otakaro-avon-river-corridor-regeneration-plan

Table 3. Examples of disruptions considered to be irrecoverable for residents

Examples of Irrecoverable Damage	Description
Critical loss of permanent housing stock	People will begin to move away from an area if they cannot obtain/maintain safe/secure/sanitary housing in a reasonable timeframe after an earthquake (n=4). A lack of housing may result from damage to single-family or multi-unit dwellings, or to neighbourhoods where the land is damaged (as was the case for the Christchurch residential red zone). Long and uncertain timeframes for repairs or rebuilding may be beyond what some individuals are willing to tolerate.
Loss of confidence in local building stock and infrastructure capacity	Widespread damage to buildings and infrastructure following a major earthquake could cause a perception that certain places are not viable places to live. People may witness earthquake damage and decide that the risks associated with continuing to live in a certain area are too great (n=1), or the disruption associated with reinstating badly damaged services and buildings would be severe and prolonged.
Loss of the ability to obtain adequate and affordable home insurance	If an earthquake the insurance available for homes is no longer sufficient to mitigate potential losses (i.e., if homes are underinsured if earthquake insurance is too expensive for most) then people may decide certain areas are too risky to build and live in (n=3).
Diminished sense of place	Loss of a critical mass of buildings (particularly iconic buildings) can impact the vibe of a city, how it looks and feels, and disruption to this could negatively impact people's sense of place in a community (n=2).
Fractured social ties	Communities may start to break down after the loss of key community gathering places such as schools and sporting facilities (n=1). *"Irreversible damage will be the complete loss of habitat… The loss of things like schools. I think you can readapt or reconfigure education to needs, but schools are very important hearts for communities. So if they were irreparable for a really long period of time, I think you'd see a breakdown of the community. Then I suppose on a lesser level, loss of things like suburban centres, the loss of sporting facilities. Irrecoverable loss of sporting facilities would strike at the heart of a community. I think that there are places where the community gathers for the sausage sizzles, or the school fairs and all those sorts of things. If they were all gone, then the community would certainly be in much worse health." – Interviewee (private sector, high seismic hazard zone, owner occupier)* The loss of social networks in a community can loosen personal ties to a place (e.g., friends or family moving away after an earthquake) (n=1).
Loss of job opportunities	Earthquake damage to businesses and homes can prevent people from being able to perform their jobs (n=2), and infrastructure damage (e.g., roads and public transportation) can prevent people from getting to work (n=1). People who cannot economically support themselves and their families may have to move somewhere with more job opportunities. Prolonged disruptions to economic activity after an earthquake could mean there are limited opportunities for advancement in certain fields, and individuals may have to/want to relocate for career development (n=1).

Table 4. Examples of disruptions considered to be irrecoverable for businesses

Examples of Irrecoverable Damage	Description
Inability to continue to operate from pre-earthquake location	Some businesses may not be able to recover if their building is declared uninhabitable after an earthquake (n=5). Additionally, major earthquake damage to surrounding buildings that result in cordons or similar restrictions that prevent people from accessing their buildings for long periods (e.g., two years or more) is considered irrecoverable for some (n=3).
Loss of confidence in economic recovery	Uncertainties in recovery timeframes can lead to a loss of confidence in an area, further delaying the rebuild (n=5). Investors and business owners may not want to take on the risks associated with rebuilding or re-establishing a business in an uncertain market. Instead, they will choose to invest their money and time in a more stable market elsewhere in the country, or abroad. *"Buildings are dependent upon the city and vice versa. So you're not going to rebuild or spend money on a 10 storey or 20 storey building if you don't know whether somebody's got demand for it." – Interviewee (private sector, high seismic hazard zone, tenant)*
Breakdown of supply chains	Extensive damage to infrastructure that supports local and international supply chains could cause irrecoverable damage to businesses. Ports, in particular, were noted as being critical to the supply chain (n=2). Also, damage to local buildings that disrupt the supply or distribution of goods could result in permanent redistribution or closures of supply chains (n=2). For example, the closure of a manufacturing facility due to earthquake damage would mean that another facility would have to process the raw materials. If the second facility is able to take on the extra raw materials without issue, the damaged facility may not be repaired.
Loss of customers	Most businesses, particularly service-based businesses (e.g., retail, hotels and tourist attractions), cannot operate in isolation. These businesses rely on the surrounding built environment to encourage people to visit an area. If the built environment is damaged, people are less likely to occupy an area, and businesses will suffer from the loss of customers (n=4). A functioning built environment is particularly important for university enrolment (n=2). Students are less likely to enrol at a university with damaged facilities and limited amenities in the surrounding community due to earthquake damage.
Loss of the ability to insure businesses	If earthquake insurance for businesses is no longer available or too difficult to obtain, business owners may decide that certain areas are too risky to build and operate from (n=3).
Loss of reputation from earthquake damage	A business that owns and/or operates from a building that was severely damaged in an earthquake and caused injuries or deaths to building occupants may suffer irrecoverable damage to their reputation for a perceived failure to provide safety for the building occupants. (n=1).

3.1.4 Key points

- All interviewees expect new buildings to withstand a major earthquake without creating a significant threat to the life safety of building occupants or passers-by. Significant structural failures, including total building collapse, are unacceptable.
- Early response priorities include the ongoing provision of services that support life (i.e., emergency response services and healthcare emergency services), providing basic needs for displaced individuals (e.g., food, shelter, water, and medication), and clear communication and information sharing from emergency response coordinators.
- The ability to communicate with others is critical to the early response, and therefore maintaining telecommunication networks (i.e., cell phone coverage) is a key priority.
- There are growing expectations that our future buildings can effectively support community recovery following a major earthquake by 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.
- The ability to keep people in their homes after an earthquake was identified as one of the most vital aspects of recovery.
- Schools form a crucial aspect of community resilience, as they are enablers for economic recovery and wellbeing.
- Uncertainty in the recovery process could lead to poor mental health, encumbered social and economic recovery, and, ultimately, the retreat of people and businesses from the affected area.
- Environmental considerations such as sustainability, carbon emissions, and waste are emerging priorities for many.

3.2 Expectations during a moderate earthquake

Interviewees expressed that the priorities for smaller earthquakes would generally be the same as for larger earthquakes, with safety still being the top priority. For smaller events, interviewees were less concerned about damage than they were about mitigating the psychological impact that the shaking, and any resulting damage, may have on building occupants. Most interviewees expected their building or buildings in the community to withstand lower levels of shaking with minimal to no impact on functionality. However, some noted that damage to non-structural systems could be costly and time-consuming to repair or that damage to surrounding infrastructure (e.g., water pipes) could affect building functionality.

3.2.1 Health and safety

Safety was top of people's minds when discussing the potential impacts of moderate earthquakes, with 18 interviewees discussing safety in some way. Some interviewees thought that health and safety should not be a concern following a moderate earthquake (n=3). Others noted that the poor structural performance of relatively new buildings in the Kaikoura earthquake presented unacceptable risks to life-safety (n=2). Though, as stated above, structural damage of any kind was generally unexpected. Non-structural, or auxiliary system damage such as contents moving around during an earthquake or unsecured items falling from ceilings (e.g., ceiling tiles or ducts) could also present a risk to building occupants (n=3). It was expected that emergency services would be fully operational following a moderate earthquake (n=2).

Outside of the initial health and safety expectations during earthquake shaking, interviewees expressed a desire to have assurances that the building is safe to reoccupy following an earthquake (n=10). These assurances could be provided by a building occupant or representative that visually inspects the building and determines no cracking occurred during the earthquake. An engineer may be called to inspect the building if any concerning cracks are discovered.

Interviewees also discussed the psychological impacts of ground shaking (n=4) and earthquake-induced building damage (n=4). Even small earthquakes can cause anxiety, triggering individuals to remember past traumatic events or worry that a larger earthquake is going to follow. Similarly, visual reminders of earthquake damage (e.g., cracked windows or GIB) may cause day-to-day anxiety for building occupants. Remediation of minor damage can reduce unease about building safety. Two interviewees also suggested that clear communication from building representatives to building occupants about building damage and steps for remediation can also help to reduce anxiety.

3.2.2 Building performance

Following a moderate earthquake, interviewees typically expected that building contents would have moved around (e.g., items would fall off shelves) (n=3). Cosmetic cracking (e.g., cracks in windows or plasterboard) may occur, but any damage should be easily repairable (n= 10). Interviewees did not expect buildings to experience any structural damage after a moderate earthquake (n=6). Buildings should remain weather-tight (n=2).

Eight interviewees explicitly expressed that they expected there to be minor to no impact on the building functionality. In homes, kitchens and bathrooms should remain usable (n=1). In offices, building systems (e.g., HVAC systems and telecommunication) should continue to work uninterrupted (n=2).

Interviewees who anticipated that building functionality could be interrupted after a moderate earthquake typically discussed the potential for damage to non-structural systems (n=8) or surrounding infrastructure (n=4). Extensive damage to non-structural building elements can be costly and time-consuming to repair. In the worst-case scenario, buildings may be demolished if they become economically infeasible to repair, despite being structurally sound. Damage to infrastructure service connections or the services themselves can also cause disruptions, as power outages and damage to pipes that affect the water supply will affect buildings' ability to function.

3.2.3 Key points

- Safety is still the top priority in a moderate earthquake, followed by mitigating the psychological impact that the shaking, and any resulting damage, may have on building occupants.
- In addition to actually being safe, many interviewees expressed that they wanted to 'feel safe' within their buildings following an earthquake.
- Following a moderate earthquake, it is typically expected that building contents to have moved around and some cosmetic cracking, but any damage should be non-structural and easily repairable.

3.3 Expectations for the occurrence of building damage from earthquakes

The following question was asked of interviewees:

> A building's design life is typically 50 years. How often in that design life do you think it is acceptable to experience the following levels of damage:
> a. A minor level of damage during an earthquake (repairs needed but minimal disruption to services)
> b. A moderate level of damage during an earthquake (repairs needed with minor disruption to services – in order of weeks)
> c. A significant level of damage during an earthquake (repairs needed with significant disruption to services – in order of months)
> d. A major level of damage during an earthquake (unoccupiable, possibly requiring replacement)

The purpose of this question was to explore how often people are willing to accept different levels of disruption due to earthquake damage. Early in the interview process, it became apparent that the framing of the question in an interview format made it difficult for interviewees to provide complete numeric answers. Therefore, rather than pushing interviewees to supply quantitative answers, we asked for commentary around tolerance for earthquake damage within a typical building design life. The commentary and numeric responses (when provided) were then analysed to identify factors that may influence earthquake risk tolerance. The analysis was intended to serve as a starting point for identifying emerging trends and patterns for further exploration. The limited pool of interviewees and sometimes uneven representation of perspectives mean that the presented results can neither rule out nor confirm possible significant relationships. A summary of the responses as well as initial qualitative and quantitative analysis of the data are provided below.

Among the 32 interviewees, four either were not asked the question due to time constraints or chose not to answer. One interviewee representing a district health board (DHB) was excluded from the analysis because of the higher performance standards already required for hospitals. One interviewee representing the national perspective provided answers for two seismic hazard zones (i.e., low and high). Two interviewees representing expert perspectives provided answers for two different building types (i.e., commercial and residential). In total, 30 perspectives to the question were recorded, with responses having varying degrees of completeness.

3.3.1 Summary of commentary

The following subsections summarise the commentary provided for each of the earthquake damage levels and other topics raised by the interviewees.

Minor damage

Interviewees were generally accepting of minor earthquake damage, with only one interviewee indicating that minor damage would be unacceptable. That interviewee represented a low seismic hazard zone perspective and did not believe earthquake damage would occur in their building.

Interviewees varied in their opinions of what constituted minor earthquake damage. Examples of minor damage typically included cosmetic damage such as damage to GIB, internal cladding, and other cosmetic (non-structural) cracking. However, there was inconsistency among the interviewees about whether or not minor damage affected the weather tightness of the building. Some interviewees indicated that minor damage should not affect weather tightness, but others indicated that cracks that let in cold air, damage to flashing, and minor water leaks were acceptable types of minor damage.

Six interviewees mentioned that minor earthquake damage would likely not require immediate repairs, and thus the repairs could be incorporated into regular building maintenance schedules. Three interviewees mentioned time periods ranging from 5-10 years are typical for routine building maintenance (e.g., paint regimes, weather tightness checks).

Moderate damage

Interviewees were also generally accepting of moderate earthquake damage, with only one interviewee indicating that moderate damage would be unacceptable. This was the same interviewee who indicated that minor earthquake damage would be unacceptable.

Moderate damage was noted to still be relatively superficial damage. Examples given for types of moderate damage were similar to those provided for types of minor damage (e.g., cosmetic damage such as damage to paint, plaster, or plasterboard and other superficial cracks). Moderate damage could also include damage to infrastructure sensors or service connections (i.e., water).

One interviewee noted that a repair timeline in the order of weeks would not be unusual for superficial damage (minor or moderate) because of the lead time required to get a tradesperson out to fix the damage.

Moderate damage from earthquakes was noted to typically trigger the need for an inspection by someone responsible for the building, who would then decide if an inspection by a structural engineer was necessary.

One interviewee reflected on moderate damage at a community level and noted, "It shouldn't be more than 10% of buildings that would require a week-long remediation".

Significant damage

Interviewees were less slightly accepting of significant damage than minor or moderate damage, with three interviewees indicating that significant earthquake damage was unacceptable.

Interviewees tended to elaborate least about significant damage, possibly because they were less aware of the types of damage that would cause disruption that lasts for months. Two interviewees mentioned that significant damage would trigger the need for an inspection by a structural engineer. The building would likely need to be closed while repairs were planned and underway, disrupting occupants.

Major damage

Most interviewees believed that major damage within a building's 50-year lifecycle was unacceptable. Only four interviewees indicated that they would be accepting of major damage, citing that New Zealand is a seismically active country, and earthquakes (with the associated potential for damage) are inevitable. These interviewees represented either a national or high seismic hazard perspective and related their viewpoint to the expected return period on known faults such as the Alpine Fault and the Wellington Fault.

Interviewees generally understood that severe structural damage would cause a building to be unoccupiable and that an engineer has the authority to deem a building unfit to occupy. However, the types of damage that would constitute major damage were not elaborated on, similar to significant damage.

One interviewee reflected on major damage at a community level and noted that "widespread building damage in a CBD is unacceptable." They stated that 5-10% of existing buildings being unoccupiable after a large earthquake would be within an acceptable range.

Other Comments

Five interviewees noted that the tolerance and acceptable periods for disruption due to earthquake damage are highly subjective. Factors perceived to affect a person's willingness to accept earthquake damage included previous earthquake experience, the vulnerability of the building occupants, and the primary use of the building.

One interviewee with experience in the building industry shared an anecdote about an organisation whose building suffered major damage in the Kaikoura earthquake, causing severe business disruptions. This organisation now has a very low tolerance for earthquake-related disruptions. Another interviewee noted that major damage that renders a building unoccupiable is unacceptable, particularly if there are vulnerable occupants (e.g., aging population) with limited resources to handle the disruption.

Conversely, some interviewees noted that organisations with office-based businesses are not necessarily dependent on the physical structure of their building and would be more tolerant of disruptions. One interviewee who represented a large building portfolio also noted that closing down one site for repairs is not 'catastrophic' because their business has several sites that could continue to operate and generate income.

Several interviewees discussed the frequency or expected return period of earthquakes. One person from a high seismic zone noted that moderate earthquakes seem to occur every 5-10 years. He believed that you should be able to plan for events that occur regularly without being adversely affected. Two interviewees mentioned specific faults (i.e., the Wellington Fault and the Alpine Fault). Based on their knowledge of fault recurrence intervals, they expect a major earthquake to occur in the next 50 years. Two interviewees were concerned about compounding earthquake damage, with one interviewee stating that 'buildings likely won't survive two big earthquakes.'

Two interviewees noted that construction quality and building maintenance would affect the performance of buildings. Cheaply constructed buildings utilising poor quality materials would not be expected to last as long or perform as well in an earthquake when compared to building constructed of higher quality durable materials. One interviewee noted that if a relatively new building were deemed unoccupiable after an earthquake, there likely would have been a flaw in the design and construction process that resulted in its poor performance.

Building design life

Thirteen interviewees commented on the statement that a "building's design life is typically 50 years." Many expressed surprise that, for seismic design of most buildings, the assumed period of exposure to earthquakes is only 50 years[13].

Eleven interviewees disagreed with the 50-year design life. Those interviewees represented a range of perspectives, and no trends in perspective were detected. Seven interviewees noted that buildings, especially houses, typically last more than 50 years. Those that believed the 50-year design life was too short gave the following reasons:

- Buildings overseas have been around for hundreds of years
- Regular maintenance and/or renovations can extend the life of buildings
- Longer building lifespans could result in less long term carbon costs and use of raw materials

Conversely, two interviewees noted that there were drawbacks associated with designing buildings to last beyond 50 years. These included the following:

- Some buildings do not last even 50 years because design or construction flaws (e.g., leaky buildings)
- The 'functional economic life' of commercial or manufacturing buildings may be less than 50 years (i.e., the buildings may become functionally obsolete)
- There are extra costs associated with building for longer lifespans

3.3.2 Acceptable damage occurrence intervals

The interviewees were encouraged, though not required, to give a numeric answer indicating the acceptable occurrence intervals for different levels of earthquake damage. Some opted to provide a binary response, indicating that the level of damage is acceptable in a 50-year time frame but not providing a numeric answer for the number of times that type of damage would be acceptable. If an interviewee indicated that a level of damage was not acceptable in a 50-year time frame, a numeric response of 0 times in 50 years was recorded. The following section provides an overview of the binary and numeric answers provided and explores perspectives that may influence tolerance for disruption due to earthquake damage.

As previously noted, the qualitative analysis presented is intended to use the available data to identify emerging trends for factors that influence risk tolerance, not to make definitive conclusions about these factors. The identified trends will be further explored and compared with other findings in this report and the accompanying focus group report.

Table 5 shows the total number and type of responses for each damage level. The following notation is used:

- $N_{acceptable}$ is the number of interviewees that provided a binary or numeric response indicating that the level of earthquake damage is acceptable in a 50 year time frame.
- $N_{unacceptable}$ is the number of interviewees that provided a binary or numeric response indicating that the level of earthquake damage is NOT acceptable in a 50 year time frame.

[13] Per NZS 1170.0:2002, the design working life for normal structures is generally taken as 50 years.

- N_{null} is the number interviewees that did not provide an answer for a particular earthquake damage level/perspective.
- N_{total} is the total number of responses for a particular perspective.
- $N_{numeric}$ is the number of interviewees that provided a numeric response for a particular damage level/perspective.

Figure 6 shows $N_{acceptable}$ and $N_{unacceptable}$ for each earthquake damage level. In general, minor and moderate damage levels were considered acceptable at least once during the 50-year design life of a building. Significant damage was also regarded as acceptable by 80% of respondents (n=12 out of 15). Major damage was largely deemed unacceptable, with 81% of respondents (n=17 out of 21) indicating that buildings should not be rendered unoccupiable due to earthquake damage within their intended design life.

Table 6 summarises the numeric responses, reporting the maximum, minimum, and average number of acceptable occurrences in 50 years, as well as the standard deviation. Figure 7 shows a boxplot for the acceptable number of occurrences of each damage level in 50 years.

For all boxplots presented, the thick horizontal black lines represent the 50th percentile (median) values. The boxes extend to the 25th and 75th percentiles, with the distance between the 25th and 75th percentiles known as the interquartile range (IQR). The top whiskers extend to the lesser of the largest data point and 1.5*IQR above the 75th percentile, and the bottom whiskers extend to the greater of the smallest data point and 1.5*IQR below the 25th percentile.

As the damage level increased, the number of acceptable occurrences and the variance in responses decreased. Minor damage had the largest variance in numeric responses, ranging from 25 times in 50 years (i.e., approximately every 2 years) to 0 times in 50 years. On average, minor damage was considered acceptable once every 7.3 years. Moderate, significant, and major damage levels were considered acceptable every 3.7, 1.3, and 0.2 years, respectively.

Table 5. Summary of all responses for the acceptable number of occurrences of each damage level in 50 years.

Damage Level	$N_{acceptable}$	$N_{unacceptable}$	N_{null}	N_{total}	$N_{numeric}$
Minor	21	1	8	30	14
Moderate	16	1	13	30	10
Significant	12	3	15	30	13
Major	4	17	9	30	21

Table 6. Summary of numeric responses for the acceptable number of occurrences of each damage level in 50 years.

Damage Level	Maximum	Minimum	Median	Mean	Standard Deviation
Minor	25	0	5.5	7.3	5.1
Moderate	10	0	2.7	3.7	2.7
Significant	3	0	1	1.3	0.9
Major	2	0	0	0.2	0.5

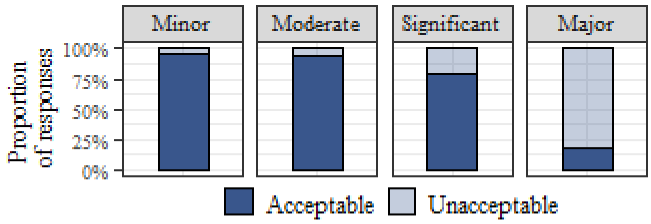

Figure 6. Responses indicating whether each earthquake damage level is acceptable ($N_{acceptable}$) or unacceptable ($N_{unacceptable}$) within the 50-year lifespan of a building.

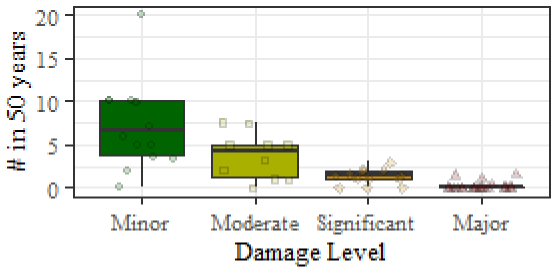

Figure 7. Boxplot for the acceptable number of occurrences of each earthquake damage level in 50 years (i.e., $N_{numeric}$ responses). The thick horizontal black lines represent median values, and points represent empirical data points.

Private versus public interest perspectives

For analysis purposes, interviewees were divided into two sectors, private (n=17) and public (n=13), to determine whether interviewees' perspectives influenced priorities. The 'public' perspective included the interviewee perspectives categorised as 'public', 'public interest' and 'research' in Figure 3.

In general, interviewees representing a private interest perspective were slightly more accepting of minor and moderate damage in terms of the acceptable number of occurrences, though there was a large variance between answers.

Table 7. Summary of responses by private or public perspective for the acceptable number of occurrences of each damage level in 50 years.

Damage Level	Sector	$N_{acceptable}$	$N_{unacceptable}$	N_{null}	N_{total}	$N_{numeric}$
Minor	Private	11	1	5	17	7
	Public	10	0	3	13	7
Moderate	Private	8	1	8	17	5
	Public	8	0	5	13	5
Significant	Private	7	2	8	17	7
	Public	5	1	7	13	6
Major	Private	2	9	6	17	11
	Public	2	8	3	13	10

Table 8. Summary of numeric responses by private or public perspective for the acceptable number of occurrences of each damage level in 50 years.

Damage Level	Sector	Maximum	Minimum	Median	Mean	Standard Deviation
Minor	Private	25	0	8.5	8.4	6.3
	Public	10	3	5	6.1	3.2
Moderate	Private	10	0	3	4.2	3.3
	Public	5	1	2.7	3.3	1.9
Significant	Private	2	0	1	1.1	0.8
	Public	3	0	1.5	1.5	1.0
Major	Private	2	0	0	0.3	0.6
	Public	1	0	0	0.2	0.3

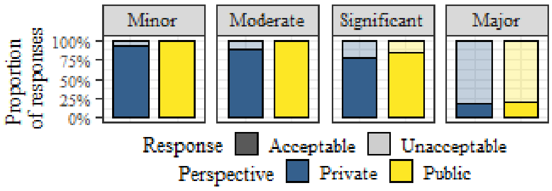

Figure 8. Responses by private or public perspective indicating whether each earthquake damage level is acceptable ($N_{acceptable}$) or unacceptable ($N_{unacceptable}$) within the 50-year lifespan of a building.

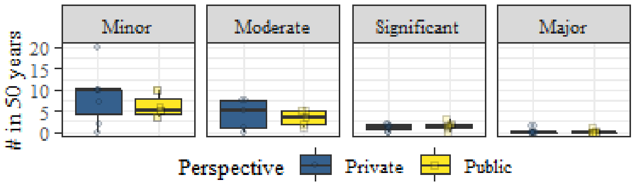

Figure 9. Boxplot for the acceptable number of occurrences of each earthquake damage level in 50 years (i.e., $N_{numeric}$ responses) by private or public perspective. The thick horizontal black lines represent median values, and points represent empirical data points.

Ownership perspectives

Three ownership perspectives were considered: Owner (i.e., long term investment interest or owner occupier) (n=16), Tenant (n=4), Other (i.e., users or multiple/expert) (n=10).

Although the sample size for tenants was small, they were generally less accepting of minor and moderate damage. Multiple interviewees (n=3) noted here the vulnerability of tenants (e.g., age and/or financial situation) would also affect their tolerance for disruption with the impacts of earthquake-caused disruptions perceived as being disproportionally harmful to vulnerable people. There were no other discernible patterns of ownership perspectives affecting tolerance for earthquake damage.

Table 9. Summary of responses by ownership perspective for the occurrence of each damage level.

Damage Level	Ownership Perspective	$N_{acceptable}$	$N_{unacceptable}$	N_{null}	N_{total}	$N_{numeric}$
Minor	Owner	10	0	6	16	7
	Tenant	2	1	1	4	2
	Other	9	0	1	10	5
Moderate	Owner	6	0	10	16	3
	Tenant	3	1	0	4	3
	Other	7	0	3	10	4
Significant	Owner	6	1	9	16	5
	Tenant	2	1	1	4	3
	Other	4	0	5	10	5
Major	Owner	1	10	5	16	11
	Tenant	1	3	0	4	4
	Other	2	4	4	10	6

Table 10. Summary of numeric responses by ownership perspective for the acceptable number of occurrences of each damage level in 50 years.

Damage Level	Ownership Perspective	Maximum	Minimum	Median	Mean	Standard Deviation
Minor	Owner	25	1	7	9.3	6.0
	Tenant	3.3	0	1.7	1.7	1.7
	Other	10	3	5	6.7	2.7
Moderate	Owner	10	1	1	4.5	3.0
	Tenant	10	0	2	3.2	3.2
	Other	5	1	4.2	3.6	1.6
Significant	Owner	2	0	1	1.2	0.8
	Tenant	2	0	1	0.8	0.6
	Other	3	0	1.7	1.6	1.0
Major	Owner	2	0	0	0.1	0.4
	Tenant	2	0	0	0.4	0.6
	Other	1	0	0	0.3	0.4

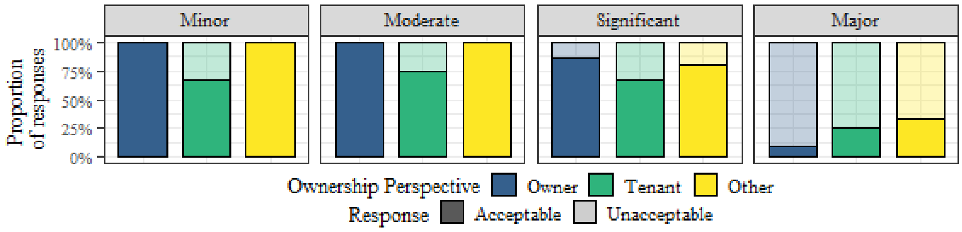

Figure 10. Responses by ownership perspective indicating whether each earthquake damage level is acceptable ($N_{acceptable}$) or unacceptable ($N_{unacceptable}$) within the 50-year lifespan of a building.

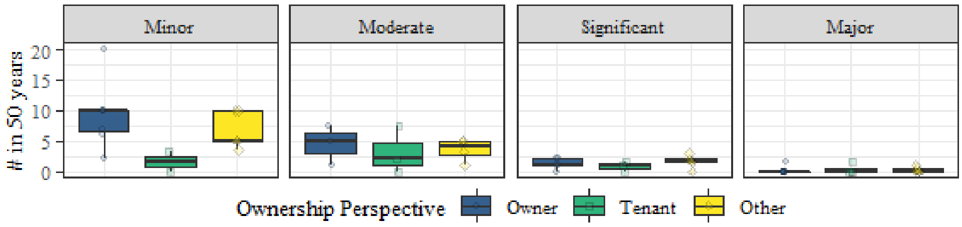

Figure 11. Boxplot for the acceptable number of occurrences of each earthquake damage level in 50 years (i.e., $N_{numeric}$ responses) by ownership perspective. The thick horizontal black lines represent median values, and points represent empirical data points.

Geographical perspectives

Three geographical perspectives were considered: national (n=14), high seismic hazard (n=11), and moderate/low seismic hazard (n=5).

Those with perspectives representing moderate or low seismic hazard zones appeared to be slightly less accepting of earthquake damage than those representing a national or high seismic hazard zone perspective. However, the one person who indicated that minor and moderate damage would be unacceptable during a building's 50-year life span spoke from a low seismic hazard perspective and did not believe that a damaging earthquake would occur.

Those representing a national perspective appeared to be more accepting of major earthquake damage. This acceptance was often attributed to the perceived earthquake risk associated with living near known active faults. Also, some interviewees representing the national perspective had a large portfolio of buildings, and were therefore more accepting of damage because of the redundancy within their network.

Table 11. Summary of responses by geographical perspective for the occurrence of each damage level.

Damage Level	Geographic Perspective	$N_{acceptable}$	$N_{unacceptable}$	N_{null}	N_{total}	$N_{numeric}$
Minor	National	12	0	2	14	6
	High	6	0	5	11	5
	Moderate/Low	3	1	1	5	3
Moderate	National	10	0	4	14	5
	High	5	0	6	11	3
	Moderate/Low	1	1	3	5	2
Significant	National	6	2	6	14	8
	High	4	0	7	11	3
	Moderate/Low	2	1	2	5	2
Major	National	3	6	5	14	9
	High	1	7	3	11	8
	Moderate/Low	0	4	1	5	4

Table 12. Summary of numeric responses by geographical perspective for the acceptable number of occurrences of each damage level in 50 years.

Damage Level	Geographic Perspective	Maximum	Minimum	Median	Mean	Standard Deviation
Minor	National	10	3	7.5	7.3	2.8
	High	25	1	4.7	7.7	6.5
	Moderate/Low	10	0	10	6.7	4.7
Moderate	National	5	1	5	3.9	1.6
	High	10	1	1.5	3.5	2.9
	Moderate/Low	10	0	3.8	3.8	3.8
Significant	National	3	0	1.8	1.5	1.0
	High	2	1	1	1.2	0.5
	Moderate/Low	1	0	0.5	0.5	0.5
Major	National	2	0	0	0.3	0.5
	High	2	0	0	0.2	0.5
	Moderate/Low	0	0	0	0.0	0.0

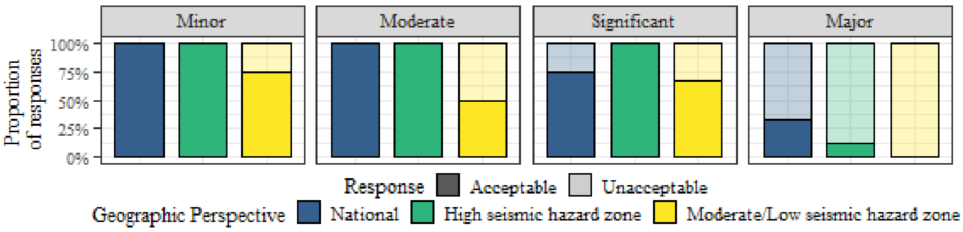

Figure 12. Responses by geographical perspective indicating whether each earthquake damage level is acceptable ($N_{acceptable}$) or unacceptable ($N_{unacceptable}$) within the 50-year lifespan of a building.

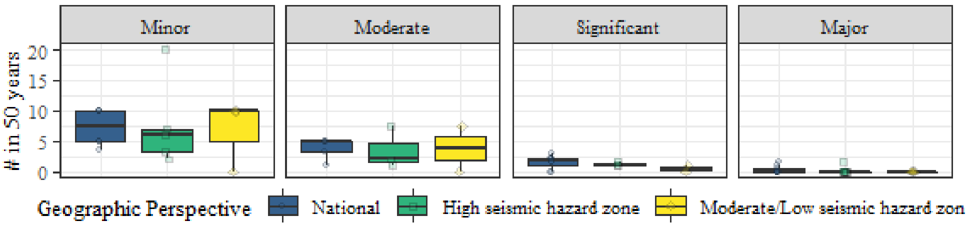

Figure 13. Boxplot for the acceptable number of occurrences of each earthquake damage level in 50 years (i.e., $N_{numeric}$ responses) by geographical perspective. The thick horizontal black lines represent median values, and points represent empirical data points.

Building use and occupancy

Building types were classified based on use and occupancy: commercial (n=17), education (n=2), manufacturing (n=2), residential (n=8), and utilities (n=1).

The commercial building type was considered as a broad category and included building used as offices (n=9), retail (n=1), mixed office/retail (n=2), community meeting places (n=2), supermarket (n=1), hotels (n=1), recreation/tourism facilities (n=1). The perspectives for education buildings included primary and secondary schools (n=1) as well as tertiary education facilities (n=1). The manufacturing building type included both essential (n=1) and non-essential (n=1) goods. The residential building type perspective was typically representative of multi-unit dwellings.

Hospitals were not included in the analysis because they are categorised as Importance Level 4 (IL4) buildings in NZS 1170 and designed to withstand higher earthquake forces than typical (IL2) buildings[14]. Nonetheless, two interviewees noted that hospitals would not be expected to sustain any level of earthquake damage in a 50-year period.

Overall, the analysis of acceptable/unacceptable damage based on building type was inconclusive, given the variance in the sample sizes for each building type and other possible confounding factors. More work is needed to understand how building type affects risk tolerance.

3.3.3 Key points

- Overall, interviewees indicated that minor to moderate earthquake damage is generally acceptable and major damage from an earthquake is generally unacceptable.
- Minor earthquake damage was viewed as non-urgent and able to be incorporated into regular building maintenance schedules.
- People accepting of major earthquake damage often believed it was inevitable in a seismically active country like New Zealand.
- Factors perceived to affect a person's ability to accept earthquake damage included previous earthquake experience, the vulnerability of the building occupants, and the primary use of the building.
- Building design life was generally poorly understood (a topic to be explored further).
- Initial analysis indicated that those representing a public interest perspective were less tolerant of minor and major earthquake damage than those representing a private interest perspective.
- Tenants and those representing moderate/low seismic hazard zones also appear to be slightly less tolerant of minor and moderate building damage. Further analysis is limited by the small sample size.

3.4 Seismic resilience compared to other building design priorities

In an effort to determine where seismic resilience sits relative to other design priorities, interviewees 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 rank the relative importance of each of the building design requirements (1 = most important to 5 = least important), explaining their decision-making process throughout. There was no limit to the number of items that could be given a particular rating. A parallel analysis was undertaken with the focus groups, see Horsfall et al., (2022)[15]. Below is a summary of the data from the interviews.

[14] NZS 1170.0:2002 defines importance levels (IL) of a structure in accordance with its occupancy and use. There are five importance level categories, with IL1 structures having low importance and IL5 structures having exceptional importance. Most normal structures are of ordinary importance (IL2), and buildings with post disaster functions such as hospitals are of high importance (IL4).

[15] Horsfall et al. (2022). Societal expectations for seismic performance of buildings. Detailed report on focus groups. June 2022.

3.4.1 Quantitative analysis

Table 13 shows how interviewees rated each design requirement (ordered from most to least important).

Table 14 further analyses the response to look at the frequency each item was indicated as most important, and least important. The spread of results is indicated by the mode and standard deviation.

Most interviewees rated safety elements (life safety during earthquake, fire safety and safety of users day to day) the most important. Heritage value and architectural value were considered least important. However, ratings for heritage value, cost (capital and whole of life) and dry air/environmental health, were the most variable across interviewees.

Table 13. Interviewee's ranking of building design requirements (Note: 1=Most important and 5=Least important). Normalised by number of respondents

Building design requirements	**Most Important** 1	2	3	4	**Least Important** 5
Life safety during an earthquake	97%	3%	0%	0%	0%
Fire safety	72%	25%	0%	0%	0%
Safety of users day to day	77%	16%	3%	3%	0%
Wellbeing of users	52%	42%	3%	0%	3%
Durability	30%	57%	10%	0%	0%
Accessibility	43%	33%	20%	3%	0%
Dry air / environmental health	39%	26%	19%	10%	3%
Sustainability / energy efficiency / carbon (both embodied and operational)	32%	26%	32%	3%	3%
Protection from other hazards (flooding/volcano/climate change induced hazards)	30%	37%	17%	10%	3%
Whole of life cost	32%	32%	16%	10%	6%
Economic recovery following an earthquake	27%	40%	13%	17%	0%
Social recovery following an earthquake	23%	42%	19%	10%	3%
Low impact on natural environment following an earthquake (waste production, reduced rebuild material requirements etc.)	13%	23%	47%	7%	7%
Adaptability of building configuration / use over time	3%	43%	40%	7%	7%
Capital cost	14%	34%	28%	10%	14%
Architectural value	0%	14%	28%	34%	17%
Heritage value	3%	17%	27%	27%	27%

0% — 100%

Darker colours correspond to importance rankings most often chosen (normalised by the number of responses to each design requirement).

Table 14. Mode, mean, and standard deviation of the interviewee's ranking of building design requirements (Note: 1=Most important and 5=Least important)

Building Design Requirements	**MODE**	**MEAN**	**Standard Deviation**	**Percent of interviewees identifying item as**	
				Most Important	**Least Important**
Life safety during an earthquake	1	1.03	0.18	94%	3%
Fire safety	1	1.27	0.44	69%	3%
Safety of users day to day	1	1.32	0.70	77%	0%
Wellbeing of users	1	1.61	0.84	52%	6%
Durability	2	1.78	0.61	30%	0%
Accessibility	1	1.83	0.87	43%	0%
Dry air / environmental health	1	2.08	1.14	39%	10%
Sustainability / energy efficiency / carbon (both embodied and operational)	3	2.15	1.04	32%	6%
Protection from other hazards (flooding/volcano/climate change induced hazards)	2	2.15	1.09	30%	13%
Whole of life cost	2	2.21	1.21	32%	19%
Economic recovery following an earthquake	2	2.22	1.03	27%	10%
Social recovery following an earthquake	2	2.24	1.04	23%	6%
Low impact on natural environment following an earthquake (waste production, reduced rebuild material requirements etc.)	3	2.68	1.02	13%	20%
Adaptability of building configuration / use over time	2	2.70	0.92	3%	23%
Capital cost	2	2.76	1.24	14%	34%
Architectural value	4	3.52	1.01	0%	45%
Heritage value	5	3.57	1.17	3%	67%

Private vs public interest perspectives

For analysis purposes, interviewees were divided into two sectors: private (n=16) and public (n=16) to determine whether interviewees perspective influenced priorities. The 'public' perspective included the interviewee perspectives categorised as 'public', 'public interest' and 'research' in Figure 3.

Statistical analysis (ANOVA) showed that the private perspective ranked the following building design requirements significantly ($p \le 0.05$) or almost significantly ($0.05 < p \le 0.1$) more highly than the public perspective: Adaptability of building configuration/use over time ($p=0.072$), Capital cost ($p=0.055$), Durability ($p=0.050$), Economic recovery following an earthquake ($p=0.014$), and Whole of life cost ($p=0.46$). There were no building requirements that the public perspective ranked significantly higher than the private perspective.

Table 15. Summary of ANOVA results for private versus public perspective

Building Design Requirements	p-value	More important to...
Accessibility	0.839	-
Adaptability of building configuration / use over time	0.072*	Private
Architectural value	0.786	-
Capital cost	0.055*	Private
Dry air / environmental health	0.692	-
Durability	0.050*	Private
Economic recovery following an earthquake	0.014**	Private
Fire safety	0.555	-
Heritage value	0.280	-
Life safety during an earthquake	0.325	-
Low impact on natural environment following an earthquake (waste production, reduced rebuild material requirements etc.)	0.794	-
Protection from other hazards (flooding/volcano/climate change induced hazards)	0.367	-
Safety of users day to day	0.149	-
Social recovery following an earthquake	0.582	-
Sustainability / energy efficiency / carbon (both embodied and operational)	0.656	-
Wellbeing of users	0.619	-
Whole of life cost	0.046**	Private

* *Correlation is nearly statistically significant ($p \le 0.10$)*

** *Correlation is statistically significant ($p \le 0.05$)*

Geographical perspective

Statistical analysis (ANOVA followed by Tukey HSD multiple comparison tests) was used to identify any statistically significant differences in the importance of building design requirements between geographical perspectives. Three geographical perspectives were considered: national (n=16), high seismic hazard (n=11), and moderate/low seismic hazard (n=5).

Moderate seismic hazard and low seismic hazard were underrepresented in the pool of interviewees. Therefore, the presented results should only be used to identify areas for further exploration but not to rule out or confirm possible significant relationships.

The results of the statistical analysis showed that interviewees from a high seismic hazard zone ranked 'Low impact on the natural environment following an earthquake' lower than interviewees with either a national perspective (p=0.026) or a moderate/low seismic hazard (p=0.039). This difference in importance is likely attributed to the belief by many of those in high seismic hazard zones that building damage, and therefore building debris are inevitable following a large earthquake.

There was also a nearly significant difference in the perceived importance of 'Wellbeing', with those with a high seismic hazard perspective ranking 'Wellbeing' slightly lower than those with a moderate/low seismic hazard perspective. There was no significant difference in importance rankings between a national perspective and either high seismic hazard or moderate/low seismic hazard for 'Wellbeing.' It is unclear what, if any, link there would be between seismic hazard and priority for building user wellbeing.

Table 16. Summary of statistical analysis for geographical perspectives (national, high seismic hazard, moderate/low seismic hazard)

Building Design Requirements	ANOVA p-value	TukeyHSD multiple comparison	
		Categories	p-value
Accessibility	0.161	-	-
Adaptability of building configuration / use over time	0.911	-	-
Architectural value	0.141	-	-
Capital cost	0.422	-	-
Dry air / environmental health	0.619	-	-
Durability	0.298	-	-
Economic recovery following an earthquake	0.937	-	-
Fire safety	0.201	-	-
Heritage value	0.166	-	-
Life safety during an earthquake	0.622	-	-
Low impact on natural environment following an earthquake (waste production, reduced rebuild material requirements etc.)	0.013**	National – High National – Moderate/low High – Moderate/low	0.026** 0.848 0.039**
Protection from other hazards (flooding/volcano/climate change induced hazards)	0.737	-	-
Safety of users day to day	0.247	-	-
Social recovery following an earthquake	0.853	-	-
Sustainability / energy efficiency / carbon (both embodied and operational)	0.690	-	-
Wellbeing of users	0.074*	National – High National – Moderate/low High – Moderate/low	0.317 0.408 0.068*
Whole of life cost	0.343	-	-

* Correlation is nearly statistically significant (p≤0.10)

** Correlation is statistically significant (p≤0.05)

Ownership perspective

Three ownership perspectives were considered: Owner (i.e., long term investment interest or owner occupier) (n=17), Tenant (n=3), Other (i.e., users or multiple/expert) (n=9).

The same statistical analysis procedure as described in the previous section was used to identify differences in the importance of building design requirements between ownership perspectives. Again, there was uneven representation of the interviewee among the ownership perspectives. Therefore, the presented results should only be used to identify areas for further exploration but not to rule out or confirm possible significant relationships.

The results of the statistical analysis showed that there was almost a significant difference between the importance of 'Accessibility' based on ownership perspective, with building owners ranking it slightly less important than those representing the building user or multiple/expert perspective (p=0.101). Building owners also ranked 'Low impact on the natural environment following an earthquake' lower than tenants (p=0.071).

Table 17. Summary of statistical analysis for ownership perspectives (owner, tenant, other)

Building Design Requirements	**ANOVA p-value**	**TukeyHSD multiple comparison Categories**	**p-value**
Accessibility	0.073*	Owner – Tenant Owner – Other Other - Tenant	0.230 0.101 0.920
Adaptability of building configuration / use over time	0.430	-	-
Architectural value	0.234	-	-
Capital cost	0.142	-	-
Dry air / environmental health	0.134	-	-
Durability	0.825	-	-
Economic recovery following an earthquake	0.590	-	-
Fire safety	0.384	-	-
Heritage value	0.643	-	-
Life safety during an earthquake	0.622	-	-
Low impact on natural environment following an earthquake (waste production, reduced rebuild material requirements etc.)	0.061*	Owner – Tenant Owner – Other Other - Tenant	0.071* 0.282 0.374
Protection from other hazards (flooding/volcano/climate change induced hazards)	0.131	-	-
Safety of users day to day	0.262	-	-
Social recovery following an earthquake	0.247	-	-
Sustainability / energy efficiency / carbon (both embodied and operational)	0.163	-	-
Wellbeing of users	0.706	-	-
Whole of life cost	0.384	-	-

* *Correlation is nearly statistically significant (p≤0.10)*
** *Correlation is statistically significant (p≤0.05)*

3.4.2 Qualitative analysis

A qualitative analysis of interview transcripts was undertaken to explore how the interviewees considered interrelations between the listed building design and their decision making process for ranking the design requirements.

The amount of commentary provided by each interviewee varied, with some interviewees providing detailed analysis of their decision-making process for each design priority and others choosing only to highlight and explain the topics that stood out to them.

Cross Topic Analysis

The transcripts of each interview were analysed to determine how often interviewees verbally related the building design requirements to one another.

For example 'dry air / environmental health' was often connected to 'safety of users day to day' with a statement such as

> *"I think [dry air / environmental health] is fundamentally important to people's health much more than people understand." – Interviewee (private sector, national perspective, expert in building sector)*

Similarly 'durability' was often connected to 'capital cost' and 'whole of life cost', for example

> *"[Durability] is important, and it's balanced by good cost analysis. Is the money spent worth it? [That's why] we do lifecycle costings on some [building] products." – Interviewee (private sector, moderate seismic hazard zone, owner/occupier)*

The results of the cross topic analysis are shown in Figure 14. Some of the strongest cross topic connections include:

- Capital and whole of life cost
- Sustainability and adaptability of building configuration
- Safety of users day to day and dry air / environmental health (likely influenced by current Covid-19 pandemic)
- Safety of user day to day and fire safety

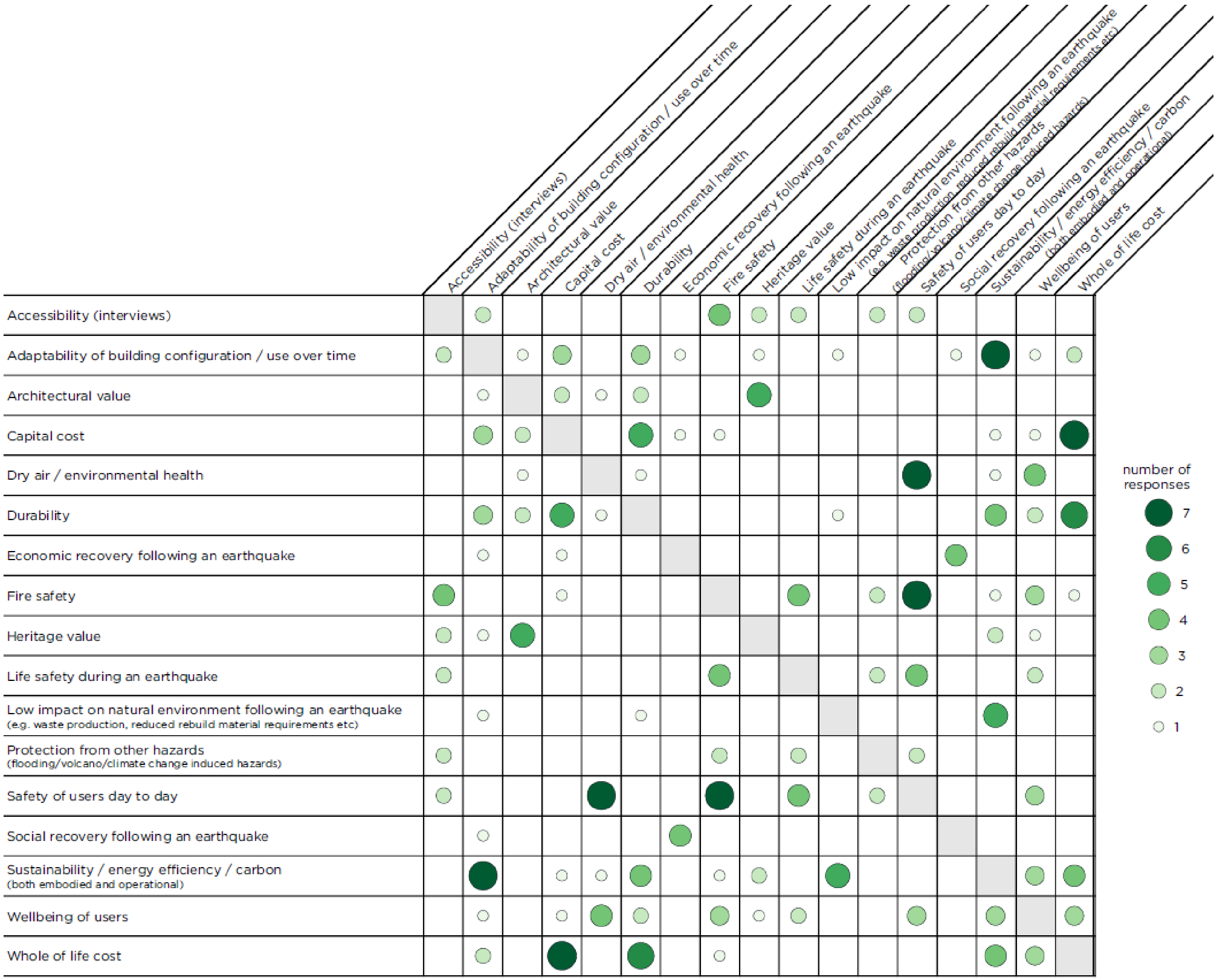

Figure 14. Cross topic analysis of building design requirements

Decision Making Rationale

The transcripts for each interview were analysed to determine how the interviewees justified their rankings. The stated reasons for low (4-5), medium (2.5-3.5) and high (1-2) rankings of building design requirements are shown in Figure 15, Figure 16, and Figure 17, respectively. Low rankings generally related to building requirements with indirect relevance to the interviewee. Medium rankings were given to design requirements that varied in importance across building types or had significant cost implications. High rankings generally related to items that represented a good return on investment or that supported larger drivers/co-benefits such as safety of users, building functionality, building longevity and equity.

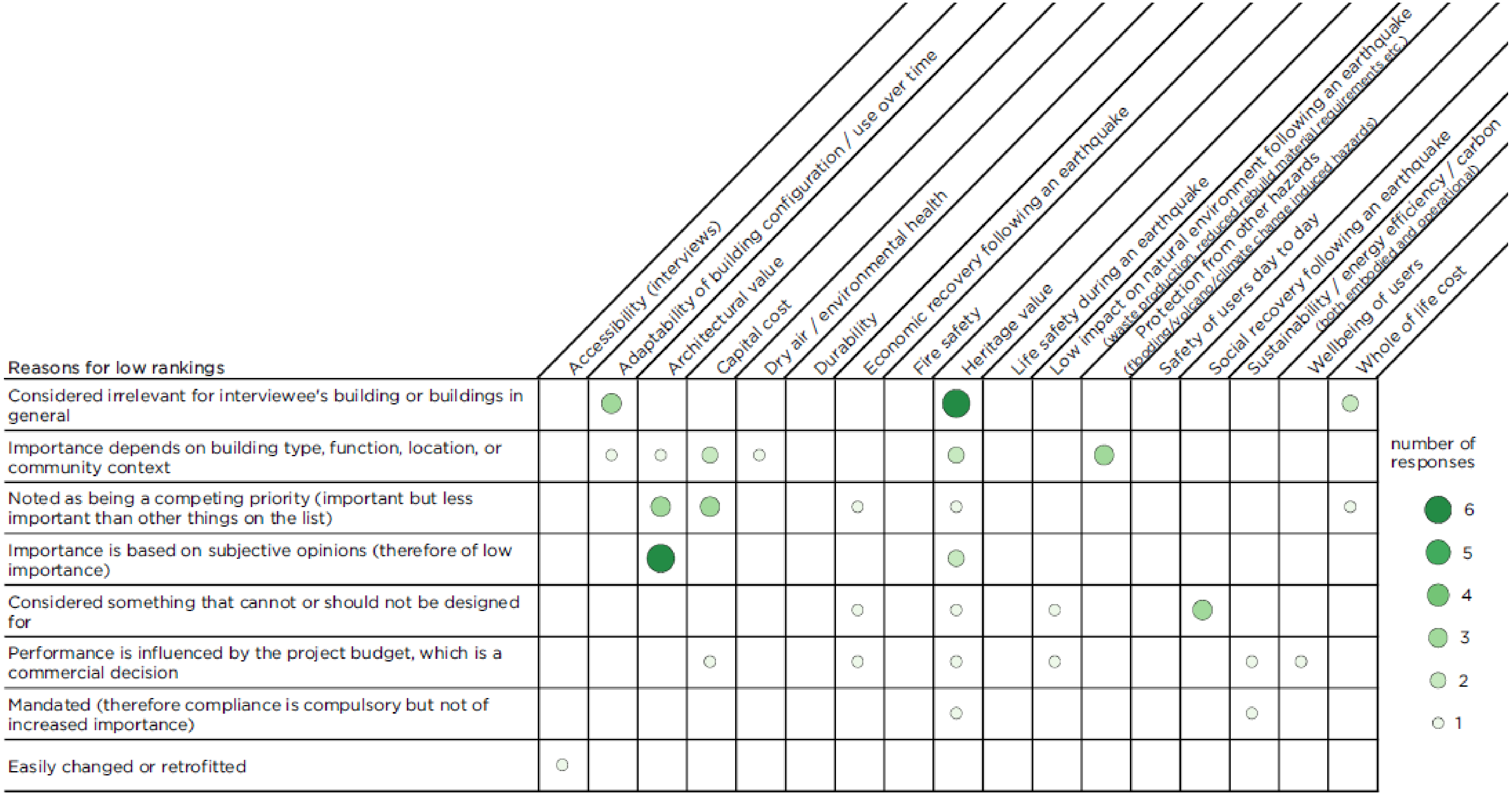

Figure 15. Reasons for low ranking of design requirements

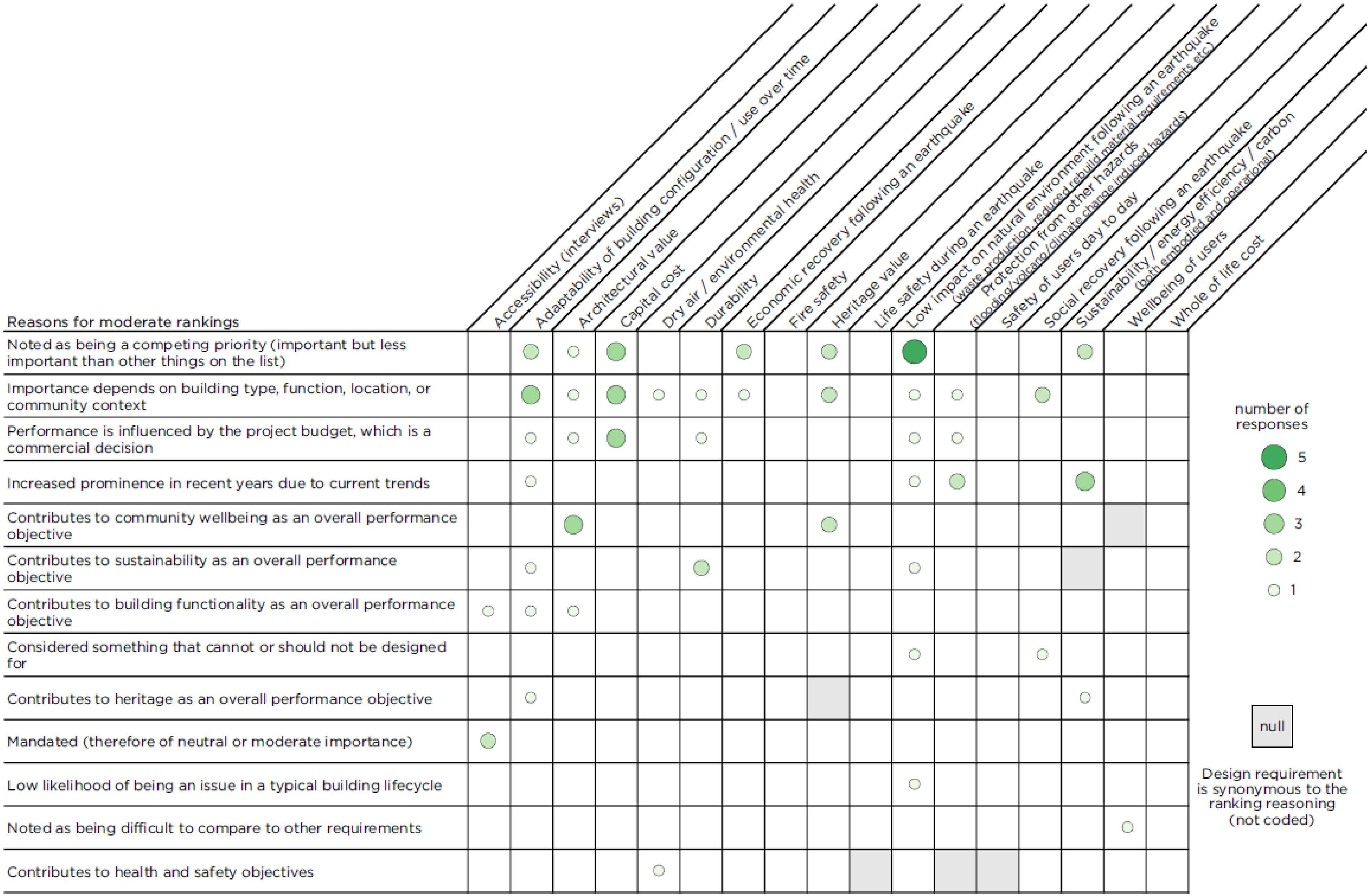

Figure 16. Reasons for moderate ranking of design requirements

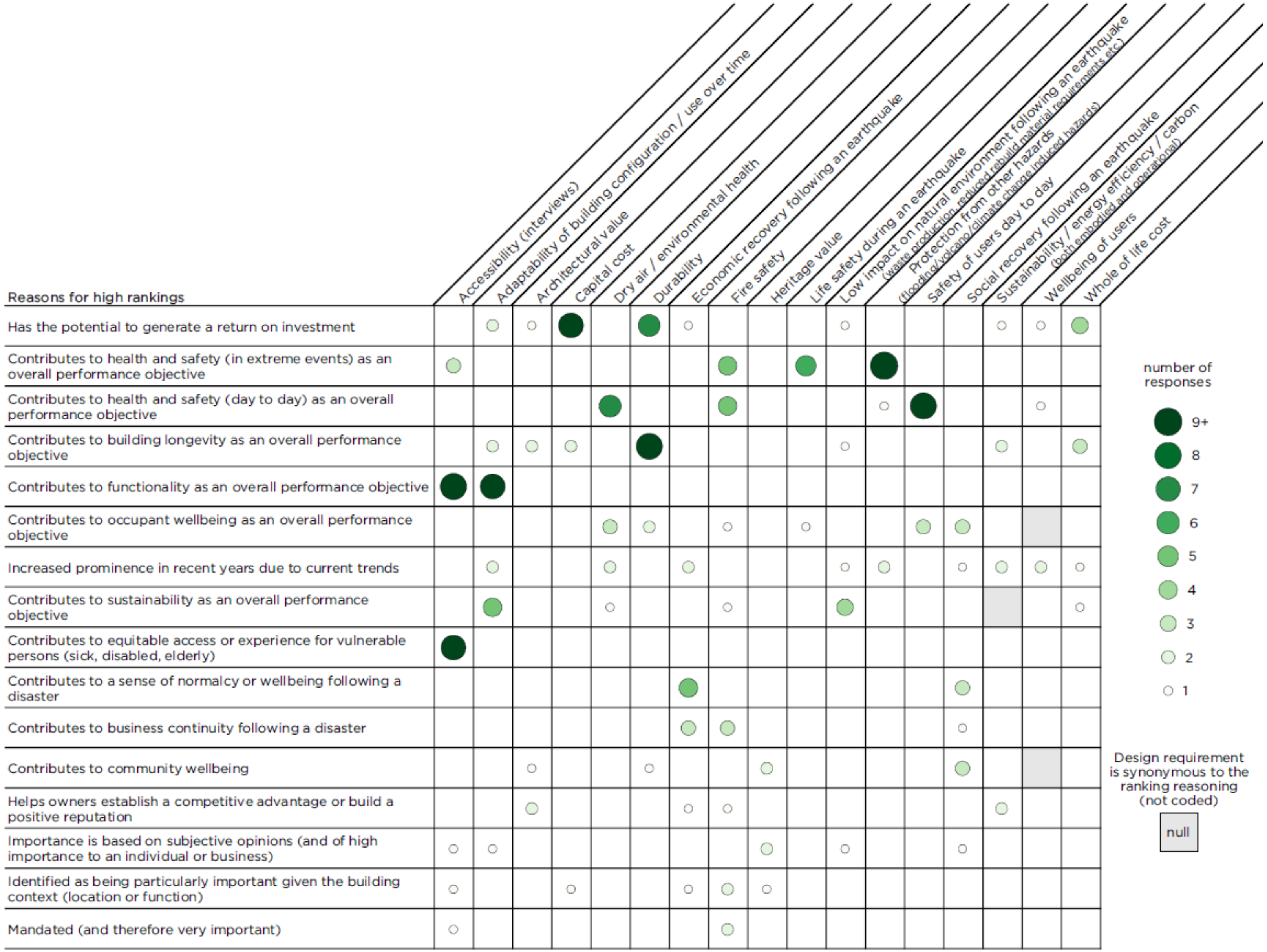

Figure 17. Reasons for high ranking of design requirements

Themes relating to prioritisation of building design requirements

The themes from the discussion around building design requirements are summarised in Table 18.

Table 18 Themes relating to prioritisation of building design requirements

Theme	Description
Safety is the first priority.	Health and safety requirements, both day to day and in extreme events, are the top priority. All buildings are expected to provide baseline safety for occupants. *"Anyone going into a building should have a right to be safe and feel safe. And perhaps know, on some level, that [the building] will withstand an earthquake or that there are procedures in place if there's a fire."* – Interviewee (private sector, high seismic zone, owner occupier)
	Safety in extreme events Life safety in earthquakes was prioritised over day to day life safety by most because of the severe consequences associated with rapid building failure. The maintenance of egress routes for building occupants to evacuate and emergency workers to enter following a fire or earthquake were identified as key building performance priorities. Some interviewees were concerned about multiple or cascading hazards (e.g., fire following an earthquake).
	Safety of users day to day Buildings are used frequently and therefore practical and reasonable steps should be taken to eliminate or mitigate safety hazards for occupants. Air quality was identified as a primary health and safety concern.
Perception of safety is important.	In addition to actually being safe, many interviewees expressed that they wanted to 'feel safe' within their buildings. The feeling of safety could come from a lack of physical building damage, reliable and redundant egress routes within the building and assurance from an engineer of building stability after a moderate or large earthquake.
Personal responsibility contributes of overall safety.	Those who did not rate safety of users day to day as 'Most Important' (1) often invoked personal responsibility (i.e., that most people should have the capacity to assess the risk associated with entering a building and decide whether or not to proceed)

Theme	Description
Building performance is influenced by cost.	**You get what you pay for** Buildings can only be expected to perform as well as they were designed, with cost typically being a primary driver of (non-safety-related) design choices. Buildings that cost more are typically designed to higher specifications (i.e., high-quality durable materials and construction quality), which leads to better overall performance for objectives such as weather tightness and earthquake resilience. Buildings that are cheaply designed and constructed are less likely to perform well.
	Return on investments Initial investment (capital costs) can keep operational, maintenance, and repair costs (whole of life costs) down. A desire for affordable options that keep whole of life costs down was often expressed. Upfront investments into priorities like architectural value, enhanced safety, and resilience can help building owners gain a positive reputation and competitive advantage when seeking tenants.
Buildings should be functional and fit for purpose.	**Functionality** Buildings are meant to be used and occupied. Ensuring that buildings are designed to suit the needs of occupants was a significant priority.
	Accessibility The ability for customers, tenants, or users to access a building and for goods to be delivered is key to overall functionality. Buildings should provide equitable access or experience for vulnerable persons (sick, disabled, elderly).
	Adaptability Some buildings need to be built for purpose (e.g. manufacturing facilities), but other buildings can benefit from establishing adaptable spaces that allow for multiple functions (e.g. offices or community spaces).

Theme	Description
Design priorities that contribute to building longevity are important.	Choosing durable materials and adaptable building configurations during the design phase can contribute to a building's overall longevity. People want buildings that will last a lifetime with minimal repairs. The need for regular maintenance is expected to upkeep building quality, but there is less tolerance for the need for significant repairs due to issues with weather tightness or earthquake damage. Buildings designed to withstand moderate to severe earthquakes with minimal damage will contribute to the social and economic recovery of towns and cities.
	Building longevity and sustainability Design requirements that contribute to building longevity are also linked to sustainability objectives. The demolition of existing buildings to enable the construction of new buildings is a major drain on natural resources and contributes to carbon emissions.
Priorities depend on desired life cycle of buildings.	A less popular opinion was that extending a building's lifespan beyond 50 or 100 years is often overstressed and unnecessary. Buildings are often knocked down because the surrounding built environment has changed and/or the building is no longer fit for purpose. Furthermore, durability is often cited as a reason for not building with low carbon materials (e.g. timber).
Sustainability is an overarching performance objective.	Environmental sustainability is of utmost importance as the environment is the foundation for human life, supporting wellbeing through the provision of natural resources.
	Sustainable building practices are becoming more important Voluntary and mandated green initiatives to combat climate change and carbon emissions have become more common in recent years, which has highlighted the importance of sustainable building practices for building developers, owners, and users. People are now more likely than ever to consider building and material life cycles in terms of carbon (embodied and operational) and desire more energy-efficient options for operations.

Theme	Description
	Co-benefits of building sustainably The use of energy-efficient building systems can reduce operating costs. Sustainability initiatives are linked with overall wellbeing in communities by contributing to the long-term environmental health of local waterways and land. As noted above, sustainable buildings are durable buildings. Buildings that don't require major repairs in their lifetime or premature replacement (either from extreme events or degradation) are lower impact on the natural environment by conserving natural and carbon resources.
Buildings should contribute to the wellbeing of occupants.	The physical and mental wellbeing of building occupants can be affected by building design, performance, and amenities.
	Physical wellbeing Buildings should provide a safe physical environment for occupants, both day to day and in extreme events. Indoor air quality was often cited as a contributor to the day to day wellbeing of building occupants.
	Psychosocial wellbeing Buildings should provide a pleasant environment for occupants. Temperature, natural light and acoustics were cited as design priorities that contribute to mental wellbeing. Access to amenities (e.g., community spaces with food and drink) can also contribute to mental wellbeing.
Individual buildings have the ability to contribute to community wellbeing.	Individual buildings within a community are locations that can provide social connectedness and a sense of belonging for building users and community members. These connections are particularly important to maintain to aid in social recovery following an earthquake. Buildings with cultural significance and/or architectural or heritage appeal can provide a sense of place for those in a community, even if community members don't use the building daily.
Architectural design contributes to performance objectives.	Architectural value was considered subjective and, therefore, less important to some interviewees. However, the importance of smart design was often referenced as a way to contribute to other performance objectives (e.g., functionality, sustainability, wellbeing).

Theme	Description
Earthquake resilience is moderately important relative to other design priorities.	Design priorities related to earthquake resilience (i.e., social recovery following an earthquake, economic recovery following an earthquake and low impact on the natural environment following an earthquake) were often lower priority than design priorities related to day to day building use. It was noted that seismic resilience priorities, beyond provision of life safety, was less important and that people tend to be resourceful and adaptable when faced with adversity.
	Context of earthquake risk It was noted that multiple stressors would influence desired levels of seismic resilience. People from a community like Christchurch, which suffered from a devastating earthquake and a terrorist attack in recent years, are more likely to place higher value on the ability to prevent more significant social and economic losses. Investing in resilience would allow a community to 'bounce back' quicker, helping to maintain morale and wellbeing in an already stressful landscape.
The importance of heritage was a divisive topic.	Heritage value had one of the widest variances in the ranking of the design priorities. Heritage value is dependent on building or place, and personal opinions and experiences contribute to its perceived importance.
	Heritage contributes to community resilience While interviewees agreed that heritage value was building or place dependent, some cited that actively creating future heritage fabric establishes 'touchstones' for community cohesion which contributes to overall community resilience.
Context influences the importance of design priorities.	Building design priorities are not one-size-fits-all. The importance of non-safety-related design priorities varied from based on the building type, function, location, or community context.
	Protection from other hazards The importance of protection from other hazards was often place-based. Most interviewees who ranked this design priority highly were concerned about their buildings withstanding storms and floods. The likelihood of climate change causing more extreme weather-related events was also cited as a concern.
COVID-19 influenced prioritisation of design requirements.	COVID-19 influenced interviewees' rankings of building design requirements. Many interviewees noted that requirements such as 'Dry air / environmental health' and 'Wellbeing of users' have increased in importance in the last few years.

3.4.3 Factors that may influence building design priorities

Upon completing the ranking of building design requirements, interviewees were asked whether priorities would change if they or their community could not access insurance. They were then asked to identify other factors that may change how they prioritise building design requirements.

Approximately half of the interviewees (n=14) did not think a lack of insurance access would change how they ranked the importance of building design requirements. Rationale for this included that they were self-insured (n=2) or did not consider insurance as an influencing factor when assigning the rankings (n=4). One interviewee explained that they viewed insurance as a secondary measure of mitigating earthquake impacts. The primary step should always be resilient design.

> *"I don't really factor insurance in as a means of mitigating these impacts. To me, insurance is the tail end of the recovery. And if that's what we're waiting for, then we've failed on so many other points" - Interviewee (public sector, low seismic hazard zone, community expert)*

This viewpoint was echoed by a representative from the insurance sector who discussed that buildings need to be designed and built with more resilience to prevent reinsurers from retreating from the New Zealand insurance market.

> *"[The extent to which] New Zealand will attract reinsurance support in the future will depend upon what happens between now and in 20 years, with respect to how resilient the new structures being built are. And the extent to which the current stock, which is still going to be around in 20 years, is made resilient. If it appears to [the reinsurance] community that little or no advance has been made to ensuring more resilience, then it may be a very different world in which New Zealand can attract that level of reinsurance support" – Interviewee (private sector, national perspective, expert in insurance sector)*

The other half of the interviewees (n=15) indicated that the loss of access to affordable earthquake insurance would heighten the importance of incorporating seismic resilience into buildings to mitigate the financial impacts of earthquake damage. Seismic resilience can be incorporated into the built environment by designing more seismically robust buildings (n=4) and through improved land use planning (i.e., building on 'good' or improved land) (n=3). The idea of living in a society without earthquake insurance was worrisome to many of the interviewees. Some went so far as to say that the risk of managing a business without insurance would be too great for many people to bear (n=7).

Aside from access to earthquake insurance, interviewees identified other factors that may influence building design priorities (Table 19). These factors included climate change, major socio-economic disruption from world events (e.g., pandemics, wars), changes to government regulations, changing community demographics, technological advances, and personal earthquake experiences.

Table 19. Factors that may influence building design priorities

Reason for shifting building design priorities	Description
Loss of access to affordable earthquake insurance	The loss of access to affordable earthquake insurance would heighten the importance of incorporating seismic resilience into buildings to mitigate the financial impacts of earthquake damage (n=15).
Changes in how communities use buildings	COVID-19 has influenced building design priorities by changing the way we use and interact with some elements of our built environment (n=16). *"I think COVID will have a big impact on the way in which we design building communities going forward… I think there's a big question mark around the future for big office buildings in CBDs. Do people want to congregate in big offices? Or are we going to be much more spread out, based in our communities, and working from home? I think it's increased the importance of wellbeing within the design of buildings. We're all more conscious of the impact of things like indoor environment quality… I think during the lockdowns, we spent so much time inside buildings that [our awareness of] the way buildings affect us, mentally and physically, has only increased." – Interviewee (public sector, national perspective, sustainable construction expert)*
	Remote working and schooling COVID-19 has accelerated the shift to online teaching and working from home (n=11). In many cases, the ability to work and learn remotely is seen as a suitable alternative to meeting in physical spaces (e.g., offices and classrooms), lessening the importance of these building types, at least in the short to medium term. Correspondingly, it has also heightened the importance of homes' resilience, particularly regarding reliable power and internet connection to enable remote working and schooling.
	Shopping habits COVID-19 has changed the way many people shop (n=3). City centres and shopping malls were typically not open for business during COVID-19 and, consequently, online shopping has become more popular. The building environment requirements for operating an online store are very different to a ''main street' store.
	Connecting with others Despite all the online communication tools available, COVID-19 has also shown us that the ability to connect in person cannot be taken for granted (n=2). Buildings that offer amenities to promote wellbeing through connectedness may be prioritised going forward.

Reason for shifting building design priorities	Description
Climate change	Climate change impacts have the potential to shift building design priorities (n=6). Individuals and businesses may have less tolerance for earthquake-related disruptions if they are already trying to manage disruptions from severe weather events due to climate change.
Government regulations	The government has the power to change societal expectations through legislation and mandates for building performance (n=4). Mandated resilience objectives would likely lead to the public having higher expectations for their buildings.
Changing community demographics	The demographics of communities are changing in many of New Zealand's towns and cities. As the socio-economic makeup of a community changes, so may the priorities for building performance (n=4). For example, some suburbs have more tenants from lower socio-economic groups moving in, replacing owner-occupiers. These tenants may have different needs and expectations than the previous community demographic.
Lived earthquake experience	The lived experience of a major earthquake influences people's tolerance for earthquake-related disruptions (n=4). For example, if a building owner's building was severely damaged in an earthquake, they may be more inclined to build or purchase a more seismically resilient building afterwards.
Time since the last earthquake	People tend to have short memories. The further we are from a major earthquake, the less of a priority earthquake resilience becomes to both individual citizens and governing bodies (n=3).
Technological advances	Technological advances have the ability to change the way we use buildings and interact with the built environment (n=2). For example, one interviewee suggested that the development of an app that shows the earthquake rating of buildings would give individuals more agency to assess risk when deciding where they want to live, work, shop, and eat.
Major socio-economic disruption from world events	Major socio-economic disruption (e.g., regime changes, civil unrest, recession) may change building design priorities, particularly if the disruptions result in less capital to invest in new buildings (n=1).

3.4.4 Key points

- Health and safety requirements, both day to day and in extreme events, are the top priority. All buildings are expected to provide baseline safety for occupants.
- Heritage value and architectural value are considered least important. However, ratings for heritage value, cost (capital and whole of life) and dry air/environmental health were the most variable across interviewees.
- Interviewees representing a private perspective ranked the economic-related building design requirements (i.e., capital cost, economic recovery following an earthquake, and whole of life cost) higher than those representing a public perspective.
- The strongest connections between building design requirements included:
    - Capital cost and whole of life cost
    - Sustainability and adaptability of building configuration
    - Safety of users day to day and dry air / environmental health
    - Safety of user day to day and fire safety
- Low rankings were generally related to building requirements with indirect relevance to the interviewee. Medium rankings were given to design requirements that varied in importance across building types or had significant cost implications. High rankings generally related to items that represented a minimum acceptable performance level (e.g., safety of users), a good return on investment or that supported larger drivers/co-benefits such building functionality, building longevity and equity.
- Design priorities that contribute to building longevity are important, as these design aspects also contribute to lower maintenance costs and sustainability objectives.
- Buildings contribute to the physical and mental wellbeing of building occupants through design, performance, and amenities.
- In recent years, sustainable building practices have become more important to building developers, owners, and users. People are now more likely than ever to consider building and material life cycles in terms of carbon (embodied and operational) and desire more energy-efficient options for operations.
- Voluntary and mandated green initiatives to combat climate change and carbon emissions have become more common in recent years, which has highlighted the need for greater synergy between resilience and sustainability.

3.5 Managing seismic risk

Earthquakes are just one of many hazards New Zealanders must consider when allocating finite resources. Throughout the interviews, many discussed how they viewed seismic risk relative to other risks (e.g., climate change, financial risks), how they manage risk, and their willingness to invest in seismic resilience.

While some interviewees explicitly expressed that they consider earthquake resilience to be the most important form of resilience to pursue in New Zealand (n=2), others explained that they believe a more holistic approach should be taken to natural hazard risk management, including heavy rainfall, floods, land slips, extreme wind, storm surges, and sea level rise. (n=3). One interviewee who favoured a holistic view of risk management discussed their belief that investing government resources into climate change mitigation will provide more long-term social and economic benefits, given the high probability of severe climate change impacts. Interviewees from both viewpoints discussed how strategic investment into infrastructure (e.g., roads, telecommunication, power, water, sewerage) should be prioritised to increase overall resilience in New Zealand (n=3).

> *"If we're going to spin the dice forward 20 years…. Then we will almost certainly see more pronounced issues around the capability of infrastructure to deal with sea-level rise and other climatic changes (high tides, storm surges, etc.) which might impact the ability to recover from an earthquake…. So, you've got to think of the system holistically in terms of the hazard risks that will impact in 20 years time." – Interviewee (private sector, national perspective, expert in insurance sector)*

> *"Where's your most important infrastructure? Buildings are not the most important infrastructure, unless it's a hospital, and then slightly lesser down, schools. Major roads and [telecommunication] and your water and sewerage are the most vital things." – Interviewee (public sector, national perspective, building user)*

> *"I think it's incredibly important to understand and balance the financial cost against idealistic safety requirements … There needs to be a bit of a balancing act. We should focus on the most important infrastructures first." – Interviewee (private sector, national perspective, owner occupier)*

At an individual building level, interviewees wanted to maximise the returns on their investments in seismic resilience (n=7). They wished to balance the upfront cost of building to higher seismic standards with whole-of-life costs, including maintenance and repair costs and reduced business disruption after an earthquake. This balancing of capital and whole-of-life costs was particularly important for owners/developers with long-term investment interests (i.e., owners that build and hold property). Several interviewees also expressed a desire for more cost-effective solutions, which may include more guidance on achieving higher performance targets and materials that are seismically resilient and budget-friendly (n=4).

> *"[Building for seismic resilience is] important, but where is the tipping point? What are you engineering to? At some point to you say, 'That's enough.'" – Interviewee (private sector, high seismic hazard zone, owner occupier)*

> *"There's the conversation around post-event functionality. I think that's a noble one that can certainly be considered for new design builds, but we need to ask, 'What is the biggest bang for buck you get from an engineering point of view? What is going to build post-event functionality into a building… that doesn't break the bank?'" – Interviewee (public sector, high seismic hazard zone, community recovery expert)*

3.5.1 Incentives and hindrances to building more seismically resilient buildings

Interviewees identified several factors that might provide an incentive to reduce risks and promote the design and construction of more seismically resilient buildings (Table 20). These incentives include building more sustainably, lowering whole-of-life costs, boosting reputation in the community, and attracting and/or retaining tenants. Conversely, many factors were presented as a deterrent or hindrance to enhanced seismic risk mitigation (Table 21). These hindrances included competing demands on finite resources, the expected poor seismic performance of neighbouring buildings and infrastructure, concern over where the cost of building to higher standards would fall, and a lack of trust in the engineering and construction sector.

Table 20. Incentives for building more seismically resilient buildings

Incentive for more seismically resilient buildings	Description
Sustainability benefits	The design of buildings to be seismically resilient is linked to sustainability objectives (e.g., reducing carbon and mitigating climate change) (n=5). Having to demolish buildings because of earthquake damage is a significant drain on natural resources and contributes to carbon emissions.
	Building Materials Material choice can contribute to both sustainability objectives and seismic resilience (n=5). Timber was suggested as a sustainable material that performs well in earthquakes (n=4).
Lower whole-of-life costs	Reducing building damage in moderate earthquakes can contribute to lower whole-of-life costs because building owners will have reduced business disruption and repair costs (n=1).
Boost reputation in the community	Constructing a seismically resilient building can help boost a company's reputation in its community by demonstrating a willingness to contribute to community resilience (n=3). *"[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 given its position in town, its name and all the rest of it, it's a highly recognized building.... 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." – Interviewee (private sector, moderate seismic hazard zone, owner occupier)*
Attracting and/or retaining tenants	Investment in seismic resilience can help building owners gain a competitive advantage when seeking tenants (n=2). *"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 is 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." – Interviewee (private sector, low seismic hazard zone, owner (long term investment interest))*

Table 21. Hindrances to building more seismically resilient buildings

Hindrance to more seismically resilient building	Description
Competing demands	Building owners, developers and communities have several competing priorities. Issues such as housing affordability and climate change implications for construction practices pose conflicting demands on building owners and users with finite resources (n=6). *"Over the long haul, there's some really big environmental issues. And impacts on biodiversity and climate change are the two biggest. And then, of course, there's a whole range of economic and social issues, which I won't try and 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" – Interviewee (public sector, national perspective, environmental expert)*
Expected performance of neighbouring buildings	The expected performance of neighbouring buildings is a significant concern to some building owners, who expressed reluctance to be the first mover in their neighbourhood (n=4). They were concerned that the damage associated with neighbourhood properties (e.g., the presence of a cordon, reduction in foot traffic, or perception of safety of an area) would prevent them from realising a return from investing in seismic resilience. *"There's not much point being the strongest and 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". – Interviewee (private sector, national perspective, tenant)*
Expected performance of infrastructure	The expected infrastructure damage is also a hindrance to improved building performance (n=4). Buildings may not be operational even if they are undamaged structurally after an earthquake if services are not available to make the building habitable or fully functional (e.g., fire suppression systems, toilets).
Perceived low return on investment	There is a perception that, given the low likelihood of a major earthquake, benefits of building to a higher standard may not match or will exceed the costs (n=4). There is also concern that the market may not understand or be able to adequately value the benefits of seismic resilience. Building users might not value or be willing to pay for the enhanced levels of building performance (n=2). *"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?" – Interviewee (private sector, moderate seismic hazard zone, owner occupier)*

Hindrance to more seismically resilient building	Description
Reliance on insurance	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 (n=5). Some interviewees 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 (n=2).
Other ways of distributing risk	Many larger businesses rely on redundancy in their business operations and business continuity planning to reduce risk from earthquakes (n=3). 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. *"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." – Interviewee (private sector, moderate seismic hazard zone, owner occupier)* Because of COVID, many businesses with office-based employees have undertaken business continuity planning to allow an easier transition for employees to work from home, thereby decreasing the overall importance of some buildings (n=3).
Concern over where cost falls	Because of recent experience with the costs of earthquake strengthening of earthquake-prone buildings across the country, some interviewees were concerned about on whom increased costs of seismic resilience would fall (n=5). Their concern was that the costs of implementing higher standards will inevitably fall on those least able to afford it: largely tenants. *"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 when it gets too hard for them, they won't participate in the conversation." – Interviewee (public sector, high seismic hazard zone, community recovery expert)*
Lack of trust in engineering and construction sector	Several interviewees expressed a lack of trust in engineers and the construction sector (n=6). This sentiment included a lack of confidence in engineers to design a building to a given standard, to manage building sites and ensure what is designed is actually built, and for contractors to build quality products. Observations of damage to relatively modern buildings in recent earthquakes and personal experience of dealing with engineers offering conflicting opinions have resulted in some individuals doubting that buildings could consistently be designed and built to withstand earthquakes (n=2). *"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*

Hindrance to more seismically resilient building	Description
	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."– Interviewee (public sector, national perspective, building 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 the builder is expected … to have the capability or have access to the capability that understands some of the engineering requirements." – Interviewee (private sector, national perspective, expert in building sector)*

3.5.2 The building code and managing seismic risk

Although not explicitly asked, several interviewees shared their opinions on the current building code settings related to seismic resilience, indicating whether they were satisfied with current code settings and identifying areas for improvement.

The seismic settings in the New Zealand building code primarily focus on providing life safety in the event of an earthquake. Buildings located in areas of high seismic hazard (e.g., Wellington) are required to withstand higher levels of earthquake shaking than those located in areas of low seismic hazard (e.g., Auckland). High occupancy buildings and buildings with post-earthquake functions are designed to withstand higher levels of earthquake shaking than buildings with normal occupancy levels. The interviewees generally understood and agreed with these life safety settings in the building code.

Post-earthquake functionality is considered only at very low levels of earthquake shaking for most buildings, except buildings considered to play a significant role in the post-earthquake response (e.g., hospitals and emergency services). Some interviewees indicated that many members of the public would be surprised that the building code does not materially protect the functionality of most buildings after a significant earthquake (n=2). Of those familiar with building code objectives, some believed that the building code should be amended to consider the post-earthquake functionality of more typical building types (e.g., houses and commercial buildings) for higher levels of shaking (n=6). Others were comfortable with it being a commercial decision (n=2).

> *"I think we need to aspire to something greater than [life safety]. Because I think the experience out of Christchurch suggests that society wants and expects more than that. And the reality is that I think the international insurance market will not insure New Zealand if it thinks the risk is too high." – Interviewee (private sector, national perspective, expert in building sector)*

> *"There is often discussion about whether buildings should be to a standard only allowing successful saving of life, or also ensuring the ability to reinstate the building quickly after an event rather than requiring demolition. I think that that decision [related to post-event reinstatement] should be left to the owner of the building, who is better placed than I am, or council is to weigh the higher up-front cost against the potential larger cost later." – Interviewee (public sector, high seismic hazard zone, tenant)*

Several interviewees also discussed how constructing more seismically resilient buildings can contribute to building longevity, which is linked to sustainability objectives (n=7). Having to demolish buildings because of earthquake damage is a significant drain on natural resources and contributes to carbon emissions.

> *"So that carbon story, climate change and so on, is definitely coming into the linguistics of building requirements more and more at an accelerating rate. And it could relate back to earthquake resilience. So, if you're contemplating a building lifespan of 100 years or 150 years, what does that look like from a seismic point of view?" – Interviewee (private sector, high seismic hazard zone, owner occupier)*

Some interviewees discussed pieces of legislation (other than the Building Act 2004) that influence building functionality (e.g., Acts related to infrastructure) and performance objectives (e.g., Health and Safety at Work Act 2015[16]) (n=3). These interviewees desired a better understanding of how different pieces of legislation can influence building seismic performance outcomes and objectives.

The overlap between seismic resilience and land use planning was also discussed. The placement of new developments on poor-quality land was a concern for some interviewees, as these areas are likely to suffer greater land damage, which can affect building performance (n=4). It was suggested that there should be a more concentrated effort, either through legislation or education, to avoid development on poor quality land to improve seismic resilience. Additionally, thoughtful urban design could enhance community resilience by boosting connections and wellbeing in a community before an earthquake (n=4). These connections could be leveraged after an event to improve the overall response and recovery efforts.

Drawbacks to codifying increased seismic performance were also discussed. There was concern that increased standards would add additional financial burden to an already expensive construction process, potentially to the point that building in places like Wellington would be prohibitively expensive (n=5). Interviewees were also worried that increased seismic regulation could negatively impact perceptions of safety and resilience in existing buildings, which is already a growing problem in New Zealand cities (n=2).

> *"If you push for a more resilient code of practice to deliver better buildings, then you've got legacy building stock that doesn't cut the mustard. And all of a sudden, the perception is that they're no good. We've been through two cycles of that recently…. And so, how do you manage that shifting requirement? And how do you manage the expectations backwards? – Interviewee (public sector, high seismic hazard zone, owner occupier)*

Some interviewees questioned the wisdom of focusing solely on the seismic performance of new buildings given the much larger stock of existing buildings, suggesting that more resources should be invested into the existing building stock (n=3).

> *"The big thing for me is, have we dealt with the existing stock of buildings? Are they robust enough? Because I think it's all very good, looking to the future. But a lot of buildings have been around for well over 50 years. Are they actually protecting our people or our industries, etc.? And, to me, that is probably one of the key things we should be asking." – Interviewee (private sector, high seismic hazard zone, owner occupier)*

These reflections illustrate the complex legislative landscape in which building regulations sit and the need for a coordinated approach to improving the resilience of the built environment. Overall, our findings indicate expectations for life safety that broadly reflect existing Code, but there is also an explicit emphasis on the 'vulnerability' of groups in the community (e.g. aged care residential settings) and essential common facilities (e.g. food distribution centres), among others. The expectations expressed by interviewees on tolerance thresholds for returning buildings to function and securing social and economic recovery, as well as a desire to contribute to environmental sustainability objectives, all

[16] Brown, C., Nuth, M., Brunsdon, D., Hopkins, W.J., Hudson-Doyle, E., Ball, R. (2021). Earthquake prone public buildings: balancing life safety risks and community costs. NZSEE Conference. 14-16 April 2021, Christchurch, New Zealand.

point to a need to consider how the onset and severity of earthquake damage to buildings can be managed and reduced.

Careful consideration is needed to plan for any transition between current code settings and future changes to minimise impacts and maximise benefits for building owners and communities.

3.5.3 Key points

- Some interviewees believe a more holistic approach should be taken to natural hazard risk management, particularly regarding climate change impacts.
- There is a desire from building owners/developers to maximise the returns on investments in seismic resilience.
- Incentives for building more seismically resilient buildings include building more sustainably, lowering whole-of-life costs, boosting reputation in the community, and attracting and/or retaining tenants.
- Hindrances to building more seismically resilient buildings include competing demands on finite resources, the expected poor seismic performance of neighbouring buildings and infrastructure, concern over where the cost of building to higher standards will fall, and a lack of trust in the engineering and construction sector.
- There were discrepancies among interviewees about whether higher seismic performance objectives such as post-earthquake functionality should be mandated or kept as a commercial decision.
- Better land use planning regulation could increase towns and cities' seismic resilience.
- There was concern that increasing seismic regulation could negatively impact perceptions of safety and resilience in existing buildings.

4. Summary

This data report provides a comprehensive summary of the interviews undertaken as part of the Resilient Buildings Project: Societal Expectations for Seismic Performance of Buildings.

The data demonstrates the breadth of perspectives across interviewees and the influence of place and time on risk priorities and preferences. The data also reveals some strong and consistent themes and priorities that have significant implications for the design and regulation of new buildings.

Analysis and synthesis of this data, alongside data from a series of focus groups, is provided in the companion report: *Brown et al., 2022. Societal expectation for seismic performance of Buildings. The Resilient Buildings Project Research Paper.*

This report highlights a number of key messages from the interviews including:

- New buildings are expected to withstand a major earthquake without creating a significant threat to the life safety of building occupants or passers-by.
- In addition to actually being safe, many interviewees expressed that they wanted to "feel safe" within their buildings following an earthquake.
- There are growing expectations that our future buildings can effectively support social and economic recovery following a major earthquake.
- The ability to keep people in their homes after an earthquake is one of the most vital aspects of recovery.
- Environmental considerations such as sustainability, carbon emissions, and waste are emerging priorities for many.
- Risk tolerance is influenced by place and time. Factors that influence risk tolerance include
    - seismic hazard zone,
    - public versus private interests,
    - the vulnerability of the building occupants, and
    - the primary use of the building.
- Seismic resilience is one of many building design requirements. The following themes are prominent:
    - Health and safety requirements, both day to day and in extreme events, are the top priority.
    - Buildings contribute to the physical and mental wellbeing of building occupants through design, performance, and amenities.
    - Design priorities that contribute to building longevity are important, as these design aspects also contribute to lower maintenance costs and sustainability objectives.
- Incentives for building more seismically resilient buildings include building more sustainably, lowering whole-of-life costs, boosting reputation in the community, and attracting and/or retaining tenants.
- Hindrances to building more seismically resilient buildings include competing demands on finite resources, the expected poor seismic performance of neighbouring buildings and infrastructure, concern over where the cost of building to higher standards will fall, and a lack of trust in the engineering and construction sector.
- Careful consideration is needed to plan for the transition between current code settings and future changes to minimise impacts and maximise benefits for building owners and communities.

Appendix A: Interview questions

Role

1. Could you start by describing your current role, your background and (if applicable) the community/interests you represent.

Earthquake experience

2. Have you ever directly or indirectly experienced an earthquake? If so, could you please briefly describe your experiences.

Expectations during a major earthquake event

Imagine, 20 years from now, that your community has been hit by a rare and significant earthquake. The prolonged and severe shaking is frightening to most people. Physical damage causes considerable and prolonged disruption to normal life.

3. Thinking about a major earthquake, of this kind, what sort of impacts come to mind for you?

4. Following a major earthquake, of this kind, what are the main things that you believe are important from the built environment? *(prompts below, if needed)*
    a. Building performance, function, disruption, repair, damage?
    b. Performance of other aspects of the built environment that buildings interact with? (critical infrastructure etc)
    c. What is the most important thing society needs from the built environment?

5. Some earthquake impacts on the built environment can cause significant secondary impacts. What kind of secondary impacts, from failures in the built environment, do you think would be unacceptable? Think about impacts on individuals, their capacity to connect, their cultural and financial wellbeing , and the effects of impacts on the natural environment. What type of impacts would be unacceptable to you? *(use following prompts if necessary)*
    a. Human (e.g. life safety, availability of critical infrastructure services)
    b. Social/cultural (e.g. social connectivity, heritage, cultural impacts)
    c. Economic (e.g. cost, business disruption impacts)
    Natural (e.g. sustainability, carbon emissions, waste)

6. What things do you think a community could live without, after this kind of earthquake event? And for how long?
    a. For one day
    b. For one week
    c. For one month
    d. For three months
    e. For six months

7. What sort of disruption might cause irreversible/irrecoverable damage to community wellbeing (in a holistic sense)?

Expectations during a moderate earthquake event

8. We've talked about a major earthquake but what about smaller earthquakes? For smaller earthquakes, that occur more regularly, what do communities need from the built environment? Are priorities the same? What additional expectations and needs do communities have?

9. A building's design life is typically 50 years, how often in that design life do you think it is acceptable (if never, is this level of damage ever acceptable?) *(imagine a typical rather than special use building)*
    a. A minor level of damage during an earthquake (repairs needed but minimal disruption to services)
    b. A moderate level of damage during an earthquake (repairs needed with minor disruption to services – in order of weeks)
    c. A significant level of damage during an earthquake (repairs needed with significant disruption to services – in order of months)
    d. A major level of damage during an earthquake (unoccupiable, possibly requiring replacement)

Relative importance of seismic resilience

10. Seismic resilience is just one thing that our buildings provide for us, there are a lot of other things that we need to consider when designing buildings (e.g. indoor environment, fire safety, architectural values).

    a. Compared to day to day priorities, how important do you think seismic resilience is to the community? Please explain.

    b. From the following list, how would you rate the importance of seismic resilience? Please explain.

Building design requirements	**Importance** ***(1=most important to 5=least important)***				
Accessibility	1	2	3	4	5
Adaptability of building configuration /use over time	1	2	3	4	5
Architectural value	1	2	3	4	5
Capital cost	1	2	3	4	5
Dry air / environmental health	1	2	3	4	5
Durability	1	2	3	4	5
Economic recovery following an earthquake	1	2	3	4	5
Fire safety	1	2	3	4	5
Heritage value	1	2	3	4	5
Life safety during an earthquake	1	2	3	4	5
Low impact on natural environment following an earthquake (e.g. waste production, reduced rebuild material requirements etc)	1	2	3	4	5
Protection from other hazards (flooding/volcano/climate change induced hazards)	1	2	3	4	5
Safety of users day to day	1	2	3	4	5

Social recovery following an earthquake	1	2	3	4	5
Sustainability / energy efficiency / carbon (both embodied and operational)	1	2	3	4	5
Wellbeing of users	1	2	3	4	5
Whole of life cost	1	2	3	4	5
Other	1	2	3	4	5
Other	1	2	3	4	5

11. Would this priority change if you/your community could not access insurance? / How do you think insurance impacts the priority given to seismic resilience? Please explain.

12. Is there anything else that might change this priority?

13. Finally, reflecting back on your answers to the previous questions, do you have any other comments about building resilience to earthquakes?