Canterbury Earthquakes
Royal Commission
Te Komihana Rūwhenua o Waitaha

Discussion Paper: Building Management After Earthquakes

1. Introduction

This discussion paper seeks comment on the implementation and effectiveness of the building management processes used after the 4 September 2010 and 26 December 2010 earthquakes. It asks what lessons can be learnt about how to manage an area's building stock to better meet the goal of ensuring public safety after a disaster. The paper also identifies some options for addressing the issues it raises and asks for comment on their advantages and disadvantages.

A series of questions designed to prompt thinking about the issues and options discussed in the paper are posed in this Introduction. People may respond to these questions directly, respond to some but not others, or generally discuss the topics in the paper.

It is a discussion paper only and the Royal Commission has not yet concluded views on the matters discussed in this paper.

This discussion paper is set out as follows:

1. Introduction;
2. The Building Safety Evaluation Framework;
3. Issues with the Development of the Building Safety Evaluation Framework; and
4. Building Safety Evaluation Models, Resourcing and Planning.

Section 2 of this discussion paper describes New Zealand's building safety evaluation framework. It then identifies how multiple processes developed alongside the official building safety evaluation operation, along with associated issues such as the development of multiple placard systems. Section 2 also discusses the issues that developed when responsibility for the building safety evaluation process transitioned from civil defence to the governance of local authorities. These issues include how the Building Act 2004 defines dangerous and earthquake-prone buildings, and the problems this causes after an earthquake. Section 2 discusses how the roles and responsibilities of building owners were unclear; issues with cordons are discussed in this context. It also sets out the barriers building owners faced to taking action to repair their buildings. How well the meaning of the placards is understood is then explored, particularly how the purpose of the system is not clear, before issues with the treatment of green placards are discussed. Section 2 then looks at the need for detailed engineering evaluations and what capabilities engineers need to carry out building safety evaluations.

Section 3 describes how New Zealand's building safety evaluation process has developed and explores the issues with this framework. It looks at how engineers mobilise to carry out a building safety evaluation operation and issues around liability.

Finally, Section 4 looks at other building safety evaluation models. It also looks at resourcing and planning, focussing on issues with information management.

The questions posed about the issues and options discussed in these sections can be grouped into three broad categories:

- questions about what New Zealand's building safety evaluation framework should be, and who should be responsible for its development;
- questions about specific aspects of the placard system used in Christchurch; and
- questions about barriers to repairing their property building owners and others experienced, particularly in the recovery phase after the building safety evaluation process transitioned from civil defence to governance by local authorities.

Questions –New Zealand's building safety evaluation framework

1. What objectives should the building safety evaluation framework should target; should its main objective be ensuring public safety, or should it incorporate other aims? What would the process look like if other objectives were added? What are the risks associated with focussing on one objective over another?
2. How did the building safety evaluation operation after the Canterbury earthquakes highlight any weaknesses and failures in the current system? Can these failures be addressed, or should we move to a different building safety evaluation model? What are the advantages and disadvantages of these models and approaches, and how do they compare with our current framework?
3. Who would be responsible for setting up and/or implementing any new framework? Should the roles and responsibilities in the building evaluation system be set at national or local level?
4. What are the risks, costs, and benefits of using a building safety evaluation system that uses volunteer engineers who have a liability waiver. Are there any options that address the risks associated with using volunteer engineers that do not discourage them from volunteering?
5. What framework should be used to evaluate buildings when a state of emergency is not declared but buildings are damaged (for example, after an aftershock).

Questions – specific issues with the placard system used in Christchurch

1. What were the issues with how people placed, maintained, and removed the placards? How did understanding or misunderstanding of the placard's meaning affect people's behaviour; think about whether the wording and/or colour of the placards contributed to any problems. What was the extent of these problems, and could they occur in other parts of the country?
2. Do you know of any situations where building owners brought in engineers to assess a building and they used a different placard system? If so, can you give reasons why this approach was taken? What did building owners and/or engineers do to inform officials of the results? How should we address any issues?
3. How well did individuals, organisations, agencies and the wider public communicate and share information with each other after the Canterbury earthquakes; identify any gaps, failures and good performance. What could have improved how people communicated and shared information?
4. What skill-sets do engineers need to accurately or adequately evaluate a building following an earthquake or aftershock? Are different skills needed to assess buildings of different ages and for different purposes? What are the advantages and disadvantages of requiring engineers to possess certain expertise/capability before they can become building safety evaluators?
5. What are the relative advantages, disadvantages, costs, benefits and risks of adopting a damage-based assessment, or other assessment methodology? Do fundamental changes need to be made to how people assess whether, how and when a building is at risk from aftershocks; for example, when it is appropriate to work out the residual seismic capacity of a damaged building?

Questions – barriers to action, particularly in the recovery phase

1. What mechanisms and tools could be used to transition the building safety evaluation process from an emergency situation to normal 'business as usual'? What do other countries do? How should buildings be followed up on after a state of emergency?
2. How do we manage the tradeoffs between closing buildings until the safety of the public can be ensured in the long-term, managing impacts (such as heritage concerns) when making decisions about the repair or demolition of a building, and acting quickly to promote recovery? What are the risks of trading one goal off against another, and who bears any costs or benefits (either directly or indirectly)?
3. What administrative issues caused barriers to repairing, re-opening or demolishing damaged buildings? Were any solutions developed in response to the Canterbury earthquakes that could improve New Zealand's building safety evaluation process? What are the advantages and disadvantages of adopting any of these solutions?
4. What should central and local government, engineers, insurers and building owners be responsible for when changing and removing placards; following up on engineering recommendations for further evaluations or work; and making sure that building owners comply with their obligations. What role does each of these groups play in making sure that damaged buildings are safe for long-term occupation? How do we improve the system?

The Royal Commission has previously called for submissions on building safety evaluation processes after earthquakes. At the Royal Commission's request, the following information was provided prior to the Commission seeking submissions:

- Ministry of Civil Defence and Emergency Management [1]. (2011). *The Civil Defence Emergency Management Framework and Response to the 22 February Christchurch Earthquake: Report to the Canterbury Earthquakes Royal Commission*:
  - a report setting out the key principles and underlying approach behind on the New Zealand's civil defence and emergency management framework;
- D. Middleton and R. Westlake [2]. (2011). *Independent Review of the Response to the Canterbury Earthquake, 4 September 2010*:
  - an independent review of the civil defence and emergency management operations after the 4 September 2010 earthquake commissioned by the Ministry of Civil Defence and Emergency Management (please note that this review was not completed because it was overtaken by events following the 22 February 2011 earthquake);
- New Zealand Society for Earthquake Engineering [3]. (2011). *Building Safety Evaluation Following the Canterbury Earthquakes: Report to the Royal Commission of Inquiry into Building Failure Caused by the Canterbury Earthquakes*:
  - a review of the building safety evaluation operations after the Canterbury earthquakes prepared by Mr Dave Brunsdon of the Kestral Group;
- E. Griffiths and D. McNulty [4]. (2011). *Building Evaluation Transition Team: Processes Used and Lessons Learnt following the Darfield Earthquake of 4 September 2010*:
  - a debrief on the processes used after the 4 September 2010 earthquake, focussing on those used after the state of emergency ended (please note that this report was not finalised and does not necessarily represent the Christchurch City Council's view of its processes or the legislation that relates to these); and
- Christchurch City Council [5]. (2011). *Report into Building Safety Evaluation Processes in the Central Business District Following the 4 September 2010 Earthquake*:
  - a technical report on the building safety evaluation operation in the Christchurch central business district after the 4 September 2010 earthquake.

The Royal Commission received seven submissions on building assessments after earthquakes, including submissions from the Department of Building and Housing and the Christchurch City Council. The other five submissions were received from private individuals. Eight submissions on other topics also discussed building assessments. These included submissions by the New Zealand Historic Places Trust, Local Government New Zealand, two local authorities, the Royal Society of New Zealand and private individuals.

The submissions and reports can be viewed on the Royal Commission's website at www.royalcommission.govt.nz.

The Royal Commission has held hearings on the Forsyth Barr and Pyne Gould Corporation buildings, the Hotel Grand Chancellor and the failure of many individual buildings causing death. Evidence heard at these hearings informs this discussion paper.

The Royal Commission has reviewed and analysed the information in the technical reports and submissions, and now seeks more information on specific topics. People are asked to give their views, robust analysis and any supporting evidence they have on any or all of the topics raised in this paper.

The paper:

- explores the efficiency and effectiveness of the framework for New Zealand's building safety evaluation process, looking at how the process is developed, and what it incorporates and excludes;
- looks at the roles and responsibilities of different groups in the development and implementation of the building safety evaluation process;
- discusses how efficiently and effectively the building safety evaluation process was implemented after the earthquakes, comparing this with the New Zealand Society for Earthquake Engineering guidelines [6] and/or best practice, along with identifying any problems that need to be addressed;
- explores how well the building evaluation process transitioned from civil defence to the building control arrangements governed by local authorities; and
- raises issues for further comment and analysis.

Submissions on this discussion paper close by 12.00pm on 27 July 2012. Submissions should be sent to the following addresses:

Email: Canterbury@royalcommission.govt.nz

Canterbury Earthquakes Royal Commission
PO Box 14053
Christchurch Mail Centre 8544
New Zealand

The Royal Commission is planning to hold a public hearing on the building management processes after earthquakes in September 2012. This hearing will cover the topics raised in this paper. The Royal Commission may ask any person who comments on this discussion paper to appear at the hearing.

1.1 Framework for Analysis

When commenting on the issues raised in this paper, it is important to:

- identify problems, risks and omissions that occurred in the response to the Canterbury earthquakes that may occur again after another disaster in Canterbury or somewhere else in the country;
- demonstrate how any solutions to these problems or other changes could result in a visible and material improvement to outcomes in the future;
- provide the evidence and/or analysis behind the problems and possible solutions identified;
- provide evidence of what has worked well overseas, identifying key differences and similarities between New Zealand and the other country that could affect how the proposed solution might work here;
- consider the advantages and disadvantages of adopting a proposed solution, including setting out the risks, barriers to implementation, and possible costs of these solutions, if possible; and
- identify who would be responsible for the development and implementation of any proposed solutions, including who would pay for any implementation costs (for example, central or local government, industry bodies, building owners, the engineering profession), and who would directly or indirectly benefit from these solutions (for example, insurers, building owners, private engineering firms, the community, the wider New Zealand economy).

The cost to implement any suggested measures may directly or indirectly fall on both the public and private sectors. Monies paid directly; fees; development costs; overheads; administrative costs; public education and having to meet any new requirements are all

examples of costs that central government agencies, local government, organisations or individuals might pay when new policies or procedures are introduced. Benefits are more difficult to quantify, but include how groups or individuals benefit from policies, procedures, goods or services that others pay for.

The Royal Commission's focus is on the management of buildings after the 4 September 2010 earthquake. It is also considering the response to the 22 February 2011 earthquake, along with the 13 June 2010 and 24 December 2010 aftershocks. The Royal Commission wishes to draw out how the building management process incorporated the lessons learnt from one event to the next.

It would be useful if submitters on this paper could advise the Royal Commission if any third party contributed to their comment.

1.2 The 4 September 2010 Earthquake

On 4 September 2010, a 7.1 magnitude earthquake occurred at 4.35am, with an epicentre 40km west of Christchurch. Within an hour of the earthquake, Christchurch City Council, Waimakariri District Council and Selwyn District Council declared a local state of emergency for their area. They each established their own Emergency Operations Centre run by a Local Controller. The Local Controller was in charge of their district's response to the earthquake, including building safety evaluation operations.

Each of the three local authorities implemented their own building safety evaluation operation. These operations were broadly based on the New Zealand Society of Earthquake Engineering[6] guidelines for building safety evaluations. In Christchurch, 1,236 commercial buildings and 6,686 residential buildings were evaluated, most during the first week following the earthquake.

1.3 The 26 December 2010 Aftershock

On 26 December 2010, a 4.7 magnitude aftershock occurred at 10.30am, with an epicentre 1.8km northwest of Christchurch Cathedral. Christchurch City Council established an Emergency Operations Centre and implemented a building safety evaluation operation.

Christchurch City Council did not declare a local state of emergency. This is because emergency services were responding adequately to the event, residential areas were not significantly affected, and any damage was limited to a small area. Christchurch City Council adapted their building safety evaluation process to reflect that no state of emergency was declared. Because of the damage caused by this aftershock, Christchurch City Council formally followed up on 177 buildings.

2. The Building Safety Evaluation Framework

The main aim of New Zealand's building safety evaluation process is to ensure public safety following a disaster. There is a direct trade-off between:

- taking the time to ensure that buildings are safe before allowing the public access; and
- getting the community and local businesses recovering from the disaster as soon as possible.

Each local authority is expected to develop and implement its own building safety evaluation process. In 1998, the New Zealand Society for Earthquake Engineering[7] developed guidelines to give local authorities a framework to use when developing their process. The

Department of Building and Housing endorsed the current version [6] of these guidelines in 2009. These guidelines draw heavily on United States systems, particularly California's.

The guidelines set out the three phases of New Zealand's building safety evaluation process:

- Overall Damage Survey;
- Rapid Assessments; and
- Detailed Engineering Evaluations.

New Zealand's building safety evaluation process is summarised in the following table.

Purpose	Timing*	Initiated by	Task	Conducted by	Comment
Overall Damage Survey	Within hours after event	Civil Defence staff, emergency service action plans, territorial authorities action plans	Assess aggregate damage and identify affected areas	Emergency services, Territorial Authority staff, Civil Defence volunteers	No entry of premises, no formal records, emphasis on extent of damage, areas of high impact, identifying rescue tasks, identifying areas of priority for rapid assessment, estimating manpower and skill base needs etc
Level 1 Rapid Assessment (Figure 1)	During a period of a state of emergency declared under the Civil Defence Emergency Management Act	Controller; Building Safety Evaluation Leader	Ascertain level of structural damage to individual buildings and note other hazards; assess building safety and decide appropriate level of occupancy; recommend security and shoring requirements	Structural and civil engineers, architects and other personnel from the building industry *volunteer status*	Formal system, typically based on exterior inspection only; placards posted on buildings, central record maintained, note made of sites needing further inspections, unsafe areas cordoned off.
Level 2 Rapid Assessment (Figure 2)				Structural engineers, building services and geotechnical engineers *volunteer status*	Formal system based on inspection of interior and exterior of the building plus reference to available drawings. Calculations not envisaged. May result in revised placards posted on buildings, central record updated, unsafe areas cordoned off, urgent work recommendations *Typically for priority inspection of critical facilities (for situations where facilities operators do not have contracted engineers), or where further information that raises concerns is received*
Detailed Engineering Evaluation and Remedial Work	Typically longer-term, but may be immediate for critical structures.	Building owners, insurance companies, Territorial Authorities	Ascertain extent of structural damage, establish losses for insurance purposes, and recommend remedial work to restore functionality and compliance with Building Code.	Engineers, architects and loss adjusters *contractual agreement*	Meets insurance and restoration requirements under the Building Act 2004 *These evaluations are likely to involve review of construction documentation, and the preparation of detailed engineering reports*

** all timings are indicative estimates only*

Table 1: Summary of building safety evaluation inspection categories (Source: New Zealand Society for Earthquake Engineering [6] guidelines for building safety evaluations, 2009)

The overall damage survey is carried out within hours of the disaster occurring. It is a quick stocktake of the extent of the damage caused by the disaster. It also aims to identify people needing to be rescued.

The Rapid Assessments are the next phase in the building safety evaluation process. The Rapid Assessment process has two parts. Both are intended to give a short-term indication of the condition of a building and to determine if the building is an immediate danger to the people using it or to the wider public. The Level 1 Rapid Assessment is a 10 to 20 minute inspection of the structural damage visible from the outside of a building. Level 1 Rapid Assessments are normally carried out on buildings up to three or four stories high. Larger and more complex buildings, along with critical facilities, are typically assessed using a Level 2 Rapid Assessment. These are also carried out when a Level 1 Rapid Assessment recommends that evaluators carry out a Level 2 Assessment. The Level 2 Rapid Assessment is a brief one to four hour check of the interior and exterior of the building. In the Rapid Assessment phase of the building safety evaluation process, evaluators place red, yellow or green placards on buildings, limit entry to buildings and erect cordons to restrict access to the area around the building. These processes are summarised in the following flow charts.

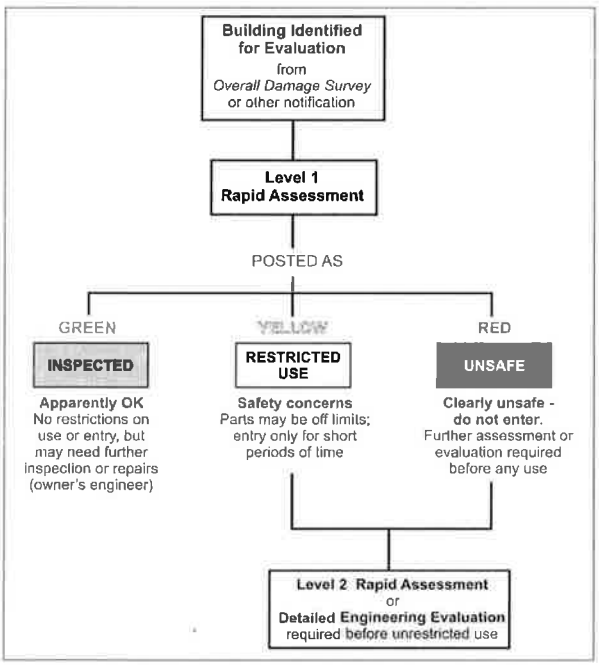

Figure 1: Level 1 Rapid Assessment

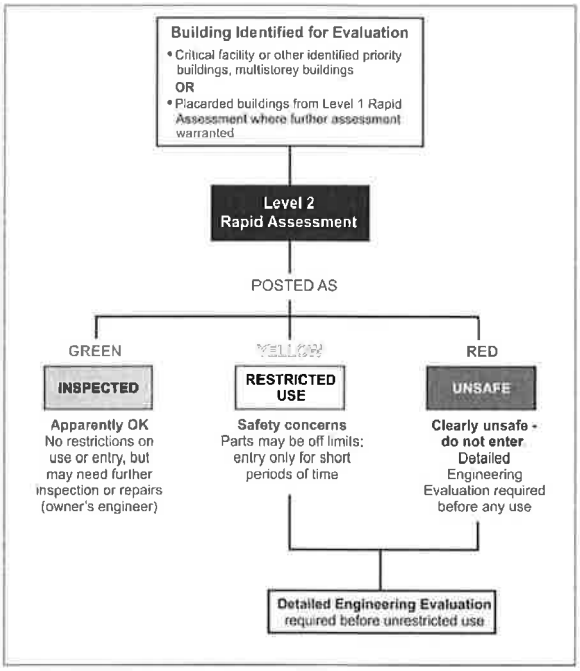

Figure 2: Level 2 Rapid Assessment

(Source: New Zealand Society for Earthquake Engineering [6] guidelines for building safety evaluations, 2009)

The New Zealand Society for Earthquake Engineering [6] guidelines for building safety evaluations state that the overall damage survey and Rapid Assessments should be carried out during a local or national state of emergency. They are carried out under the authority of a civil defence Local Controller, who can, under the Civil Defence and Emergency Management Act 2002:

- issue and control the use of signs: section 18(2)(c);
- carry out inspections: section 92;
- evacuate people and exclude them from any premises or places: section 86; and
- prohibit or restrict access to public roads and places to prevent or limit the extent of the emergency: section 88.

Civil defence workers usually carry out the overall damage survey. Local authority building officials and volunteer engineers work together in teams to carry out Rapid Assessments.

Detailed Engineering Evaluations are the final phase in the building safety evaluation process. Because they involve accessing all of the information on the building, thorough internal and external inspections, and performing calculations, they are often carried out after a state of emergency. In 2006, the New Zealand Society for Earthquake Engineering [8] released guidelines on how to assess whether a building is potentially earthquake-prone; these guidelines also refer to carrying out detailed engineering evaluations. The Detailed Engineering Evaluations in this discussion paper are those referred to in the New Zealand Society for Earthquake Engineering guidelines on building safety evaluations, not their guidelines on how to assess whether a building is potentially earthquake-prone. A comparison of these two sets of guidelines is set out in Appendix 1.

2.1 Issue: Development of Multiple Processes

After the 4 September 2010 earthquake, a parallel building safety evaluation process developed as engineers engaged by owners carried out evaluations of varying detail alongside the official operation. Building owners engaged their own engineers to assess the damage to their buildings during the state of emergency and after the building safety evaluation process transitioned from civil defence to local authorities.

Evidence the Royal Commission has received to date indicates that these engineers carried out the equivalent of Level 1 Rapid Assessments, Level 2 Rapid Assessments, Detailed Engineering Evaluations, or assessments that fell between one or other of these categories. Privately contracted engineers are not required to undertake the same process as official building safety evaluators. There is also no requirement to follow the New Zealand Society for Earthquake Engineering [6] guidelines for building safety evaluations.

Some of the engineers engaged by building owners had volunteered in Rapid Assessment teams during the state of emergency, but others had not. Consequently, some of the engineers engaged by owners had no experience assessing buildings after an earthquake.

In addition, there was no way for local authorities to access the evaluations carried out by engineers engaged by owners because these reports were not part of the official process. Building owners and their engineers are not legally obliged to share the information in these reports with their local authority. However, these reports sometimes contained information that could have led to the changing status of a building. Some building owners shared this information, but others assumed that their own independent evaluation was sufficient to change the status of the building. Consequently, some building owners and engineers changed the official placard placed on the building.

It appears that the Canterbury Earthquake Recovery Authority (CERA) developed processes after the February 2011 earthquake to better integrate evaluations made by engineers engaged by owners with CERA's own records.

2.1.1 Multiple Placard Systems

Some engineers developed and used their own building safety evaluation forms and placards. Typically, these were adapted from templates used by the New Zealand Society for Earthquake Engineering, the Christchurch City Council, and/or the civil defence response.

This led to the growth of multiple placard systems after the Canterbury earthquakes. By late November 2010, a building could be stickered with:

- the (red/yellow/green) Rapid Assessment placard placed under a civil defence warrant;
- the placards developed by engineers engaged by building owners, placed during and/or after the state of emergency;
- the red section 124 Building Act 2004 notices to fix placed by the local authority after the state of emergency; and/or
- a variety of general engineering assessment notices.

2.2 Issue: Changing the Placards

It appears that there were issues with changing the placard placed on a building. During the state of emergency, only civil defence and emergency management could change or remove a placard. After the state of emergency, only local authorities had a mandate to change placards.

Placards were removed from buildings by people who were not authorised to do so when people did not understand their meaning or status. Building owners or engineers would remove placards based on the findings of a Detailed Engineering Evaluation, not realising that only the local authority could legally change or remove placards.

Inefficient information recording meant that officials and building owners had problems knowing the status of a building at a given point in time. Westlake and Middleton [2] contend that sometimes the only way to find out if the status of a particular building had changed was to carry out a visual check. On the other hand, sometimes official records would note a change to the building's status, but a new placard was not placed on the building [3]. Fading of the placards over time also caused confusion.

It is not clear how placards or assessments were formally changed during the state of emergency. Some of the engineers engaged by owners obtained an official Level 1 or Level 2 Rapid Assessment form, filled it in, and returned it to the civil defence Emergency Operations Centre or the local authority. Others chose to send in their evaluation of the building so that civil defence or local authority workers could change its placard [5]. It is not clear how a placard was changed during the state of emergency when engineers did not share information with officials about the buildings they evaluated for building owners. In the evidence the Royal Commission has heard to date, it appears that how well different groups communicated and shared information was an issue after the 4 September 2010 earthquake.

2.2.1 CPEng Certificate

Christchurch City Council developed processes and procedures for changing the placards after they transitioned from civil defence to the building control arrangements governed by local authorities. Initially, the Council requested that building owners submit a Detailed Engineering Evaluation completed by a chartered professional engineer. The technical reports and evidence the Royal Commission has heard to date indicate that some evaluations were not carried out by chartered professional engineers and the level of detail in these reports varied. Building owners found the process for changing a building's placard unclear.

For these reasons, the Council introduced a new certification form that chartered professional engineers submitted to request a change of placard. This form assured Christchurch City Council that the building was safe for occupancy and posed no further hazard to people or property before the status of a red or yellow placard building placard was changed. The process gave engineers the option of strengthening the building to 67 per cent of new building standard, or securing it to "…at least the same condition that existed prior to the earthquake of 4 September 2010" [5] and strengthening it by September 2013.

Christchurch City Council workers discussed when and how to change a building's status with the certifying engineer if they needed to consider additional factors like removing cordons.

2.3 Issue: The Transition from Civil Defence to Local Authorities

The technical reports and the literature on building safety evaluations suggest that a key issue with the building safety evaluation process after the September 2010 earthquake was how responsibility for the process transitioned from civil defence to normal building control arrangements governed by local authorities.

The initial building safety evaluation operation takes place during a state of emergency under civil defence arrangements. Placards only have legal status during a state of emergency. To be able to follow up on damaged buildings, the New Zealand Society for Earthquake Engineering [6] recommends placing a notice to fix on the building before the end of the state of emergency. A notice to fix is issued under section 124 of the Building Act 2004. Fixing a building can include removing the danger associated with a building, securing or repairing the building, or demolition.

After the 4 September 2010 earthquake, most placards expired before the status of the building was resolved. New Zealand's building safety evaluation process was first used in Gisborne in 2007. At this time, the smaller number of damaged buildings meant that notices to fix could be placed on red and yellow placard buildings before the state of emergency ended. Christchurch City Council [5] has stated that the large number of buildings damaged after the 4 September 2010 earthquake meant that it was not possible to do the same.

The Canterbury Earthquakes (Building Act) Order 2010 extended the status of the red and yellow placards for a further 60 days, deeming them section 124 Building Act 2004 notices. This gave the Christchurch City Council time to develop the processes it needed to transition the building safety evaluation process into its building control arrangements. The Council established the Building Evaluation Transition team from 20 September 2010 to the end of November 2010. This team audited the placards of approximately 580 commercial properties over October 2010 to maintain an accurate schedule of building safety evaluations. It developed a process for incorporating the reports generated by engineers engaged by building owners and for changing the status of placards on a building [3]. The team also carried out inspections of dangerous or unstable buildings, maintained cordons and arranged for notices to fix to be placed on buildings. Most building owners had until the end of January 2011 to fix their buildings, unless it was particularly dangerous or impeded traffic flow or public access [4]. Evidence the Royal Commission has heard indicates that work to follow up on the status of these buildings was ongoing in February 2011, when the 22 February 2011 earthquake struck.

2.3.1 Lack of Transition Mechanism

It is unclear what planning had been done to manage the transition of the building safety evaluation process from civil defence to the Christchurch City Council. Christchurch City Council [5] accurately states that there was no precedent for managing the transition from a state of emergency for the scale of building damage that had occurred in Christchurch in September 2010. In addition, the Council's Enforcement Team normally investigates approximately 65 complaints a year about dangerous buildings, issuing between two and five notices to fix. The large number of damaged buildings expected to receive a section 124 Building Act 2004 notice meant that the workload of this unit would be much greater than usual. Consequently, the Council developed its policies and procedures about how to treat red and yellow placard buildings after the state of emergency ended. However, Griffiths and

McNulty [4] refer to planning done during the state of emergency that Christchurch City Council did not use.

In a 2010 thesis on how the civil defence and building regulatory legislation affects the recovery from a disaster, James Rotimi [9] highlights the issues arising from having no clear transition mechanism from a state of emergency into the recovery phase. He contends that this leads to the roles and responsibilities of groups being unclear after the state of emergency ends, particularly if response activities are ongoing. This could lead to inconsistent policy decisions made across the response and recovery phases.

The technical reports and submissions propose developing formal transition mechanisms shifting the building safety evaluation process from civil defence to building arrangements in local authorities. Several suggest placing them clearly within planning documents and/or relevant legislation. Some suggest setting out recovery mechanisms in civil defence within civil defence planning documents. Others believe that they should be placed within the building regulatory framework. The authors of the technical reports and submissions clearly believe that developing these mechanisms before they are needed is important, regardless of what format these mechanisms take.

2.3.1.1 The Definitions of Dangerous and Earthquake-prone Buildings in the Building Act 2004

A notice to fix issued under section 121 of the Building Act 2004 normally applies to dangerous buildings. Under the Building Act 2004, the definition of a dangerous building specifically excludes buildings that are earthquake-prone. Changes to the definition of a dangerous building in the Canterbury Earthquakes (Building Act) Order 2010 meant that buildings defined as dangerous could also be considered earthquake-prone, and vice versa. Christchurch City Council could therefore require owners to address the earthquake proneness of their building if it was damaged in the Canterbury earthquakes. There is some evidence that this approach caused uncertainty and delays for building owners, insurers and officials. For this reason, in October 2010 the Building Evaluation Transition team introduced a process that allowed building owners to carry out immediate repair work on their building and undertake strengthening work by 2013.

2.3.2 Roles and Responsibilities of Building Owners are Unclear

Several commentators suggest that the responsibilities of building owners were not clear following the Canterbury earthquakes. Normally building owners are responsible for emergency repairs on a building and any barricades erected while this work is ongoing. Ultimately, building owners are responsible for confirming that their building is safe after a disaster.

However, after the September 2010 earthquake civil defence emergency management and local authorities organised for assessments of buildings and setting up of cordons. It appears that there were issues with how the responsibility for the damaged building transferred from the Christchurch City Council to building owners. Some building owners waited for civil defence or council workers to evaluate their building, assuming that officials would inform them if any problems existed. The technical reports, submissions and other evidence the Royal Commission has heard to date indicate that people did not clearly understand that building owners are responsible for organising Detailed Engineering Evaluations.

2.3.2.1 Cordons

In addition, the technical reports, submissions and the evidence the Royal Commission has heard to date suggests that it was not clear who was responsible for setting up and maintaining cordons after the state of emergency ended. Normally, building owners are expected to organise safety fencing around damaged buildings or construction sites and manage these until the work on the site is complete. During the state of emergency in September 2010, civil defence workers set up a cordon around Christchurch's central business district. Civil defence workers then set up cordons around particular buildings or areas as they slowly re-opened access to the wider central business district.

After the state of emergency ended, the Christchurch City Council decided when cordons were to be placed, moved or dismantled. However, evidence the Royal Commission has heard to date indicates that building owners may have been expected to take over some responsibility for maintaining the cordons around their buildings, especially when they were carrying out repairs to the building but using council barricades and cordons.

The technical reports and submissions note that civil defence workers and the Christchurch City Council came under pressure from building owners, business owners, tenants and the wider public to remove cordons that impeded traffic and pedestrians, and to allow access to damaged buildings. Evidence the Royal Commission has heard to date indicates that some cordons were not wide enough to ensure public safety in the 22 February 2011 earthquake.

2.3.3 Barriers to Action

Some building owners were motivated to address the damage to their building after the 4 September 2010 earthquake. However, they were not able to carry out work on their buildings because of insurance issues, problems finding a contractor, or the need to consider heritage or other issues requiring resource and/or building consent [5].

2.3.3.1 Legislative Barriers

James Rotimi [9] contends that the Civil Defence and Emergency Management Act 2002, the Resource Management Act 1991 and the Building Act 2004, and their regulatory guidelines in particular, are a barrier to coordinated and unhindered recovery from a disaster. He also highlights the lack of cross linking between these statutes, and inadequate statutory powers to coordinate recovery efforts.

The technical papers and submissions identify meeting the requirements of the Resource Management Act 1991 as a significant barrier to recovery. Notices to fix under section 124 of the Building Act 2004 do not override the need for a resource consent under the Resource Management Act 1991 (for example, to repair a heritage building). The Canterbury Earthquake (Resource Management Act) Order 2010 let local authorities act immediately to fix a building without resource consent if they did the work themselves [2]. Section 129 of the Building Act 2004 also allows local authorities to act immediately to fix a building if it is an immediate danger. However, the threshold for determining immediate danger is recognised to be high. Local authorities have indicated that they do not feel empowered to take action to immediately fix and/or demolish non-earthquake-prone buildings that have been damaged in an earthquake and pose a danger.

Meeting the requirements of section 112 of the Building Act 2004 also has the potential to act as a barrier to recovery. Section 112 requires local authorities to make sure that any application to alter a building complies as near as practicable with the Building Code to ensure escape from fire and access to the building by people with disabilities. Building consents for repairs to buildings damaged in the 4 September 2010 earthquake would

normally trigger these requirements. In most cases, Christchurch City Council [5] decided not to require a building consent for interim securing work to avoid triggering section 112 of the Building Act 2004. This is because it was not always practical to immediately require that buildings meet these requirements, but work needed to be done to secure the damaged building.

The main issues appear to be with the consenting processes, rather than objections to the need to get a resource or building consent. These issues can be exacerbated by conflicting provisions between the Resource Management Act 1991 and the Building Act 2004; for example, the resource management framework takes a bottom up approach that favours community participation but the Building Code is developed at national level, to be applied uniformly [8].

Middleton and Westlake [2] note that groups presented arguments for and against developing a fast track process for granting resource consents for repair work on damaged buildings after the 4 September 2010 earthquake. Rotimi [9] suggests streamlining resource and building consent processes to facilitate recovery, including giving Ministers the power to override the consenting process for nationally significant consents. However, ideally local authorities should use scenario planning to develop guidelines for these processes well before an event. This would ensure that the right people were involved in the development of agreed processes.

2.3.3.2 Meeting the Requirements of Insurers

Issues with settling their insurance claims caused delays for owners attempting to repair their buildings after the September 2010 earthquake. Owners had little control over the time it would take to repair their buildings while still in negotiation with their insurers [4].

What insurers will pay for makes the decision about the level of strengthening local authorities require for a building after an earthquake more complex [3]. It appears that this issue arose after the Canterbury Earthquakes (Building Act) Order 2010 allowed the Christchurch City Council to require owners to ensure that their building was not earthquake-prone when they repaired any damage from the earthquake [4]. Insurers, however, debated whether their policies covered repair works to this level. To help manage these issues, Christchurch City Council[5] developed a protocol with insurers covering when their earthquake-prone building policy applied. Issues about what work insurance policies covered also arose after the Gisborne 2007 earthquake [5].

2.4 Issue: Understanding of the Placard System

The building evaluation process results in placards being placed on buildings. These placards indicate the status of the building. New Zealand uses colour-coded placards to indicate a building's status. Level 1 and Level 2 Rapid Assessments use the same placards. Red placard buildings are considered unsafe and should not be entered. Yellow placard buildings are identified as structurally damaged, and should only be entered for essential purposes. Green placard buildings have been inspected and there is no restriction on their use, although the placard suggests that further inspection may be needed. Although they are designed for commercial buildings, the same placard system is used for residential and commercial properties. North America, Japan, Indonesia, Greece and Italy use comparable colour-coded placards in their building safety evaluation processes.

2.4.1 Meaning of the Placards is not Clear

The technical reports, submissions and literature on building safety evaluations in New Zealand and overseas agree that the meaning of the placards is not well understood by the

public, building control officials and people in building safety evaluation teams. They contend that the wording of the placards is unclear and confusing. This is an issue because the placard is often the main way that tenants or the wider public know whether a building can be entered and used. In particular, green placards are frequently interpreted as meaning that the building is safe, and needs no further inspection. The placard's green colour may reinforce this view: people associate red with 'stop', yellow with 'caution' and green with 'no issues (go).' However, the New Zealand Society for Earthquake Engineering [6] guidelines, and the placard itself, states that building owners should obtain a detailed structural engineering review even if their building has a green placard.

Civil defence and local authorities used a variety of communications tools to let the public know:

- what the building safety evaluation process was;
- what the placards meant;
- the responsibilities of building owners; and
- how to deal with their damaged buildings.

These tools included material like flyers, posters and public meetings. Christchurch City Council also set up a web-based newsletter people registered to receive.

2.4.2 Detailed Engineering Evaluations

Because the New Zealand Society for Earthquake Engineering [6] guidelines focus on the Rapid Assessment phase of the building safety evaluation process, they do not describe exactly what is involved in carrying out a Detailed Engineering Evaluation. In addition, the green placard recommends that owners obtain a "detailed structural engineering assessment" [5], not a Detailed Engineering Evaluation (as described in the New Zealand Society for Earthquake Engineering [6] guidelines for building safety evaluations). It is not clear what processes engineers used when carrying out Detailed Engineering Evaluations between 4 September 2010 and 22 February 2011.

2.4.3 Purpose of the placards is not clear

Not understanding their meaning reflects a lack of understanding about the purpose of the placards and the building safety evaluation process as a whole. The building safety evaluation process is designed to triage the structural damage to buildings after a disaster. In the rapid assessments phase, the process is designed to:

- confirm where the damaged buildings are concentrated;
- indicate whether to restrict access to damaged buildings; and
- start the gathering of data on building damage to inform response and recovery decision making [3].

Officials and building owners use the placards to prioritise which buildings need a more thorough engineering review. For example, evaluators were directed to carry out a Level 2 Rapid Assessment if a yellow placard was placed after a Level 1 Rapid Assessment.

Buildings are assessed for damage to ensure that they do not pose an immediate threat to the safety of the public using them. It is not clear if, or when, the placards indicate the long-term safety of the building for reoccupation beyond initially managing access to damaged buildings.

The technical reports noted that because the public, building control officials, and people working in other agencies misunderstood the building safety evaluation process and the placards, they applied them to other processes inappropriately. For example, welfare agencies used the placards to prioritise access to emergency financial assistance. Westlake and Middleton [2] suggest that giving the placards a financial value they were not designed for could have led to people changing placards themselves or abusing the assessment process. They note that some evaluators debated what to placard a home depending on the owner's insurance settlement or need to move out, rather than the safety of the building.

According to the New Zealand Society for Earthquake Engineering [3], establishing clear criteria and processes for when to re-occupy a building after an earthquake is a feature of best practice for building safety evaluation processes. They suggest considering the concept of 'interim occupancy' for green and yellow placard buildings. Some access to the building would be possible, but full occupancy should only follow a further engineering assessment of the building after the rapid assessment process but before long-term re-occupancy. Japan's Post-earthquake Damage Evaluation and Rehabilitation guidelines are specifically designed to determine how a building can be used temporarily after repair but before full, long-term, earthquake strengthening. They have criteria that tag occupancy to observed damage and residual seismic capacity calculations [10].

Hare and Galloway [11] also suggest developing a process to determine when a building is safe for re-occupation. They believe that green and yellow placards should only be placed on buildings after a Level 2 Rapid Assessment; these placards allow re-occupation of the building (or parts of it). Level 1 Rapid Assessments should only identify dangerous buildings and evaluators should carry out Level 2 Rapid Assessments on the rest of the buildings they looked at. Hare and Galloway [11] propose developing a matrix tool matching the damage to the building, information of how it was expected to perform in an earthquake (gathered before the event) and re-occupancy.

Establishing a clear process for when to re-occupy a building is important because the Rapid Assessments are only designed to indicate the condition of the building for a short period. These assessments are quick and their results are inevitably coarse. This is appropriate for a basic sifting method, but a brief assessment of the damage to a building is unlikely to identify the capacity it has left to withstand damage from further aftershocks. For these reasons, the New Zealand Society for Earthquake Engineering [6] guidelines for building safety evaluations envisage that Detailed Engineering Evaluations will be carried out on all buildings after the state of emergency ends.

2.5 Green Placards

When and how officials should manage the assessment and repair of green placard buildings is unclear. Because the process is designed to prioritise which damaged buildings to focus on, buildings often fall out of the system as soon as a green placard is applied. Green placard buildings were not followed up during the rapid assessment phase unless their Level 1 Rapid Assessment form noted the need for a Level 2 Rapid Assessment. Although the Level 2 Rapid Assessment form for green placard buildings allowed evaluators to classify a building as requiring work, evidence the Royal Commission has heard indicates that civil defence workers and building control officials did not appear to have a formal mechanism for following up on a building able to be used, but in need of repair.

Green placards had no status after the state of emergency ended. The Canterbury Earthquakes (Building Act) Order 2010 only dealt with the status of red and yellow placard buildings. Consequently, Christchurch City Council had little interaction with the building owners of a green placard building after the building safety evaluation process transitioned from civil defence to local authorities.

Evidence the Royal Commission has heard indicates that after the Canterbury earthquakes, networking was a key tool in obtaining and disseminating information about the damage to a building and its status. This was particularly important for green placard buildings, as local authorities had no way of finding out information about these buildings after the state of emergency ended. For this reason, local authorities encouraged building owners and engineers to let them know if a detailed evaluation showed up any problems that would affect the building's status.

2.6 Need for Detailed Engineering Evaluations

The New Zealand Society for Earthquake Engineering [6] guidelines for building safety evaluations state that building owners are responsible for organising Detailed Engineering Evaluations. Middleton and Westlake [2] suggest that local authorities are able to require owners to provide these after the September 2010 earthquake. However, the Christchurch City Council [5] states that they could not legally require building owners to order a Detailed Engineering Evaluation of their building. It is not known how many owners did authorise engineers to carry out full evaluations of their buildings. Evidence the Royal Commission has heard to date suggests that some building owners did not follow up on their engineer's initial recommendation to carry out a more detailed evaluation of their building.

Under section 51 of the Canterbury Earthquake Recovery Authority Act 2011, the Canterbury Earthquake Recovery Authority can compel building owners to provide a Detailed Engineering Evaluation. However, the technical reports, the literature on building safety evaluations and submissions note that a full engineering evaluation, using the methods and approaches engineers employ in normal circumstances, is both costly and time-consuming. They ask whether this is feasible without taking months, and question whether buildings can be left unoccupied in the meantime without significant economic and social impacts. The international literature also recognises that requiring a full engineering evaluation of all buildings after a disaster may be unrealistic.

Other countries have developed engineering evaluations that are more detailed than a rapid assessment, but less than a full engineering evaluation. This is the Detailed Engineering Evaluation in the United States building safety evaluation system [12]. Japan's Post-earthquake Damage Evaluation and Rehabilitation guidelines are another example of this approach [10].

When they first released their building safety evaluation process guidelines in 1998, the New Zealand Society for Earthquake Engineering [7] mirrored the United States approach, where the Detailed Engineering Evaluation sat between the Rapid Assessments and a full Engineering Evaluation. However, only the 2009 version has Detailed Engineering Evaluations that should meet "...insurance and restoration requirements under the Building Act 2004" [6].

2.7 Capability of Engineers

The international literature on building safety evaluation processes indicates that the quality of the assessments made by individuals can be inconsistent. Some assessments are overly conservative, but others allow access to buildings that are unsafe. Saito and Thakur [13] note that moderate damage to a building can be particularly difficult to evaluate. Submitters and commentators in New Zealand noted that the quality of the building safety evaluations in Christchurch varied, although some stated that they thought the poorer-quality assessments tended to be too conservative.

Other countries using similar building safety evaluation frameworks include descriptions of the damage that each type of building is likely to experience in an earthquake in their guideline documents. Some also produce field manuals setting out these damage descriptions; evaluators carry these when evaluating buildings after a disaster. New Zealand has yet to develop a field manual for building safety evaluators.

2.7.1 Carrying out Detailed Engineering Evaluations

The engineers engaged by building owners to carry out Detailed Engineering Evaluations were expected to use their existing knowledge and refer to New Zealand and United States materials if they needed to. However, both the international literature on building safety evaluations and the New Zealand Society for Earthquake Engineering [8] guidelines on how to assess whether a building is potentially earthquake-prone (used before a disaster) indicate that many engineers may not be sufficiently skilled in this area. Engineers need to assess how individual structural elements affect the overall response of the building, which requires considerable engineering judgement. The processes used to assess the structural performance of a building in an earthquake are different from the processes used when designing buildings. Traditionally, engineers have assessed how a building would perform in an earthquake by attempting to invert the design process. This has not been successful because the current capacity design processes for new buildings are deterministic in nature. For these reasons, the New Zealand Society for Earthquake Engineering [8] guidelines on how to assess whether a building is potentially earthquake-prone recommend that the assessments should only be carried out by a chartered professional engineer with experience in earthquake engineering. The international literature indicates that a failure to ensure this may also explain why the quality of initial assessments made after an earthquake can be inconsistent.

Both the New Zealand Society for Earthquake Engineering and the Department of Building and Housing believe that engineers need more training on how to identify structural weaknesses after an earthquake [2]. When describing the recent changes to Japan's guidelines for quantitatively assessing the damage to a building after an earthquake, Nakano et al. [10] state that "...a technical guide that may help engineers find appropriate actions required for a damaged building is most essential." The Department of Building and Housing is currently drafting guidelines [14] for engineers to use when carrying out Detailed Engineering Evaluations. Drafts of the guidelines are publically available on the Structural Engineering Society New Zealand website.

2.7.2 Methods Engineers Use

As a result of the hearings it has held to date, the Royal Commission is interested in learning more about how engineers evaluate buildings when carrying out Rapid Assessments and Detailed Engineering Evaluations. Looking at what methods, frameworks and methodologies engineers use is important because different skill sets are needed to respond to particular disasters. The differences between locations and the varying building stock (for example, with different ages, sizes, construction and condition) in different places also affects what skills people need when assessing the damage to buildings and structures. For example, after the 22 February 2011 earthquake geotechnical engineers undertook Rapid Assessments of buildings in the Port Hills, evaluating the danger to them from unstable cliff-faces and falling rocks.

Evidence the Royal Commission has heard to date in relation to unreinforced masonry buildings that failed in the 22 February 2011 earthquake causing death suggests that allowing occupancy of such buildings after a significant earthquake in reliance only on a damage-based assessment may be problematic.

2.7.2.1 Damage-based Assessment

Most of the countries with similar building safety evaluation systems assess the damage the earthquake has done to the building. These damage-based assessments identify those buildings that are obviously unsafe and therefore at risk of collapse in an aftershock. From October 2010, damage-based assessments in Christchurch were carried out by evaluating whether the condition of the building is no worse than it was before the 4 September 2010 earthquake. This is the approach taken by engineers in Japan when they assess the capacity of the building to withstand aftershocks in a detailed engineering evaluation [10].

Most countries also assess the danger from the non-structural parts of a building, such as hazards like parapets that could fall on passers-by in an aftershock. Some countries' building safety evaluation systems also look at the danger a building might pose to its neighbours and consider whether other hazards like broken utility lines, asbestos or chemicals are present.

Some researchers suggest that evaluators use particular models and methods when carrying out damage-based assessments. Several propose using the European Macroseismic Scale (EMS) in damage-based assessments. EMS grades a building from 0 to 5 depending on the intensity of the damage described. The damage within each grade has been set by looking at how particular types of building are damaged in an earthquake.

At the 2004 World Conference on Earthquake Engineering, Carreño et al. [15] describe their user-friendly computer programme that supports the decision-making of building safety evaluators. This model was developed using data from building safety evaluation system like New Zealand's.

2.7.2.2 Seismic Capacity Assessment

The building evaluation systems in Greece and the United States both recommend assessing the seismic capacity of buildings damaged in an earthquake, although only Greece does so explicitly. Engineers would do so as part of the damage-based assessment rather than doing a full evaluation of the seismic capacity of the building. This is because it is not generally easy to fully identify the residual capacity a building has to withstand aftershocks quantitatively from quick inspections. In Japan, engineers carrying out the equivalent of a detailed engineering evaluation also calculate the residual seismic capacity of a building after an earthquake, within a damage-based assessment.

Calvi et al [16] discuss how seismic vulnerability assessment methodologies have developed over the past 30 years, including how to assess the residual capacity of buildings after an earthquake. In Turkey, the rapid assessment of reinforced concrete buildings after recent earthquakes there has led to some researchers proposing building safety evaluation methods that define the lateral load resistance systems using mathematical modelling. In 1997, Hassan and Sozen [16] suggested using a Priority Index to define the vulnerability of buildings damaged in an earthquake. Buildings are given a number that is a function of the wall index and column index. Yakut's [17] 2004 paper suggests using a Capacity Index to evaluate buildings after an earthquake. This index looks at the design elements and construction of the building, focussing on its lateral load resisting structural system. In 2005, Ozdemir et al. [16] adapted the Japanese Seismic Index Method to develop a Seismic Safety Screening Method. This rapid seismic safety evaluation method gives a building a seismic index value that is a function of its strength and ductility, and compares this with a value that represents a region's seismicity. Luco et al. [17] suggest developing a similar model that is also adapted to account for aftershocks.

These researchers suggest that officials could use these methods to help civil defence workers' decision-making, prioritise which buildings need further evaluation, and determine when to allow people to reoccupy a building after an earthquake. Calvi et al. [16] believe that they could play an important role in prioritising buildings for seismic strengthening. However, Calvi et al.[16] also believe that the use of such methods in large-scale seismic risk models is limited because evaluators need to consider buildings individually in a deterministic way, which is not economically feasible.

2.7.2.3 Anticipating the February 2011 Earthquake

The Canterbury earthquakes were unusual seismic events: the shaking in Christchurch's central business district in the 22 February 2011 earthquake was more intense than the shaking in the larger 4 September 2010 earthquake. A building is usually expected to withstand a smaller aftershock if it came through a major earthquake with little structural damage. Consequently, building safety evaluation best practice does not plan for this scenario. Evidence received by the Royal Commission to date indicates that engineers are also unlikely to have evaluated buildings expecting an aftershock to do more damage than the main shock. However, Luco et al. [17] describe models developed overseas that specifically account for aftershocks when determining if a building can be re-occupied.

2.7.3 Training of Engineers

The technical reports, literature on building safety evaluations and submissions raise questions about the level of training engineers need to carry out both Rapid Assessments and Detailed Engineering Evaluations after an earthquake or other disaster. However, it is not clear how much training and education engineers need, or who should provide this training. The need to respond if a disaster occurs must be balanced with the costs of training people and planning for an event that may only occur infrequently; the challenge is to provide meaningful training when the likelihood of this training being used is low.

Developing and delivering training helps build the capability to carry out a building safety evaluation process. Training endeavours to reduce variable quality and inconsistencies with placing placards and information recording. Pilot training resources were developed for the revised 2009 version of the New Zealand Society for Earthquake Engineering [6] guidelines. Most of the Christchurch City Council engineers and building control officials carrying out building safety evaluations after the 4 September 2010 earthquake had received this training. However, few of the volunteer engineers had received training on this process, or had previously used the New Zealand Society for Earthquake Engineering [6] guidelines. From 5 September 2010, members of the rapid assessment teams received a 30 minute briefing on the New Zealand Society for Earthquake Engineering guidelines and the process they were to follow. However, because of when they arrived and were deployed, not everyone received this briefing. Nevertheless, in their incomplete review of the civil defence response to the September 2010 earthquake, Middleton and Westlake [2] contend that the building safety evaluation process is well documented and understood by both civil defence workers and building safety evaluators.

Several submitters and commentators propose a training and warranting system for building safety evaluators similar to the system used in California. In contrast to New Zealand, volunteers in California must be formally registered and warranted as building safety evaluators with the California Safety Assessment Program. Their registration as evaluators must be renewed every five years and they must attend training to keep it current. Engineers registering as building safety evaluators must be the equivalent of a chartered professional engineer.

The Royal Commission has released a discussion paper 'Training and Education of Engineers and Organisation of the Engineering Profession', and is seeking submissions on that paper by 27 July 2012.

3. Issues with the Development of the Building Safety Evaluation Framework

There appear to be several issues with the development of New Zealand's building safety evaluation process.

3.1 Mandate and Accountability for Developing the Building Management Process

Currently, it is not clear who is responsible for developing New Zealand's building safety evaluation process or associated guidelines. Works Consultancy Services (formerly the Ministry of Works) released New Zealand's first guidelines for developing a building safety evaluation process in 1991. Then, the New Zealand Society for Earthquake Engineering [7] essentially took responsibility for developing New Zealand's building safety evaluation process in 1998, when it released its guidelines. In 2008, the Department of Building and Housing established a reference group to feed into the Society's review of their guidelines. The New Zealand Society of Earthquake Engineering [6] released its new guidelines, endorsed by the Department, in 2009. Currently, the Department and the Ministry of Civil Defence and Emergency Management are revising the guidelines again following the Canterbury earthquakes. Local authorities have no legislative or regulatory obligations to use these guidelines and they cannot be enforced.

New Zealand's building safety evaluation process does not have a specific legislative mandate in either the Civil Defence and Emergency Management Act 2002 or the Building Act 2004. No central government agency is clearly responsible for supporting local authority planning. A formal organisational structure and management process for New Zealand's building safety evaluation process has not been developed at either national or local level. At a national level, little provision is made for monitoring the capability to carry out building safety evaluation operations, training or producing standard information.

Consequently, informal arrangements supporting the development of New Zealand's building safety evaluation system have developed. The technical reports and submission contend that the Civil Defence and Emergency Management Act 2002 and the Building Act 2004 provide some legal basis for the building evaluation process. The Department of Building and Housing has recently taken on a leadership role in supporting the development of the New Zealand Society for Earthquake Engineering guidelines and the building safety evaluation process as a whole.

The New Zealand Society for Earthquake Engineering [3] contends that a building safety evaluation process having a legal mandate that authorises its implementation in a range of circumstances is a feature of international best practice. This promotes the establishment of a central government focal point to guide and support local authority planning, another feature of international best practice. The central government agency would develop and maintain core components of the building safety evaluation system, along with common tools like training materials. It would also give the system a formal structure and provide resources to support local authority planning.

The technical reports and submissions recommend that New Zealand's building safety evaluation process be given a legal mandate. Some submitters and commentators recommend mandating the process through the civil defence legislation. This is because a building safety evaluation operation will be triggered by a disaster and the initial building safety evaluation operation is coordinated by civil defence workers. Others suggest placing it within the building regulatory framework, with the Department of Building and Housing as the lead agency. This is because the building safety evaluation process focuses on building safety and the Department has the building and engineering expertise to understand its technical aspects. Several submitters also suggest that a central government agency should be responsible for developing one building safety evaluation process for the whole country.

3.2 The Mobilisation of Engineers

The ability to carry out an effective building safety evaluation operation depends on the number of skilled people available. For this reason, effective planning for how to mobilise trained professionals at both local and national levels is important. In New Zealand, groups like the Institution of Professional Engineers New Zealand and the Building Officials Institute of New Zealand make their members available to assist after a disaster. The technical reports note that the Institution of Professional Engineers New Zealand led the mobilisation of engineers from around the country after the September 2010 earthquake. Local Government New Zealand arranged for workers from other councils to support local councils. Approximately 250 volunteers carried out building safety evaluations in Christchurch during the state of emergency, from 4 to 15 September 2010. Of these, about 75 engineers worked with the 25 Urban Search and Rescue engineers in the rapid assessment teams.

The technical reports detail how the response to the 22 February 2011 earthquake incorporated some of the lessons learnt about staffing and training issues after the 4 September 2010 earthquake. The building safety evaluation management team was better resourced than its September 2010 equivalent. It also implemented a formal roster to ensure that workers did not become too tired and therefore make mistakes. This, along with more workers, allowed the management team to support a wider range of activities conducted in parallel. Recognising the risk to the teams' safety due to the extent of the damage and ongoing aftershocks, only chartered professional engineers evaluated buildings in the Central Business District Red Zone. Chartered professional engineers are recognised as being more experienced than non-chartered engineers. For this reason, officials believed that they would be better able to assess the damage to a building, and therefore the risk to their team and ultimately the wider public, from on-going aftershocks. Non-chartered engineers had carried out building safety evaluations in the central business district after the 4 September 2010 earthquake [3].

3.2.1 Liability

When the New Zealand Society for Earthquake Engineering guidelines were reviewed from 2004 to 2009, engineering consultancies made it clear that they would not volunteer their workers for a building safety evaluation operation without a waiver of liability. A waiver would recognise that engineers are volunteering in an emergency situation, and that they would carry out their evaluations differently if they had more time. However, a waiver of liability could also potentially lead to variable quality with assessments. A large group [18] made up of government, industry and technical engineering societies concluded that Section 110 of the Civil Defence and Emergency Management Act 2002 was the best way to manage these concerns. This section provides protection from liability for damages or loss for engineers and other civil defence workers during a state of emergency, unless they acted in bad faith or were grossly negligent.

Applying section 110 means that New Zealand's building safety evaluation process can only be carried out during a state of emergency. The unwillingness of some engineers to do building safety evaluations following the 26 December 2010 aftershock without the protection of a liability waiver, because no state of emergency was declared, is a clear case of how having a waiver incentivises individual behaviour.

4. Building Safety Evaluation Models, Resourcing and Planning

Whether or not the current system is the right approach or model is a fundamental policy question this paper also asks. In addition to the Indicator Building system that developed in Christchurch after the 4 September 2010 earthquake, Vidal et al. [19] identifies the following ways to carry out building safety evaluations after an earthquake:

- earthquake damage scenario modelling;
- a detailed aerial survey by experts;
- damage mapping; and
- local reconnaissance teams with two or three members.

As well as looking at whether the right model was implemented, this discussion paper also discusses information management and pre-planning. The technical papers and submissions indicate that these could be critical factors for the successful implementation of a building safety evaluation operation.

4.1 Building Safety Evaluation Models

4.1.1 Technology-based Building Safety Evaluation Models

Scenario modelling to assess earthquake damage, aerial surveys, and damage mapping are usually carried out electronically and often rely on computer analysis. Scenario modelling involves looking at the characteristics of the building stock in an area and modelling what would happen in various disasters before the event. This modelling can be carried out on various levels. Researchers identify an area's building stock and research the likely damage to particular building types based on previous events. They may also assess individual buildings and aggregate this data to get the wider picture. After an earthquake, scenario modelling can be used to decide how to prioritise building evaluation operations; for example, evaluators could assess particular building types (like unreinforced masonry buildings) first.

Vidal et al. [19] describe how aerial laser-scanning by aeroplanes can be used to determine the damage to areas, or even to individual buildings. This data is fed into a computer for analysis, to inform officials' decision-making. Laser-scanning allows evaluators to gain a more detailed picture about where and how a building is damaged than traditional aerial scanning for damage mapping.

Damage mapping describes how civil defence workers compare landscapes, buildings and objects captured in photographs and maps before and after an event. It is increasingly carried out using high-resolution satellite imagery.

Remote sensing using radar and other active sensor systems is also used in damage mapping. Researchers are exploring the efficiency and effectiveness of installing remote sensors in individual buildings. Placed at critical structural points throughout the building, these sensors record the damage as a disaster occurs and send this information offsite for

computer analysis. If adopted widely, remote sensing could develop into a fully automated building safety evaluation process.

Generally, these approaches work better for assessing the overall damage following a disaster, rather than assessing individual buildings. This is because these methods tend to be less accurate when applied to a single building. Consequently, these building safety evaluation models tend to work better in places where there has been significant building collapse; aerial surveying and damage mapping have been used in Haiti, China, Turkey and Iran. Civil defence workers used these approaches to decide where to focus search and rescue operations, prioritise their building safety evaluation process, and to inform decision making about how to mobilise their workers.

Some countries have adopted building safety evaluation models that incorporate the use of computer-based analysis tools with local reconnaissance teams. Colombia has officially adopted Carreño et al.'s [15] computer analysis tool. China's building safety evaluation process sets out when evaluators are to remotely access a computer programme that helps them to calculate the damage and residual seismic capacity of a building after an earthquake. Chai et al. [20] suggest that the limited number of experienced engineers available in China to carry out evaluations prompted the development of this tool.

Avery and Berrill [21] have developed a semi-automated building safety evaluation model for New Zealand. Their model combines pre-event scenario modelling of individual buildings, analysing data from remote sensors in the building, and activating an assessment process building owners and their engineers have pre-arranged. They contend that this model will identify unsafe buildings that appear unscathed better than a visual inspection; reduce costs, as using remote sensing data is more accurate and less time-consuming than a visual inspection process; and minimise disruption because decision making will be better informed.

Technology-based building safety evaluation approaches rely on high quality digital information about the area, or individual buildings, being available before and after a disaster.

4.1.2 Local Reconnaissance Teams

New Zealand's building safety evaluation framework uses local reconnaissance teams to assess the damage a disaster causes to an area's building stock. This approach, which places colour-coded placards on buildings, first developed in Europe in the late 1980s. It is used in the United States, Japan, Italy, Greece, Colombia, Mexico and other countries.

4.1.3 The Indicator Building model

The Indicator Building model developed in Christchurch after the September 2010 earthquake. After the February 2011 earthquake, this model was expanded and formalised. Officials identify a specific set of buildings to check after significant aftershocks; these are the Indicator Buildings. If they are sufficiently damaged, officials may decide to revisit or re-start their building safety evaluation operation. The New Zealand Society for Earthquake Engineering [3] contends that this model proved invaluable for determining how to use the resources available to carry out building safety evaluations in Christchurch's central business district after significant aftershocks. This is because the process provides a rational decision making tool for officials.

4.2 Information management

Civil defence literature suggests that access to good quality information is a key component in making initial assessments of the situation and informing ongoing decision-making. The

New Zealand Society for Earthquake Engineering [3] recommends developing a database to receive and record information. In September 2010, an excel spreadsheet was developed to record the results of the Rapid Assessments. This became the basis for the information systems used when the responsibility for the building safety evaluation process transitioned to the Christchurch City Council.

Records for each building appear to have been kept according to its postal address. If a building has several entry points, (for example, where there are multiple tenancies), then the local authority may have several addresses for the same structure. These addresses may not be the same as the postal address or the street address for the building and/or tenancy. Commentators suggest that this may have led to issues with identifying buildings. After the 22 February 2011 earthquake, the Ministry of Civil Defence and Emergency Management did not manage the building safety evaluation data by address.

Issues also arise when buildings joined by a party wall act as a single structure in an earthquake or other disaster. Because the buildings are separate properties, each is treated individually. To address this issue, the Canterbury Earthquake Recovery Act 2011 allows the owners of two or more adjacent buildings to act together for their benefit.

When discussing information sharing within a civil defence context, Doyle and Johnston [22] contend that effective teams under high pressure commonly adopt a communication style characterised by expecting people to tell them the information they need to know, rather than team members explicitly asking for it. After the Canterbury earthquakes, networking was a key tool in obtaining and disseminating information about the damage to a building and its status. This was particularly important for green placard buildings, as local authorities had no way of finding out information about these buildings after the state of emergency ended. For this reason, local authorities encouraged building owners and engineers to let them know if a detailed evaluation showed up any problems that would affect the building's status.

Good networking and information sharing was also important after the 22 February 2011 earthquake, when geotechnical and structural engineers were evaluating the same site. Several submitters stated that inadequate information-sharing led to structural and geotechnical teams changing the placard assigned to a building; for example, structural engineers did not understand why the geotechnical team had assessed the building as dangerous and the placard did not say it was assessed for geotechnical reasons. This meant that evaluators had to revisit and replace placards at some dangerous sites.

Several submitters proposed using information technology tools to collect and analyse data on damaged buildings. Submitters proposed integrating together a variety of tools like portable personal computers (such as tablets, notebooks), GPS, and cellular telephones. Shibayama and Hisada [23] found that their electronic information management system, which was based on these tools, was more efficient than using conventional paper-based information gathering methods. This is despite practical issues with obtaining good quality digital maps and using portable personal computers. Technological advances should address these issues.

Like technology-based building safety evaluation approaches, electronically based information management systems should interface with existing electronic records. This may not be the case, even in first world countries. Although some local authorities have some building control records on microfiche or in digitised formats, not all records are kept electronically and stored offsite. In Christchurch, engineers and building owners reported not being able to access records as they were held in the Christchurch City Council's earthquake damaged building. It may therefore be worth exploring whether building records should be digitised and stored offsite.

4.3 Pre-planning for a Building Safety Evaluation Operation

The extent of planning in the three local authorities in the greater Christchurch area before September 2010 is unclear, although all three had taken steps to implement the New Zealand Society for Earthquake Engineering [6] guidelines for building safety evaluations. Some commentators indicate that the building safety evaluation process was planned immediately after the earthquake.

Under New Zealand's civil defence and emergency management framework, local authorities take the lead in responding to a disaster. The Ministry of Civil Defence and Emergency Management manages the response to large scale emergencies beyond the capacity of local authorities. Although the response to the September 2010 earthquake was officially under local control, commentators suggest that people outside of the region organised and led some parts of the response (including the building safety evaluation process). However, how much people from outside the Christchurch City Council led the response and the reasons they did so are unclear. It is also unclear which version of the guidelines was used after the September 2010 earthquake: the 1998 version, the revised 2009 version, or an unpublished 2010 version.

The New Zealand Society for Earthquake Engineering [6] guidelines recommend that local authorities plan their building safety evaluation process before the event. International literature on building safety evaluations also stress pre-planning how to implement a building safety evaluation operation, and this is best practice. However, the extent to which any lack of planning affected the response to the Canterbury earthquakes is unclear.

Appendix 1:
New Zealand Society for Earthquake Engineering Guidelines

Guidelines for carrying out structural assessments of the seismic resistance of existing building stock can be broadly defined in two categories, involving increasing levels of thoroughness and accuracy.

Building assessments in preparing for future earthquakes	Building assessments post-earthquake
Initial Evaluation Procedure	Overall Damage Survey or Initial assessment
Desktop study	Rapid Assessments (Levels 1 and 2)
Detailed Assessment	Detailed Engineering Evaluation

Confusion can arise in the types of structural assessments being used. There are many similarities and some overlap in these types of assessments.

1. Building assessments in preparing for future earthquakes

It is important to have agreed procedures for evaluating the seismic resistance of existing building stock. Their purpose is to determine the susceptibility of buildings to damage from earthquakes and to devise and implement structural improvements that will bring all buildings up to or above a predetermined minimum level. Evaluation of an existing structure requires not only knowledge to the current design standards but also additional experience of the potential limitations that older buildings have. These include material properties, methods of construction, potential weakness in form, and judgement on the significance of observed damage. The results of this evaluation is often expressed as a percentage of the standard required for a new building.

In 2006, the New Zealand Society for Earthquake Engineering released guidelines for assessing whether a building is potentially earthquake-prone to assist local authorities to prepare for future earthquakes. These guidelines are *Assessment and improvement of the structural performance of buildings in earthquakes: including Corregendum No1.*

2. Building assessments post-earthquake

In the immediate aftermath of a major earthquake, the Overall Damage Survey and Rapid Assessments are used as a basic sifting method for identifying the worst of the immediate hazards. For Rapid Assessments, evaluators do a quick visual assessment of the type and extent of a building's structural damage, and on that basis can post a green (inspected), yellow (restricted use), or red (unsafe) placard. The percentage new building standard is **not** calculated in this process.

The Detailed Engineering Evaluation is a similar assessment to a Detailed Assessment, with the difference being that there is an assessment on the effects of the damage caused by the recent earthquakes. A percentage new building standard may be calculated in this process.

In 2009, the New Zealand Society for Earthquake Engineering released the latest version of its guidelines for building safety evaluations. These guidelines are *Building Safety Evaluation During a State of Emergency: Guidelines for Territorial Local Authorities.*

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