
SEISMIC REPAIR AND RETROFIT PRIORITISATION FRAMEWORK

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The 2010-2011 Canterbury earthquake sequence caused significant damage to the Canterbury District Health Board (CDHB) building stock. The extent of damage, post-earthquake changes to the seismic code, new legislation around earthquake-prone buildings and ongoing changes to clinical service requirements created a challenging decision-making environment for capital works repair and retrofit. In this paper we present a framework designed to assess the seismic resilience of buildings from a holistic perspective and to determine appropriate levels of seismic retrofit. The framework design ensures that decisions are driven by building criticality in the context of a healthcare system. It helps users to balance life safety risk and the demands of delivering critical clinical services day to day: resulting in safe facilities that provide effective health services under a range of future conditions. Pilot application of the framework enabled the reprioritisation of significant capital toward buildings that provide the most life safety and health service resilience benefits in the long term. The process and resulting framework from this project is applicable to a wider range of building owners navigating seismic retrofit

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decision-making and the emerging movement toward functional recovery based building regulation.

INTRODUCTION

Canterbury District Health Board (CDHB) provides primary, secondary, and tertiary public healthcare to over 550,000 residents of the Canterbury region, as well as specialist and emergency healthcare services that support the whole of the South Island of New Zealand. To facilitate delivery of their services, CDHB has approximately 130 buildings. The 2010-2011 Canterbury earthquake sequence caused significant damage to CDHB's building stock. The high peak ground acceleration of 0.547g at the Christchurch Hospital site, combined with the site's susceptibility to liquefaction, caused structural and non-structural damage to clinical and non-clinical buildings as well as internal and external infrastructure supporting building function. Liquefaction caused flooding in several buildings, cutting off tunnels connecting clinical and non-clinical facilities. Retaining walls separating the Avon river from the hospital failed and lateral spreading caused severe damage to sewage lines. Although there were no catastrophic structural failures, severe structural damage forced temporary closures in parts of Canterbury's largest hospital precinct which houses the only emergency department and intensive care unit in the region (McIntosh et al, 2012).

Immediately after the earthquakes CDHB undertook a programme of emergency works to re-open essential facilities and remove any immediate risks. Beyond these initial repairs, CDHB had to manage the remaining building repair and seismic retrofit programme within significantly constrained financial resources. Repair and retrofit costs were exacerbated by several post-earthquake changes to New Zealand's Building Act and seismic loadings code. First, in 2011, the Z factor, was increased from 0.22 to 0.3 in Canterbury. The Z-factor is used in the calculation of the expected earthquake load on a building. The Z-factor varies based on the seismic risk in a region. This effectively reduced the seismic rating of buildings in the region, increasing the degree and cost of post-earthquake repair and strengthening work (Marquis et al, 2017). Second, in 2016, the Building (Earthquake-prone Buildings) Amendment Act was enacted, which set in place time frames around remediation of earthquake-prone buildings. Earthquake-prone buildings are those buildings where the ultimate capacity of all or part of the building is likely to be exceeded in a moderate earthquake; and the collapse of the building or part would be likely to cause death or injury or damage to other property (at any level of earthquake shaking). A moderate earthquake is defined as an earthquake that is the same duration but one third the strength of an earthquake that would be used to design a new building (Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005, as amended by the Amendment Regulation 2017). In addition to managing these structural performance requirements, CDHB has an ongoing requirement to comply with a number of healthcare service regulations and meet societal expectations for service provision.

These challenges created a need for a decision-making process that would enable CDHB to prioritise buildings to repair and guide the extent of retrofit needed. This process had to balance life safety risks from earthquakes with other pressing healthcare service delivery needs now and into the future.

Current publicised approaches to seismic performance decision making do not provide a sufficiently nuanced assessment of buildings to ensure that investment or disinvestment decisions are effectively balancing life safety and service provision. Without a sound approach to decision-making, significant investment in seismic building upgrades could be made with limited payback or limited understanding of the value of the investment (Hare, 2019). There is little literature that currently addresses this challenge, and there are many large public and private sector organisations with broad property portfolios in seismically active zones that are facing these decisions. Both the development process and the resulting CDHB decision framework will be of interest to the growing movement toward functional recovery-based building codes (FEMA-NIST, 2021; Porter 2021; Tanner et al, 2020) as well as practitioners facing similar capital works prioritisation projects to improve seismic safety.

This paper sets out the decision-making framework that was developed to assist CDHB both meet legislative requirements and allocate limited financial resources to provide the greatest resilience and operational benefit to health services while also effectively managing life safety.

BACKGROUND

SEISMIC DESIGN – LIFE SAFETY

In New Zealand, buildings are typically designed for life safety (Ultimate Limit State, ULS) and checked for functional performance (Serviceability Limit States, SLS1 and SLS2). The seismic strength required for a new building is determined based on its Importance Level (IL) rating and the design life of the building. Under AS/NZS1170:2002, importance levels are defined based on a combination of building function and occupancy. Importance Level 4 (IL4) buildings are those that are required post-disaster (such as emergency surgical facilities, fire, police, and utilities). IL3 buildings are those that house large numbers of people (such as non-emergency surgical facilities, theatres, outpatients facilities etc). Most buildings are IL2.

At ULS a new building is expected to allow for safe evacuation but may no longer be habitable. Collapse occurs at a higher threshold. ULS for IL2 buildings is based on a 10% probability of exceedance during the nominal 50 year life of the building (this is equivalent to a 1 in 500-year return event). For IL3 and IL4 the design probability of exceedance is 5% and 2% respectively for the same 50 year life.

Today, percent of New Building Standard (%NBS) is a commonly used metric to represent the seismic strength of an existing building: that is, the expected capacity of the building relative to the seismic demand the Loadings Standard applies to an equivalent new building on the same site. While %NBS may appear at face value a straightforward concept, the complexities of seismic events and the nuances of structural design mean that the link between %NBS, building performance and life safety risk is not always linear. Earthquakes have a range of different ground-shaking effects and %NBS will not predict how the building will perform in a particular earthquake (Hare, 2019). Percent NBS does not predict seismic performance from one earthquake to the next (Hare, 2019).

Another factor that contributes to building life safety risk that is not integrated in a sufficiently nuanced way into current assessments of seismic safety (i.e. %NBS) is occupancy rates. The Importance Level classifications are based on the function and occupancy level of a building, but they focus on peak occupancy. The average occupancy of a building, including how many people use the building and the frequency and duration they occupy it, is not considered. However, average occupancy is an important measure of the exposure of people to seismic risk and allows for a more graduated measure and assessment of life safety risk. For example, buildings more frequently occupied by a greater number of people pose a higher life safety risk. Having a more nuanced measure of exposure is particularly important where building owners are having to distribute constrained resources across a portfolio of buildings and maximise life safety and other benefits.

Table 1 describes how life safety risk increases, as %NBS decreases (MBIE, 2017). The ranges in the table indicate the uncertainties and complexities described above – including the variability in earthquakes, complexities in the building code, different importance levels of buildings and the range of occupancy types.

Table 1. Estimated life safety risk of buildings based on %NBS (MBIE, 2017)

Percentage of New Building Standard (%NBS)	Alpha rating	Approx. risk relative to a new building	Life-safety risk description
>100	A+	Less than or comparable to	Low risk
80-100	A	1-2 times greater	Low risk
67-79	B	2-5 times greater	Low to Medium risk
34-66	C	5-10 times greater	Medium risk
20-33	D	10-25 times greater	High risk
<20	E	25 times greater	Very high risk

Accordingly, a %NBS rating does not represent an absolute assessment of risk or safety and a rating of less than 34%NBS (the threshold for an earthquake-prone building in the Building Act) does not mean that a building poses an imminent life safety risk nor is that building expected to collapse in moderate levels of earthquake shaking. The aim of the %NBS metric is to provide a relative assessment of structural seismic risk. Qualified engineering advice is important to provide a more nuanced assessment of seismic risk, potential collapse mechanisms (based on structural system) and other factors such as structural form, building ductility and known conservatisms in the building code.

SEISMIC DESIGN - FUNCTIONAL PERFORMANCE

As well as Ultimate Limit State (ULS), the Loadings Standard NZS1170.0 sets Serviceability Limit States (SLS) which define levels at which the building must remain operational. The SLS levels are significantly lower than ULS. All structural and non-structural components must be undamaged in a 1 in 25 year return period earthquake event (SLS1, for IL2, 3 and 4 buildings). IL4 buildings have an additional requirement that the structure maintains operational continuity during a 1 in 500 year event (SLS2, for 50-year design life building).

There is a movement internationally to create a step-change in seismic performance: moving beyond codes based on life safety to a focus on improved functional recovery (FEMA-NIST, 2021; Porter, 2021; Tanner, et al., 2020). Many authors are also calling for elucidating societal expectations of performance into the development of building codes to better reflect societal risk tolerance (MBIE, 2020; Tanner, et al., 2020).

As CDHB considered their repair and retrofit programme it became clear that existing measures, like %NBS, were not suitable to prioritise building upgrades nor to inform the degree of seismic retrofit that was optimal. %NBS did not provide a sufficiently nuanced or robust determination of the life safety risk or resilience of buildings to effectively prioritise building seismic retrofit works. Moreover, the metric and the SLS levels set in the Loadings Standard narrows users' perspectives to just safety rather than functionality, usability and considerations of the building (and functions within that building) in a wider system. CDHB needed a decision framework that ensured prioritisation considered the resilience of the health system, not just the life safety or functioning of an individual building.

BUILDING PRIORITISATION AND PERFORMANCE RATING SYSTEMS

While seismic strengthening prioritisation systems exist, they often focus purely on structural performance (e.g., Sevieri et al., 2020; Grant et al. 2007). Some prioritisation frameworks take a multi-capital approach to prioritisation and evaluate benefits of seismic strengthening such as economic and socio-cultural benefits (e.g., Aigwi, 2019). Neither approach addresses how to prioritise a building as part of a networked building system, in particular a system that supports a complex and interconnected service such as a health care service. The authors were unable to identify any comprehensive literature on seismic strengthening prioritisation frameworks that focus on the resilience and functionality of a networked building system.

Seismic performance rating systems perform a similar function as a prioritisation system, in that they define criteria that makes a building, or network of buildings, more resilient. This provides some parallels to the desired outcomes of the prioritisation framework and criteria to assess the gap between current building resilience and desired resilience.

Table 2 summarises four health and non-health related building performance rating systems. These frameworks, to varying degrees, propose metrics or criteria to assess a building's performance beyond seismic strength.

Table 2. Health and non-health-related building performance rating systems.

System	Assessment	Key Criteria	Reference
United States Resiliency Council (USRC)	Building system	- Safety (risk to life, risk of injury) - Repair costs - Time to regain basic function	(USRC, 2021)
Resilience-based Earthquake Design Initiative (REDi)	Building System	- Organisation resilience - Building resilience - Loss assessment - Ambient resilience metrics	(Almufti et al., 2013)

World Health Organisation and Pan American Health Organisations' Health Safety Index (HSI)	Health System	- Geographic location - Structural - Non-structural - Emergency and Disaster Management	(WHO, 2015)
Multi-disciplinary Center for Earthquake Engineering Research (MCEER)	Health System	- Structural - Non-structural - Lifelines - Personnel	(Yavari, et al, 2010)

Both USRC and REDi are based on quantitative analysis/modelling of building performance, applicable to any building use-type. USRC addresses damage at the building level only, whereas REDi includes an assessment of the resilience of a building owner/occupier and any anticipated impacts from neighbouring structures. HSI and MCEER are health-specific performance rating systems that move beyond just structural safety assessments and consider infrastructure services, emergency planning, staff, and supplies.

These systems give good examples of the typical criteria considered in building performance such as lifelines condition, personnel, downtime assessment, utility disruption, critical building contents, structural resilience, and non-structural resilience. However, some authors note limitations to these performance rating systems (Boston and Mitrani-Reiser, 2016). The rating systems are typically conservative. Impact ratings (particularly for the quantitative methods) are driven by the maximum damage state, and the systems have limited capacity to capture and account for emergent human behavior that could mitigate the effect of the disruption. This can lead to an over-estimation of damage and loss of operability (for example, if the damage only affects part of a building) (Boston and Mitrani-Reiser, 2016).

METHOD

To inform the development of the CDHB prioritisation framework, interviews were carried out with 1) CDHB representatives, 2) engineers, and 3) experts involved in capital works prioritisation projects. These interviews aimed to:

1. Clarify CDHB's requirements for the revised building investment prioritisation framework (6 representatives from CDHB)
2. Identify performance objectives against which an individual or portfolio of buildings can be assessed (representatives from CDHB and 3 engineers)

3. Identify and assess different techniques for prioritisation (3 experts involved in capital works prioritisation projects)

Using this baseline data, and literature review results, a decision support framework was developed. The framework was tested and refined through two end-user workshops.

Workshop One tested the overall framework concept with the CDHB Executive Team ensuring the prioritisation criteria aligned with the CDHB's objectives, and that the resultant levels of risk were acceptable. Workshop Two focused on testing the usability and robustness of the updated framework, and to sense check results with a range of hospital staff representing facilities management, clinical/operations, and site redevelopment unit.

INTERVIEW FINDINGS

CDHB Interview Findings

CDHB staff who were interviewed highlighted an opportunity for the framework to clearly and transparently articulate the trade-offs that CDHB was having to make in its seismic remediation programme. Interviewees hoped the framework would provide the structure and language to better demonstrate the risk profile being carried, not just related to seismic risk, but risk to service delivery and staff comfort also. In particular, interviewees suggested a framework that looked beyond the blunt engineering seismic rating tool of %NBS to broader resilience and functional considerations, such as residual building life and usefulness, and opportunities during a retrofit to contribute to the 'long-life, loose fit' goal for CDHB building stock. From a hospital context 'long-life, loose fit' means a building portfolio that not only has longevity, but also has the ability to be adapted as health service delivery needs change in the future.

Interviewees were asked to identify potential criteria they would use to prioritise building repairs/retrofits, considering both emergency requirements and business-as-usual. Key themes that emerged as priorities are summarised in Table 3. The top priority for interviewees was building safety and compliance. However, there was also a strong message that this risk should be assessed relative to the essential services that CDHB provide, and the framework should aim to achieve a 'balance of harm' between life safety risks from low probability earthquakes other pressing, day-to-day healthcare service delivery needs now and into the future.

Table 3. Criteria for prioritisation of seismic retrofit

Safety	Post-disaster functionality	Long term focus	Impacts of seismic retrofit works
Building and infrastructure integrity	Ability to relocate patients from damaged buildings	Alignment with Strategic and Master Plan	Disruption to services
Legislative compliance (acknowledging legislation is dynamic)	Infrastructure needs	Flexibility of building for changing clinical needs (long life loose fit)	Impacts of technology upgrades
Staff perception of safety	Equipment needs to treat patients safely	Operational efficiency (both building and clinical services)	Relocation costs
Patient safety/acuity of service	Role as an emergency service provider for the whole of South Island	Co-location of clinical services	Infection control
Risk to neighbouring buildings/infrastructure		Accessibility	
Balance of harm (seismic and clinical safety)		Management of non-seismic risks (natural and clinical)	

Engineer Interview Findings

A unanimous opinion from all engineers interviewed (as noted above) was that %NBS is a crude way of estimating life safety and building performance. It may not align with the general performance or the consequences of failure for the operation of the facility (either at building level or health system level), and in some cases can be conservative in the assessment of some building types. Engineers noted that performance needs to be assessed on a case by case basis based on the functional requirements of the building. However, there are certain considerations that engineers can make to assess collapse potential or performance relative to calculated %NBS. **Collapse potential** can be determined through understanding the structural system (e.g. unreinforced masonry vs reinforced concrete). Masonry buildings pose the highest life safety risk to those outside the building, whereas concrete structures will cause higher casualties because they collapse inward and tend to be bigger and have higher occupancy rates. Beyond collapse potential, a qualitative assessment could be carried out based on the level of confidence of the %NBS value. This assessment could include factors such as **building**

ductility, **known conservatisms in the building code** (e.g. shear capacity of concrete) and **structural form** (shape, height etc). Currently, there are no established tools to measure these, so the assessment would rely on judgement from experienced engineers. This judgement should be based on an assessment of the current state of the building and not on its original design assumptions.

All engineers agreed that, with an experienced engineer, a relative assessment of building quality (considering not just %NBS) could be done relatively quickly. Modelling against different earthquake events is possible but is much more time consuming and expensive. The assessments become more difficult with complex buildings and those that have been extended/added to over time.

Engineers also discussed how as part of the consideration of life safety, a risk lens may be necessary to weigh the relative safety risks to staff and patients. Current 'Importance Levels' defined in AS/NZS1170 Structural Design Actions are based on peak occupancy (and functionality) but generally do not consider the frequency of occupancy. Staff inevitably will have greater exposure (compared to patients) to risk from unsafe buildings, but this has to be weighed against the risk to patients of non-delivery of services.

The performance of non-structural elements can be almost as critical as structural performance when considering post-event functionality. Even if the structure performs well, services can be disrupted by damage to wall and ceiling linings, building mechanical equipment (e.g. HVAC) and potentially damaged or inaccessible critical medical equipment and stock. Damage to critical medical equipment can be highly disruptive, especially if it is difficult to replace. Service disruption potential is not typically included in a %NBS assessment. Protection of hazardous material may also be critical. Decisions around repairs may be about balancing the cost spent on structural vs non-structural repairs/upgrades. For example, it may be more beneficial for buildings with a temporary life (e.g., 10 years) to focus on having quality non-structural strengthening to avoid services being disrupted in small to moderate earthquakes.

Expert Interview Findings

Three experts were interviewed based on their role in developing and using similar capital works prioritisation processes in other contexts. Across the interviews, eight key principles emerged for the successful design and application of a prioritisation framework:

- Recognise and articulate the decision context - the urgency of decisions, decision constraints and the presence of divergent views.

- Create and use a clear and transparent framework but acknowledge the need for adaptability (e.g. in the face of resource constraints or external influences).
- Consider building retrofit as just one part of the risk management process (in conjunction with emergency and building continuity plans and procedures and emergency training).
- Accept that 'do nothing' is an option, even if money has been spent on assessments.
- Bring key stakeholders, including building users, into the decision process.
- Communicate and be open about the process and create a sense of togetherness.
- Include individuals with diverse views into the prioritisation process and help them to understand and manage the trade-offs being made.
- With end-users, talk about 'confidence' in building strength, rather than 'safety'.

THE PRIORITISATION FRAMEWORK

The prioritisation framework set out to help CDHB decision makers work through the following three key objectives: 1) to prioritise the CDHB Earthquake Programme of Works; 2) to determine suitable repair/retrofit levels for buildings; 3)to clearly articulate the trade-offs CDHB is having to make and the risk profile it is carrying.

PRIORITISATION PROCESS

The prioritisation framework is shown in Figure 1. The four main steps in the decision process are 1) criticality categorisation, 2) assessment of repair and retrofit options based on the gap between current and desired performance of building, 3) cost assessment, and 4) other considerations. This process is intended to be an iterative process. While the process is applied building by building, the framework prompts users to consider the building (and functions housed in the building) as part of a wider health care system to ensure resources are allocated effectively across the building portfolio.

Criticality categorisation

A clear outcome from the framework development process was the importance of letting the building function drive the prioritisation of seismic repair and retrofit. This message was clear from both an engineer's point of view and CDHB interviews. As shown in Figure 1, the first step in the framework aims to categorise the building stock based on their life safety risk and functional importance, considering both now and future building use in the long term Master Plan. This step explicitly prompts users to consider the building and services from a network perspective, bearing in mind the local, regional, and national role of the hospital.

The criticality rating (A to D, where A is the most critical) is based on 6 criteria:

- Building occupancy (number, vulnerability, mobility of users and frequency of use)
- Importance of continued function post-disaster
- Risk to neighbouring structures/key access routes/critical infrastructure
- Ability to relocate services/patients
- Acuity or sensitivity of service (e.g. NICU, acute theatres, high infection-risk services, biohazards, high-security risk, forensic mental health, acute dialysis, etc)
- Health system failure potential

This step provides a relative measure that can be used to express the risks that remain if there is insufficient budget to retrofit all buildings to a standard suited to their criticality level.

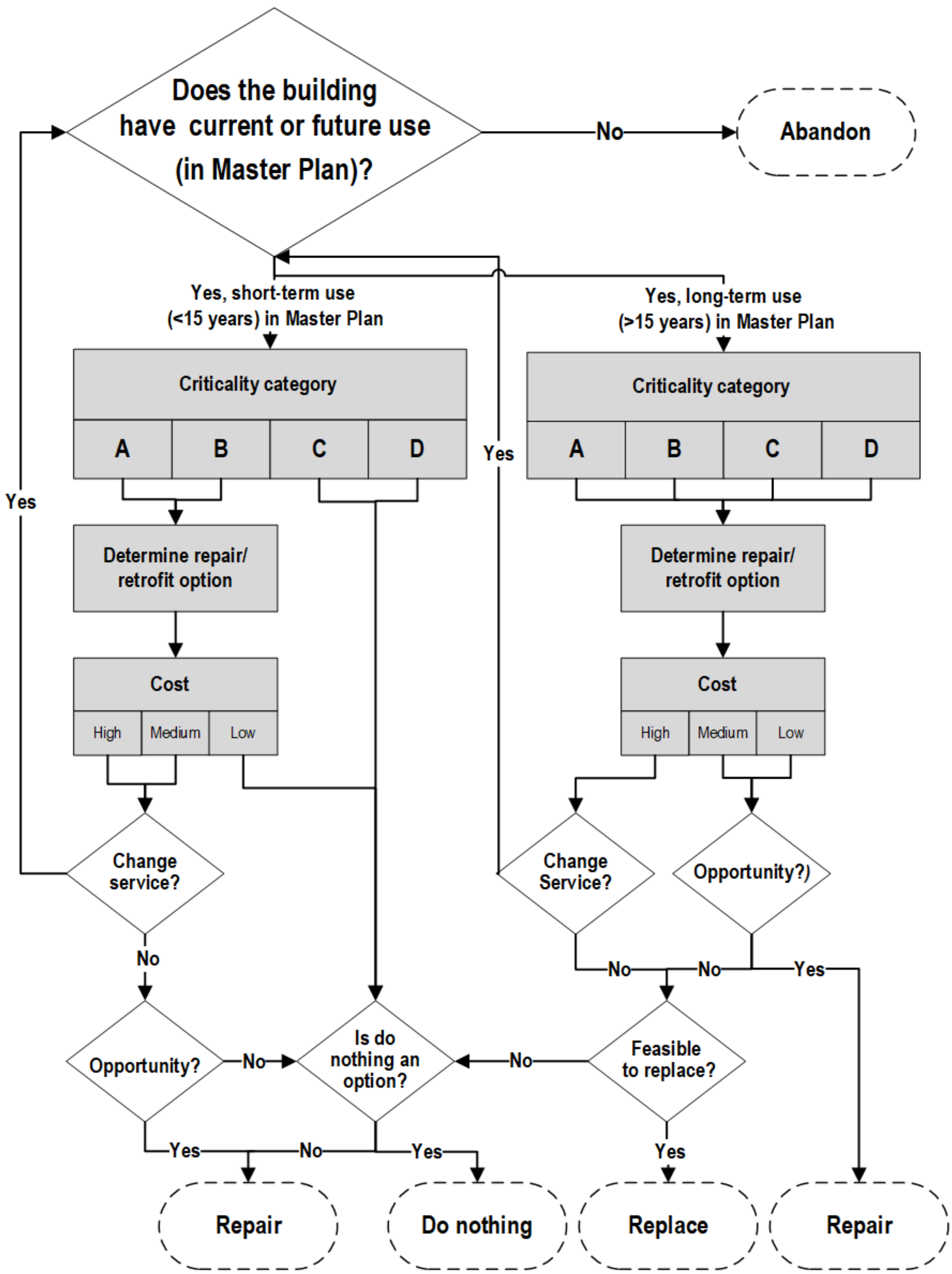

Figure 1. CDHB Prioritisation Framework Diagram (note that this is an overview, tables and notes to support decision framework are not included for brevity)

Assessment of Repair and Retrofit Options

For each criticality category, the framework defines a set of performance objectives. Given the challenges identified in both the engineer and CDHB interviewees, the framework set out to provide more clarity and nuance around structural performance than those set out in the building code and loadings standard.

The performance objectives include life safety (the ultimate limit state (ULS)) as %NBS, operational continuity (the serviceability limit state (SLS2)), expected performance during a significant event, and building-specific performance criteria.

Due to the importance of operational continuity for healthcare, the emphasis of the building performance requirements is on 'operational' performance. The life safety performance objectives in the framework meet minimum Building Code requirements. The operational continuity expectations are necessarily set at a higher level than required in the Building Code (this includes creating SLS2 performance criteria for IL2 and IL3 buildings, as there are currently no such provisions in the Building Code). The intent is to focus resources on reducing disruption to operations during smaller earthquake events, rather than improving life safety in more significant events. For example, the operational continuity expectation for criticality A buildings are set at a 10% chance of exceedance during the 50-year design life of the building. This is equivalent to designing for a 1 in 500 year event and is current SLS2 performance criteria for IL4 hospital buildings. The operational continuity expectation for category B and C buildings are set relative to this: 18% for criticality B buildings (1 in 250 year event) and 40% for criticality C (1 in 100 year event) (none specified for criticality D).

The framework also provides some qualitative statements of expected performance under a given earthquake. Under the NZ Loadings Standard, the ULS design earthquake is different for buildings of different Importance Levels. This makes it difficult for owners of a portfolio of buildings to understand how their entire building stock might perform in a given event and therefore understand the impact it would have on their ability to deliver services. The expected performance criteria are intended to create a common understanding between CDHB staff and engineers on the relative performance of buildings of each criticality category. For this framework, expected performance statements are created for an earthquake with a 10% chance of exceedance during the life of the building. The statements describe usability immediately following the event, usability in the short to medium term, and a damage description. Table 4 gives an example of the description for a Category A building.

Table 4. Category A performance expectation criteria

	Performance expectation
Usability Immediately Post Earthquake	Parts/components required to maintain those operations for which the building is designated critical are required to be returned to a fully operational state within an acceptably short time frame (minutes or hours).
Usability Short to Medium Term post-Earthquake	Repair will cause little or no disruption to services
Damage	Damage requiring cosmetic repairs of a minor and non-urgent nature is acceptable in localised areas. Repair can be carried out with minimal disruption to a functioning department.

The framework also provides a set of questions that need to be discussed between CDHB and engineers, so that engineers fully understand the performance needs of the hospital. For example, these needs could be related to patient evacuation, infection control, protection of specialistic equipment, and security requirements.

Using the criticality categories assigned to buildings, and the above performance criteria, engineers evaluate the gap between the current state of the building, the expected life of the building, and the desired performance objectives. Note that the assessment is based on the desired performance given the current use of the building and not the original design parameters for the building. Based on that, CDHB staff and engineers will undergo an iterative process evaluating repair and replacement options. Factors considered in this stage include: the current performance of buildings, the necessary degree of repair and strengthening given the criticality category, and desired performance objectives. Replacement options would also be considered at this stage, if applicable. During this stage, some buildings may drop out of the process if they already meet the performance standards for their criticality rating.

Cost Assessment

The next step is to evaluate the relative costs of one or more options. The cost assessment criteria asks users to evaluate 1) the repair and retrofit options relative to the cost of replacement and 2) cost of disruption to services during repairs from a repair or replacement option. Users then make qualitative adjustments for savings or benefits related to 1) reduced maintenance, operations and non-structural capital upgrades; and 2) service efficiency benefits. This cost assessment is designed to ensure options fully consider the direct and indirect, capital and operational, short and long term impacts. Each building will be assigned a High, Medium, Low rating based on the relative costs and benefits. Users are then prompted to consider ways to enhance the outcome and/or efficiency of the selected option through a Change of Service in the building, other Opportunity to enhance the building/service delivery, potential to Do nothing or Replace the building.

Other Considerations

Change Service

If a repair or replacement option has a high cost, one option is to change the use of the building. By changing the function of the building and/or relocating some or all the services within the building the criticality category can be reduced and therefore so are the building repair/retrofit requirements. Evaluating this would require a discrete piece of work and would need to be carried out in consultation with the master/strategic plan from a health service delivery perspective.

Opportunity

If a retrofit option requires major physical works there is an opportunity to add value, efficiency or resilience at marginal cost. Opportunities include the potential to: reduce risks from other hazards (fire, flood, pandemic, infection, asbestos); improve operational efficiency (e.g. co-location of services to improve staff and patient flows); reduce operational costs (heating, maintenance etc); upgrade to meet current standards/best-practice; provide a new service; offset future expenditure; improve staff wellbeing; repurpose to house another service; consider the use of a building to act as a decanting space during repairs; or as a flexible space that could be used in an emergency response.

Do Nothing

Before a decision to do something is made, the option to ‘do nothing’ should be considered. In some cases, the cost of repair may not be worth the improved performance outcomes. However, a ‘do nothing’ option should consider issues such as availability or cost of insurance, lost opportunity for efficiency gains through the repair process, and regulatory penalties that may be incurred due to non-compliance with legislative requirements. Buildings where ‘do nothing’ is the final outcome will often still need non-structural repairs (e.g. plasterboard cracks) but this can be done as part of on-going maintenance and capital upgrade work programmes.

Replacement

For options where the repair option is high relative to building replacement, or there is potential to reduce significant ongoing operational and maintenance costs of a building, then replacement should be considered. An option to replace a building should fully evaluate the time and cost to plan and build a new building and the ability to relocate services during the rebuild (if the rebuild is at the same location as the damaged building).

Decision Sense Check

When the framework leads to an abandon, repair or replace decision, it is then subject to a subjective discussion: "Is this the right thing to do now?". This point is where a reality check on decisions is made considering the context and timing of the decision from a health care system perspective. It is also used as an opportunity to consider any external risks that the building/service faces (e.g. potential to be in a cordon or to have damage from a neighbouring building etc), or if there are other ways to mitigate the risk to the people/services (e.g. by relocation of the services or by rearranging the services within a building).

At this stage legal checks are also undertaken to ensure compliance with the Building Act, Health and Safety at Work Act, Civil Defence and Emergency Management Act and Health and Disabilities Act. The potential disruption due to repairs and the ability to decant or move services to allow for repairs is also considered. However, this is in many cases a scheduling issue and is part of the implementation stage.

Final Prioritisation

Once the above is completed and the scope of works has been defined for each building, the general priority order of all buildings in the CDHB portfolio designated as 'repair' or 'replace' needs to be determined. This is to help prioritise the order of capital works and ensure that limited financial resources are directed towards the most critical buildings: as driven by the needs of the health system (both day to day needs and post-earthquake needs). The framework suggests prioritising building retrofits first by direct risk to life safety (e.g. building collapse, fire risk, and patient safety); second, meeting legislative requirements; third, criticality (as defined in this framework); fourth, where there is opportunity for efficiency improvements; fifth, where buildings provide flexibility of space (long life, loose fit); and last, where staff wellbeing will be improved.

FRAMEWORK EFFICACY

The framework is designed to be run as a collaborative process. Participants in the pilot workshops noted how the framework p evoked quality, deep thinking about each building and helped users to consider buildings in the context of the entire health system. The collaborative process allowed a range of CDHB staff to connect their different perspectives and contribute to a joint decision.

Engineers contracted by the CDHB noted how effective the framework was for creating a conversation between engineers and healthcare workers. The process and conversation prompts helped engineers develop a better picture of how a building should perform. For example, to enable safe evacuation of spinal patients, it is important to have floors that do not crack and displace creating obstacles to roller beds.

During the pilot workshops, the framework was applied to two hospital campuses in Canterbury. The original programme of works (prior to framework development) was based on a goal of achieving 67-100%NBS across all buildings regardless of the buildings role or importance in the health service delivery system. Application of the framework enabled approximately 75% of the original capital budget for the pilot campuses to be reprioritised for use on buildings that provided the most life safety and service resilience benefits in the long term. Retrofit recommendations resulting from the framework focused on achieving greater operational performance (SLS2) for smaller earthquake events, while reducing focus on life safety (ULS) in extreme events. The framework, therefore, achieved the desired ‘balance of harm’ between life safety in extreme events and the quality and continuity of clinical services during smaller earthquake events and in the face of a range of other risks. The framework has been adopted and is being rolled out for CDHB’s earthquake affected building stock.

SUMMARY

The aim of the prioritisation framework was to help the CDHB look at their seismic retrofit programme with a resilience lens: to look beyond the minimum requirements set in the Building Code for individual building performance and to critically evaluate what performance they desired to support the efficient and continued functioning of the health system.

The framework provides a structured process to ensure that limited financial resources are allocated prudently. Following a major and catastrophic event, such as the Canterbury earthquakes, there can be a tendency to be risk averse and a desire to restore staff/public confidence by improving the seismic performance of all buildings. But there are practical and financial limits to this. In a healthcare context, it is important that resources are used to balance harm between disruption to healthcare services and life safety risk during a significant but low probability earthquake. It is also essential to consider all risks, not just seismic risk.

The criticality categorisation in the framework helps CDHB define how important each building is in the context of life safety and healthcare continuity from a network perspective. This criticality rating then informs the appropriate level of seismic strengthening. Considerations of cost and opportunity help users to think beyond the instinctive response to restore what was broken to its original form and function and to look for opportunities to improve service efficiency or even change the use of a building.

Both the development process and the resulting framework will be of interest to the growing movement toward functional recovery based building codes as well as practitioners facing similar capital works prioritisation projects to improve seismic safety. There is an opportunity to take some of the ideas in this paper and consider how they may be integrated into building codes, regulations and standards to enable engineers to take a more risk and resilience based approach to building design. This includes developing a deeper understanding of how a building will be used during and after an earthquake, extending seismic assessment beyond structural performance to functional or operational performance and moving from building by building perspectives to a network perspective of risk.

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