A survey of the effect of institutions on disaster outcomes following earthquake

Report to Government Office for Science: Foresight Disasters project.

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Published online March 2015 at: www.carltd.com/downloads

Reference:


**Key recommendations for institutions and scientific advancements**

*Preventable deaths* should be the key message to all institutions involved in disaster management. Implementation of code and effective preparedness programmes save lives and the seismic community need to work together to identify and prioritise actions and research to help prevent deaths, physical destruction and reduce social and economic impacts.

The following recommendations are established from lessons learnt from the three surveyed earthquakes in this review. It follows the classification of institutions as suggested by North, 1990.

1) formal rules/laws,
2) organisational structures e.g. buildings, premises.
3) informal rules e.g. behaviour.

**Rules and Regulations**

1. Engineering analysis and scientific research needs to be used to modify building codes, risk maps and land use zoning. In depth studies of actual buildings after earthquakes provide valuable information for the appraisal of the adequacy of codes and regulations and need to be standardised and promoted.
2. Upgrade the building stock in earthquake-risk areas by promoting the application of the earthquake code, and progressive replacement of older building stock, with priority for schools and highest-risk areas.
3. Revise building codes to include more realistic estimates of the ground shaking levels which need to be designed for; and to include design for post-event repair as a standard design approach.
4. Explore mechanisms to encourage building owners to adhere rigorously to existing building codes, e.g. adoption of mandatory earthquake insurance schemes. In poorer earthquake-risk countries, promote capacity-building to support building code enforcement.

**Organisational Structure**

5. Promote equality. There is a tendency to focus efforts on areas of political and commercial importance, e.g. Istanbul, which has the same hazard as Van. The lack of awareness of marginalised populations is detrimental to disaster outcomes.
6. Emergency plans need to be redundant, flexible, and detailed to handle the unexpected in very large disasters. In addition different plans are needed to address the needs of rural and poorer regions, even in the same country.
7. Improve robustness of tsunami warning technology and apply tsunami awareness training to transient populations.
8. Recognise the competing personal and professional demands that are made on staff after a disaster and include contingencies in emergency plans.
9. Recognise vulnerabilities in communication and power systems and make comprehensive backup plans to avoid complete communication collapse.
10. Strengthen local capacities and synergies with governmental and non-governmental organisations
11. Coordination of the many ordinary and extraordinary organisations involved in both relief and recovery needs to be defined and rehearsed well before any disaster e.g. ShakeOuts.

**Behavioural norms/social and cultural factors**

12. Promote a “safety culture” of earthquake awareness and mitigation action in areas where it is missing.
13. Educate the population, comprehensively and continually, about what will happen during the event.
14. Education is crucial but practical drills are as important. Comprehensive earthquake drills including joint Government, private sector, NGO, emergency responder, and community exercises are essential before the event to rehearse evasive actions and management procedures.
15. Develop and improve seismic loss estimation models to provide realistic scenarios for planning community-based resilience.
16. There needs to be comprehensive public consultation on the strategic options for change and stakeholder involvement in strategic planning decisions.

**Recommendations for scientific advancement**

1. **Form alliances in scientific research.** Seismologists, engineers, urban planners, public health specialists and emergency doctors need to work together to help prioritise research. For example, understanding the ways buildings collapse and the causes of deaths and types of injuries to help guide S&R personnel, prepare emergency rooms and stockpile aid. Understanding will also help target methods of strengthening buildings.
2. Develop and test **cost-effective methods** for the strengthening of older, historic buildings.
3. Rethink the concept of design: **design for repair** in developed country and **for life safety** in developing countries.
4. Develop techniques for **systematic post-event surveying** of affected populations and buildings to determine levels of mitigation action carried out pre-event and their relationship to prior institutional actions, and institute an international programme of conducting such surveys.
5. Research to **define key indicators** to monitor recovery, for example construction of permanent homes and the restitution of livelihoods and local economies.

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**1. Introduction**

Recent earthquakes in Haiti, New Zealand and Japan are painful reminders that damage and death from a natural disaster often has much less to do with the strength of an earthquake than they do with the preparedness, or lack thereof among institutions and the affected population. There is no evidence that earthquakes themselves are becoming stronger or more frequent but with the ever increasing global population concentrating in megacities, the outcomes of earthquakes could in the future be much more severe unless we take action.
Figure 1 shows the locations of the world’s megacities housing more than two million people and their proximity to zones of the high plate boundary strain rate, as calculated by Kreemer et al., (2003). Areas of high strain (in brown) are where recurrence intervals of large earthquakes are of the order of 100 to 200 years.

Figure 1 shows the locations of 194 supercities (each with a 2005 population exceeding 2 million) and their proximity to zones of high plate boundary strain rate (Kreemer et al., 2003). (diagram from Bilham, 2009).

For earthquakes, which cannot be predicted, the best strategy is to focus on the four phases of the Disaster Risk Reduction (DRR) Cycle and control the consequences by mitigation strategies and preparedness programmes.

This report presents a survey of the effect of institutions on disaster outcomes following recent earthquakes, based on the four phases of the DRR cycle. The review will start with a brief description of the three selected earthquakes. The events have been chosen as the recorded ground motions were similar, though for the Chile event, a much larger area was exposed. This is followed by four sections focusing Mitigation, Preparedness, Response and Recovery. For each earthquake, the effectiveness of the respective institutions in delivering the four elements of the DRR cycle is examined using evidence from literature and personal experience on post-earthquake reconnaissance missions. Where possible, ways to improve the outcomes of the earthquakes are explored and suggested.

The last section of this review concludes with lessons learnt from the three events.

2. The Selected Earthquakes
2.1 The Maule, Chile Earthquake of 27th February, 2010
The Maule Chile earthquake of 8.8Mw occurred at dawn (3.34am) on the 27 February 2010 at a depth of 35km. The epicentre was located 60km southeast of the nearest city in the Maule region (400km south of the city of Santiago). The earthquake generated a tsunami, affecting 500km of coastline, where a section of the earth’s crust called the Nazca Plate subducted under the South American Plate.
The map below is taken from US Geological Survey (USGS) and shows the intensity of ground motions, according to the Modified Mercalli Scale\(^1\) (MMI) and the exposure of the affected area in grey (for more information, visit http://earthquake.usgs.gov/earthquakes/pager/). An important point to note here is the size of the affected area. The same maps will be shown for the other two earthquakes in this report for ease of comparison.

![Map showing ground motions and exposure](image)

**Figure 1:** ShakeMap showing the level of ground shaking, population exposed and exposed cities (from USGS PAGER [http://earthquake.usgs.gov/earthquakes/pager/events/us/2010tfan/index.html](http://earthquake.usgs.gov/earthquakes/pager/events/us/2010tfan/index.html)) for the Maule, Chile 2010 event.

The maximum MMI was VII, as depicted by the orange contour (USGS); the right hand photo shows a recently completed 23-story Torre O'Higgins 241 office tower in Concepción suffered partial storey collapses (source EERI).

The earthquake and successive tsunami caused hundreds of deaths and serious damage to homes and other infrastructure, primarily in the Maule and Bío Bío regions. Since the earthquake happened in the middle of the night and on a weekend, most people were asleep in their homes. In total, 521 people were killed with 56 still considered missing and 124 of the deaths were attributed to the ensuing tsunami. Nearly 370,000 buildings, equivalent to 11% of building stock in the affected area were destroyed or damaged.

**2.2 The Canterbury, New Zealand earthquake sequence from September 10, 2010**

On September 4, 2010, a 7.1Mw struck the Canterbury Plain region in New Zealand’s South Island but it caused no fatalities though many of the unreinforced masonry building in the Central Business District (CBD) suffered damage. The Canterbury Plain is a region of relatively low seismicity in New Zealand and the structure that ruptured was a previously unmapped fault (Gledhill et al., 2011). Compared to the average New Zealand aftershock decay model, the aftershock sequence was relatively under-productive for the first 5 months until February 22, 2011, when a Mw6.3 aftershock occurred 7 km northwest of the city of Christchurch and caused 185 deaths and over 7,000 injuries. Over 70% of the 185 confirmed deaths are attributed to the collapse of two mid-rise reinforced

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\(^1\) For more information on the Modified Mercalli Scale (MMI) and the colour scaling, refer to [http://earthquake.usgs.gov/learn/topics/mercalli.php](http://earthquake.usgs.gov/learn/topics/mercalli.php)
concrete (RC) office buildings in the CBD from this lunchtime event. A ground shaking and exposure map from the USGS and a picture of the collapsed Canterbury Television building is shown in the figure below. 75% of the occupants in this 6 storey building died.

![ShakeMap and Canterbury TV Building](image)

**Figure 2**: ShakeMap showing the level of ground shaking, population exposed and exposed cities (from USGS PAGER) for the Christchurch, NZ earthquake in 2011 source: NZ Herald. The maximum MMI was VII, as depicted by the orange contour.

### 2.3 The Van Earthquake of 23rd October 2011

A 7.1 Mw earthquake struck eastern Turkey near the city of Van on Sunday, 23 October 2011 at 13:41 local time. This was followed by a 5.6Mw earthquake on the November 9th, which brought down a hotel housing international relief workers. The 23 October earthquake killed 604, wounded more than 4000, and left tens of thousands homeless. The second earthquake killed 40 people. In total, 14,000 buildings were deemed uninhabitable from the two earthquakes.

A ground shaking and exposure map from the USGS of the 7.1Mw Van earthquake and a picture of the collapsed buildings in the town of Erciş are shown in Figure 3.
3. **Earthquake Mitigation**

Earthquake risk differs from other natural hazard risks in two basic ways, which fundamentally affect the appropriate mitigation strategy. First, earthquakes occur largely without warning, and therefore protection of the population by means of warnings and evacuation is not possible. The earthquake will occur when people are carrying out their normal daily occupations, at school, at work, in the home or travelling and protection must be provided in these locations. Secondly, the vast majority of deaths and injuries in earthquakes occur because of the collapse or destruction of buildings; and therefore mitigation strategies need to focus on ensuring that buildings in earthquake-prone areas are able to resist the largest likely ground-shaking (and any other associated effects, landslides, liquefaction, fire, tsunami). The centrality of this basic strategy for earthquake risk mitigation is overwhelmingly supported by the research literature (Coburn and Spence, 2002, Bolt, 1999, Dowrick 2003), According to Comerio (2004), all earthquake risk mitigation strategies fall into one of the following four categories:

- Land-use regulation
- Building codes and building-for-safety measures
- Public awareness-raising
- Insurance

**Land-use regulation** can be used (as in Turkey, Gülkan 2011) to ensure that urban development does not take place in the highest-risk locations e.g. on soil deposits which will amplify ground motions, in locations potentially subject to landslides or tsunamis, or close to known active fault-rupture zones. Due to the twin pressures of land-shortage and land speculation, even if land-use regulations have been adopted in the past they have often been ineffective (Johnson, 2011).

Formal **building codes** are documents which define, for different methods of building, the forces which should be designed for, the arrangement of the structural elements, and the quality of
materials and workmanship required to provide adequate resistance to the earthquake likely to be experienced in a building’s lifetime. Although nearly all countries have earthquake design codes, they are not always mandatory, even for multi-storey apartment buildings; and even where they are, they are often not adequately enforced, both because there is a lack of trained engineers who are able to implement them in design; and because local authorities do not have the capacity, or the will, to exert the kind of supervision and control over the building process which is needed, creating opportunities for corruption (Johnson 2011, Gülkan 2010, Bilham 2009). An alternative to formal codes are informal community-based approaches to building control which recognise the variety of local materials that are likely to be used, the capacity of the local builders largely responsible, and aim to provide simple, easily understood rules of size, materials, wall thickness, opening positions etc., and recognise the need for training programmes to develop the necessary understanding and skills. (Coburn et al., 1994).

**Public awareness** is an essential element of both these strategies. Whether the formal or informal approach is to be used, success has been found to depend crucially on the extent to which owners and occupants themselves understand the earthquake risk, and are prepared to insist on earthquake-resistant design being incorporated into the buildings they will occupy (Olshansky, 2005). Experience of a recent earthquake is by far the most effective means to build such public awareness, but many institutional actions including school programmes, earthquake-awareness days, or large-scale earthquake simulation events can be used to help build a “safety culture” (Comerio 2004, Coburn and Spence 2007).

**Earthquake insurance** is potentially a very important component of earthquake risk mitigation. Not only does earthquake insurance provide, for individual building-owners, the funding needed for post-disaster recovery and reconstruction, thus building community resilience; but it can also be an effective instrument for encouraging pre-event risk-mitigating behaviour through linking insurance premiums to building quality or to the application of a building code. In countries where insurance penetration is low, various organisational actions can be taken to stimulate its take-up. At the household level, micro-insurance is one option currently being developed (Stojanovski et al., 2010); while Earthquake Catastrophe Bonds can be used by Governments as an alternative funding mechanism to provide funding for relief and recovery (SwissRe, 2012).

### 3.1 Global progress in earthquake risk mitigation

In a recent survey of the successes and failures of earthquake risk mitigation since 1960, Spence (2007) distinguished four groups of countries. The **success stories** were those countries (USA, Japan, and New Zealand) which had made clear and effective progress in tackling earthquake risk. A second group (including most of the European countries), the **slow progressers** had made some, but limited progress partly because of low public awareness. A third group of poorer countries the **movers**, were found to have made a great deal of progress in recent years, through a combination of experience of recent earthquakes, and rapid economic development (Turkey, China and Colombia were in this group). In a fourth **growing risk** category was a group of relatively poor countries (including Iran, India, Nepal, Algeria) where in spite of dedicated work by many dedicated professionals, little was being done at a national level to counter the growing risks from uncontrolled urbanisation. Figure 4 shows one measure of the relative risks reported in the survey, the proportion of the national building stocks in the four groups considered to be “unsafe” (i.e. likely to be seriously damaged or
collapse in the event of a foreseeable earthquake). While in the success stories, typically less than 10% were considered unsafe, in the growing risk countries up to 90% of the building stock was considered unsafe.

![Figure 4: Proportion of unsafe buildings in national building stocks in 25 countries/regions (based on Spence 2007)](image)

3.2 Limitations of current mitigation research

One limitation in much research on earthquake risk mitigation is the difficulty of producing clear definitions of disaster outcomes. Metrics frequently used to measure overall outcomes include numbers of deaths and injuries, economic losses, numbers of houses or buildings destroyed, and numbers of homeless. This data is commonly derived from either the EMDAT database of CRED (www.emdat.be) or Munich Re NatCat Service (www.munichre.com) databases. Apart from numbers of deaths caused, all of these metrics suffer from lack of precision in the definition; and all of them are derived not from field research, but from official government or relief agency figures which may be distorted. To investigate impacts of mitigation activity, cohort studies among victims or those vulnerable to disasters are often used, for instance to investigate causes of death and injury (So 14WCEE, Petal, 2011), the influence of socio-economic and demographic variables on disaster outcomes, or individual mitigation responses to various potential strategies (Rossetto, 2011). But such studies are not regularly carried out, tend to be on a relatively small scale, and for a variety of reasons it is difficult to make them truly representative of the populations at risk (So, 2009).

Similar post-event cohort studies of samples of affected buildings have been widely used to define the relative vulnerability of different classes of buildings (eg reinforced concrete vs masonry), and these have led to a relatively robust classification of building vulnerabilities in many countries, which can be used as a basis to define and test apparent improvement in building standards over time (Coburn and Spence, 2002). Nevertheless, methods to test the overall impact of large-scale government policy initiatives against disaster outcomes remain elusive, not least because of the infrequency of events providing testable data.

3.3 Mitigation Experience in recent events

*The Canterbury, New Zealand earthquake sequence from Sept 10 2010*

New Zealand has long been regarded as being among the success stories in earthquake risk mitigation. Its earthquake design codes, based on local research and the first to adopt the capacity design concept, are among the most advanced in the world, and the level of enforcement in new buildings has been high. New Zealand was the first country in the world to start a compulsory
programme of identifying and strengthening older “earthquake-risk buildings”, but recent progress in this area has been slow. Although there have been few destructive earthquakes the Napier earthquake in 1931, New Zealand’s public awareness of earthquake risk and the need to counter it is very high (Dowrick 2003, Meggett 2006); and a compulsory national insurance scheme (EQC) for householders has been in place for many decades, which includes requirements for minimum standards of building, leading to a progressive reduction of the worst risks.

In spite of this risk mitigation context, the impact of the Canterbury earthquake sequence starting in Sept 2010 was very severe. Partly this can be attributed to characteristics of the ground motion and the sequence of shocks, which imposed much higher structural demands than the earthquake code allowed for (Kam et al., 2011). Also, a great deal of the damage was concentrated in the older masonry structures which form the characteristic core of Christchurch (Ingham et al., 2011), and was exacerbated by widespread ground liquefaction, and by the frequency of aftershocks with a damaging level of ground motion. It could be said that given these extreme conditions, the performance of most building structures was good: even though they suffered much damage, loss of life was relatively low (the principal aim of the design codes), and largely concentrated in two older reinforced concrete structures which would be due for strengthening under current regulations. Additionally, insurance payouts will enable most owners to repair or rebuild their damaged buildings. Nevertheless, in terms of the overall economic cost, the Canterbury earthquakes, with about $15bn loss, of which 80% is insured (SwissRE, 2012), rates as among the most costly to date; and the cultural cost, through the loss of perhaps 90% of the entire Central Business District (Marriott, 2012), including the iconic late 19C cathedral, is huge. Lessons for future earthquake risk mitigation are many: they will certainly include developing new building regulations and codes which allow both for the higher ground motions which must now be expected, but also require “design for repair”, not just for life safety. New rules will certainly be needed to speed up strengthening of older earthquake risk and historic buildings (throughout New Zealand); and new land-use requirements restricting construction in areas subject to liquefaction. How these changes are adopted in New Zealand will provide valuable pointers for other countries.

The Maule, Chile earthquake of Feb 27th 2010

Chile was not one of the countries reported in the earthquake mitigation survey described above, but like New Zealand, should be counted among the “success stories”. Its location along the coast adjacent to the subduction zone boundary between the Nazca and South American Plates has resulted in many strong earthquakes in the last 70 years, those in 1940 and 1960 having been particularly devastating. Overall along the Chilean coast there have been 13 earthquakes of magnitude 7.0 or greater since 1973. (USGS, 2012). As a result, the population has a high awareness of the earthquake risk. Earthquake codes, first introduced in 1928, have been regularly updated, and the implementation rate in modern buildings has been high. In addition, Chile has a law that holds building owners liable for the first 10 years of a building’s life for any losses resulting from inadequate application of the building code during construction. This law was cited as the prime reason for the good performance of the engineered structures (ARC, 2011).

In rural areas, the traditional practice of building in adobe construction was prohibited since the 1960 earthquake, and masonry construction is permitted only if reinforced or confined masonry is
used. There has also been a longstanding programme of strengthening older masonry buildings of historic importance.

For tsunami protection a warning system is in place, and in some areas, waterfront buildings were designed to survive tsunami impacts. Chile does not have a compulsory national earthquake insurance scheme, but residential insurance penetration at 0.03% of GDP is at a comparable level with Japan and California (SwissRe, 2012), and commercial insurance penetration is much higher.

As a result of this mitigation work, the impact of the 27th Feb 2010 earthquake, although severe, was much less than it might have been. Given the magnitude of the earthquake, the strength of the ground shaking, and the very large areas affected by strong ground shaking, the number of collapsed buildings, and the death toll from building collapse was relatively small. Most modern buildings survived without collapse (although there was widespread damage). A large number of older unreinforced masonry buildings were destroyed in the earthquake though many of these were already abandoned (EEFIT, 2010). The economic loss from this event was $30bn of which 27% was insured (SwissRe 2012).

*The Van, Turkey earthquake of 23 October 2011.*

Turkey was categorised as one of the *movers* in the 2007 survey, on account of the significant progress in earthquake mitigation achieved following the 1999 Kocaeli earthquake (Gülkan, 2011). A good modern earthquake code has been in place from 1998, and some progress is being made towards better implementation of standards through improving local authority capability and through the training of well-qualified earthquake engineers; land use legislation is being used to prohibit construction in high-risk areas. Public awareness is high, particularly in the Marmara Sea and Istanbul regions where the 1999 earthquake was strongly felt. Some strengthening of existing high-risk public buildings such as schools has been taking place (Gülkan, 2008). In addition, a national earthquake insurance scheme, DASK (theoretically, but not effectively, compulsory) which ensures minimum levels of repair and rebuilding costs for householders, was introduced in 2000, which by 2012 had close to 4 million policy-holders nationally. However, mitigation achievement is not uniform nationally, and is significantly lower in the poorer Eastern Anatolian region where the Van earthquake occurred. In this part of Turkey, for example the take-up rate for the DASK earthquake Insurance is 14% by comparison with 32% in the Marmara region (DASK, 2009).

The earthquake of 23 October was located between the cities of Van and Erciş, and therefore a test of the mitigation progress of Eastern Anatolia. These cities have not been affected by an earthquake since the M5.9 Van-Erciş event in 1941, which few alive today will remember, and it has been reported that earthquake awareness is not high in this region (Yenidogan, 2012). Much of the housing in the area, whether urban or rural is of unreinforced masonry or adobe construction which suffered serious damage or collapse (Erdik et al., 2012) in the areas of strongest shaking. The relatively smaller number of reinforced concrete frame buildings performed better, although there were some collapses amongst older buildings. The total death toll was 604, broadly in line with modelling estimates given the building stock (Erdik et al., 2012). SwissRe (2012) have estimated that the total damage for the event was $0.75bn, only about 4% of which was insured, so insurance loss is very small.
4. **Earthquake preparedness**

Recent earthquake and tsunamis have highlighted the need for disaster preparedness, especially for tsunamis where early warnings are available and can save many lives. In addition, in rural communities where roads are frequently cut off following a disaster, a preparedness programme can help families and communities reduce the effects of an earthquake while increasing their ability to effectively respond until external assistance arrives.

Three main components to earthquake preparedness examined are:

1. Hazard assessments and maps
2. Earthquake scenarios
3. Earthquake drills

The provision of *seismic hazard assessments and maps* by seismologists stating probable levels of ground motion in a given region is vital. Based on studies of likely ground motions and variations of these motions due to soil and topographical effects, *earthquake scenarios* can then be used to model the likely effect on the exposed population inhabiting buildings or carrying out daily activities. The scenarios help authorities target the most vulnerable areas, prioritise their mitigation programmes and prepare emergency plans. Based on these scenarios and emergency plans, *earthquake drills* can be carried out.

In particular, it is worth highlighting the ShakeOut earthquake drill which has been held annually in California since 2008 and has now been extended to other parts of the US, British Colombia, Guam, Puerto Rico, Japan and New Zealand. Additional areas considering ShakeOut drills are southeast states in the US (Georgia, South Carolina, North Carolina, and possibly Virginia), Hawaii, Alaska (2014), Turkey and Chile.

![Figure 5: The first Japanese ShakeOut, in the Chiyoda ward of central Tokyo, occurred on March 9, 2012 two days prior to the anniversary of the 2011 Tohoku earthquake and tsunami enhanced regular earthquake drills of schools and businesses](image-url)
4.1 Evidence and effectiveness of preparedness measures in recent events

All of the three countries have active scientific communities dedicated to earthquake research. Seismic hazard maps and scenarios exist for the regions where the recent earthquakes happen but what is evident is the need for a constant review of the science behind these outputs, to bring the tools developed in scientific research institutions to the forefront of national mitigation and preparedness programmes. Seismological information from each new event must be used to inform and update models, e.g. Figure 6 shows the previously unrecognised Greendale fault (Gledhill et al., 2011) from the Canterbury earthquake sequence of 2010-2011.

Figure 6: Map of the Canterbury region showing epicentres of the Darfield and Christchurch earthquake sequences. (GNS Science)

In New Zealand the Ministry of Defence and Emergency Management, formed in 1999 was set up to provide strategic policy advice on New Zealand’s capability to manage and be resilient to the social and economic costs of disasters. A National Civil Defence Emergency Management Plan Order was put in place in 2005 and the Ministry started the ‘Get Ready Get Thru’ campaign. In addition, the New Zealand Red Cross advises citizens to take steps to help lessen the effects of a disaster with proper planning and emergency kits. In 2009, a smaller drill was held along the New Zealand West Coast and had 8,000 participants and following the Canterbury sequence, 2012 will be the first year of New Zealand ShakeOut http://www.shakeout.govt.nz/.

In Chile, Brian Tucker, president of GeoHazards International, a nonprofit organization based in Palo Alto, California was recently quoted as saying “on a per-capita basis, Chile has more world-renowned seismologists and earthquake engineers than anywhere else,” and the performance of modern engineered structures in the Maule demonstrated this as highlighted in the mitigation section of this
However, as explained in the subsequent section on response, the well-formed management derived from this scientific knowledge did not materialise.

In Turkey, the earthquake itself was no surprise to seismologists. In the seismic hazard map shown in Figure 7, the region of Van has the highest postulated hazard level. The most important lesson, however, from the Van earthquake is that earthquake awareness needs to be raised to create the conditions for improved mitigation strategies. Preparedness training programmes are now being undertaken by the Turkish Red Crescent (TRC, 2012). In addition, these programmes must also cater for social inequality and geographical importance of regions. (CEDIM, 2012).

![Seismic hazard map for the Van region (USGS)](image)

**Figure 7:** Seismic hazard map for the Van region (USGS)

![Disaster preparedness and response in Chile](image)

**Figure 8:** The New Zealand ShakeOut will be held in September 2012 hope to attract more than 100,000 participants

Disaster preparedness and response in **Chile** is managed through a centralised federal agency (ONEMI) that coordinates response across various agencies and among federal, regional, and local
jurisdictional levels in Chile. ONEMI operates a national earthquake drill called “Chile Preparado” with an ethos of promoting a culture of emergency preparedness in the community. In addition, Chile Preparado tests the response skills of both the community and the local authorities, by simulating realistic scenarios.

For the Maule event, at first glance it would seem that the preparedness programmes were effective. Though 12 million people, three quarters of the population of the country, were in areas that felt strong shaking, the death toll was just over 500.

However, there were difficulties with the tsunami warning system. An initial warning was cancelled by the Navy’s Hydrographic and Oceanographic Services and the warning had to be subsequently announced on the radio by Chilean president. Remarkably, only about 124 people were killed by the tsunami, in spite of run-up heights of several meters over 500 km of coastline (EERI, 2010) along which many tens of thousands of people were at risk, and in spite of the failure of the official warning system. This was largely due to a high degree of tsunami awareness, resulting from long-standing school tsunami awareness and education programmes, signage showing evacuation routes and other measures (EERI, 2010). The most vulnerable group were transient and tourist populations who had not had tsunami awareness training.

A key lesson from Chile was that one of the most important preparations for the disaster came from relationships formed before the event. The communities with strong connections between different government services generally fared well. The initial response and resilience of individuals and communities was another important component. Communication system failures limited the ability of a central government to assist impacted communities, or to issue tsunami warnings. It also delayed the response since the government did not know (in some case for several days) the impact and needs of local governments.

In Turkey no information was found to access the level of public awareness for the region of Van but drawing from accounts from the 5.9Mw Simav earthquake in the same year in the western province of Kütahya, which left three dead and injured over 120, perhaps the country’s lack of preparedness for earthquakes can be illustrated by injuries from the wrong evasive action by two of the three killed who had jumped from windows to their deaths during the earthquake.

In November 2009, books about earthquake safety were distributed to schools, but earthquake drills are not conducted in every school in Turkey (Zulfikar, 2012). Practical education and drills should be encouraged by the AFAD (Disaster and Emergency Management Directorate). In addition, the AFAD English website does not contain any information on emergency plans nor ‘dos and don’ts’ in the event of an earthquake, a problem identified in Chile’s preparedness campaign.

5. **Response to Earthquakes**

The first criterion for assessing response is the existence of the following four capabilities:

   a. Search and rescue
   b. Medical response
   c. Relief supplies and deployment
   d. Housing
All three studied countries have well established disaster and emergency management plans. New Zealand is headed by the Ministry of Civil Defence & Emergency Management, the Chileans have the National Emergency Management Office (ONEMI) and Turkish efforts are led by AFAD and The Turkish Red Crescent. However, to be effective, response relies heavily on a good organisational structure able to deploy and mobilise these resources in a timely manner. The sections below review the successes and failures of these institutions at an organisational and behavioural level in response to the three selected events.

![Forklift transferring tents](image)

**Figure 9:** A forklift transfers tents for distribution to earthquake victims at Van's airport on October 28, 2011 (source: Reuters)

A day after the *Christchurch earthquake*, the Ministry of Civil Defence in New Zealand declared a national state of emergency and Civil Defence became the lead agency in emergency response.

In the immediate moments following the quake, rescue and response was conducted by civilians and emergency services on duty. The New Zealand Fire Service subsequently coordinated search and rescue, particularly the Urban Search and Rescue (USAR) teams from New Zealand and Australia, UK, USA, Japan, Taiwan, China and Singapore, totalling 150 personnel from New Zealand and 429 from overseas (New Zealand Herald). Emergency department staff at the Christchurch Hospital and health workers across the Canterbury region coped well with the unprecedented emergency (The Lancet, 2010). Immediately after the earthquake, Housing New Zealand provided a temporary accommodation service to the displaced people.
To all intents and purposes the response to the Christchurch earthquake was exemplary with national government working closely with local authorities and communities. The New Zealand response was generally praised by the international disaster management community for its coordination efforts and the use of satellite imagery to help with search and rescue efforts. However, the Christchurch City Council decided on a policy of ‘business as usual’ after the first earthquake and did not adequately cordon off damaged buildings in the city centre (Heather, 2011). The Engineering Advisory Group reported that there was also confusion about the system of inspecting and tagging building damage (Hare et al., 2012). This meant the when the much more destructive earthquake struck six months later many people were injured in the streets from falling masonry or trapped in buildings that should have been closed.

By contrast, in Chile, the immediate response to the earthquake and tsunami was much more challenging for emergency personnel and search and rescue teams. The main issue was the loss of communications. The national response to the event was marked by confusion and a lack of clear situational awareness. Immediately following the earthquake, there was confusion about whether or not a tsunami would follow. It was reported that the outgoing president, based on misinformation from the Navy’s Hydrographic and Oceanographic Institute, initially announced that there was no threat of tsunami, and then minutes later warned that there was a threat. Few people in the tsunami-impacted areas heard either announcement since communications with Santiago were lost, and according to officials from the City of Talca, the first wave hit before a tsunami warning could have been issued (ARC, 2011).

The emergency response plans were inadequate and failed at all jurisdictional levels for the response to the February 27th earthquake in Chile. Within the health sector, regional and local representatives stated their plans were inadequate and never “taken off the shelf,” since the plans were not designed to cope with disasters of this magnitude (ARC, 2011). Planned response was further disrupted because many emergency response facilities were destroyed and unusable (EERI, 2011. The regional emergency operation centre for the Health Ministry in Concepción was also severely damaged and all of their communication equipment was destroyed or inaccessible.
ONEMI acknowledged that the communications systems and plans that existed at the time of the event clearly failed, leaving the agency initially unable to communicate with the impacted areas. ONEMI indicated that the absence of any major disasters in Chile for over 20 years and the resulting reduction in their profile and funding were contributing factors to this failure. This was not, however, the case. The instinctive response and cultural awareness of the local communities actually saved lives. In the health sector, these instinctive responses resulted in the rapid evacuation of hospitals without centralised control in the early response phase. (ARC, 2011) In fact, many lives were lost and effective coordination to support life-sustaining efforts was gravely impacted due to a lack of inter- and intra-agency coordination (ARC, 2011). And in spite of efforts by the Emergency Committee formed by the new government, the central government’s initial slow emergency response led to some looting and breakdown in civic order in the region.

Although their disaster role has been traditionally limited in Chile, the Chilean Red Cross volunteers were among the first to assist people in the impacted areas (ARC, 2011). The Chilean Red Cross mobilised more than 1,700 volunteers to provide assistance for the earthquake response, providing health services, food, water, clothing, tents, and sanitation support services. Local fire and police departments and the police also provided support with limited resources, personnel, and initially no outside support. The Army was widely praised for its effectiveness and comportment in maintaining post-disaster order, but it was not deployed immediately for various reasons.

![Figure 11: A police officer guards a street in Talcahuano, Chile (Source: Associated Press)](image)

The relief operations in Turkey after the Van earthquake were coordinated by the AFAD and the Turkish Red Crescent. Local search and rescue, medical and first aid personnel from 48 different provinces and 39 different institutions were deployed to the region. In all, 4,446 search-rescue personnel were deployed and 252 people were rescued. This statistic of number of rescued over the total number of rescuers deployed again raises the question of efficiency of search and rescue operations, providing a clear argument for national governments to promote mitigation to save lives and resources.
In the first days after the earthquake, the Turkish government rejected all offers of help on the grounds that it was not needed. However, it soon became clear that there were not enough tents, food had not been distributed well enough to reach all survivors equally, and there had been a general lack of organisation. A number of trucks carrying equipment and food had been looted, and health officials had repeatedly warned against the spread of diarrhoea and other diseases.

The total aid received from 30 countries, UNHCR and OCHA is shown in the Table below. The response and governance is further complicated by the political setting in the region of Van.

<table>
<thead>
<tr>
<th>Province and Districts</th>
<th>Type of the Material</th>
<th>Family Sheltering Tent</th>
<th>Mevlana House (Set)</th>
<th>Blanket (Sum)</th>
<th>Tent General Purpose</th>
<th>Heater and Stove (Sum)</th>
<th>Sleeping Bag (Sum)</th>
<th>Kitchen Set</th>
<th>Various Food (Kg)</th>
<th>Food Package (Sum)</th>
<th>Provisi on (Sum)</th>
<th>Bed (Sum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Van/Center</td>
<td></td>
<td>41.657</td>
<td>3.194</td>
<td>162.147</td>
<td>402</td>
<td>3.902</td>
<td>7.633</td>
<td>17.779</td>
<td>1.680.620</td>
<td>41.419</td>
<td>11.944</td>
<td>14.400</td>
</tr>
<tr>
<td>Van/Erciş</td>
<td></td>
<td>11.184</td>
<td>450</td>
<td>50.538</td>
<td>7</td>
<td>2.904</td>
<td>15.978</td>
<td>3.717</td>
<td>367.079</td>
<td>12.948</td>
<td>12.000</td>
<td>810</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>285</td>
<td>150</td>
<td>705</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1. List of aid items sent to the Van region (source: AFAD)

5.1 Limitations to this report
Information on the Van earthquake was limited as many documents are written in Turkish and also possibly bias as the main two references on relief were written by the responsible disaster management agencies.
6. Earthquake Recovery

Disasters leave huge scars in people’s lives, the economy and infrastructure. Yet despite the damage they can be catalysts to ‘build back better’. Typically lasting about 18 months, there is a window of opportunity for better ways of doing things to take hold.

Economic recovery is usually the most serious issue facing communities in the post-disaster period. (Bolton, 1996). Land use is also important and there are essentially three choices: rebuild in the original place, partially move to a safer adjacent neighbourhood or relocate to a new place. The decision depends largely on the degree of damage, the willingness of the inhabitants to move, the difficulty of mitigating future risk and the economic implications of the move (Ye, 1996)

In planning recovery Hass (1977) suggests that a number of fundamental issues should guide the planning process. This idea is adapted in the following headings.

- Governance: normal or extraordinary decision-making?
- Regulation: what codes and regulations are in place and should these be modified?
- Consultation: how are public informed and community and stakeholder engaged?
- Plans: what economic development, land use and transportation plans are in place?
- Information: what base line damage assessment and risk data is available?
- Funding: how can elevated needs for public expenditure be financed?
- Monitoring: who should monitor and evaluate recovery, and how should this be done?

6.1 Governance

Many organisations are involved in recovery. Some of these are regular local, regional and national authorities, some are earthquake specific. In all there may be as many as fifty key players. The roles and remit of these different organisations overlap and there is a need to coordinate their efforts.

In many countries, however, it is unclear which agency, organisation or department is responsible for planning post-disaster recovery. There is often tension between local, regional and national authorities. Local officials often begin planning for recovery after a disaster occurs and fail to involve regional land use planners in decision-making. Equally national planning often fails effectively to address local needs. (Smith, 2010)

In New Zealand after the 6.3Mw earthquake in February 2011, legislation was passed giving the Minister and the Canterbury Earthquake Authority (CERA) wide ranging powers to manage recovery and reconstruction. CERA has been effective in coordinating planning policy. (CERA, 2012) However, there has also been criticism that local authorities have been sidelined, especially in deciding on the programme of demolition in the city centre. (Lochead, 2012)

Chile appointed a national coordinator of the urban reconstruction programme who quickly determined that the State is unable reconstruct everything or even control the process of recovery centrally. Responsibility was delegated to each region, town council and community to develop its own plans. A group of 10 architects/planners was seconded to the Regional Government to assist the affected local authorities.
In Turkey relief and recovery was coordinated from the centre by the Vice Prime Minister. Its recent report asserts that the work of Governmental institutions, NGOs and the private sector was well coordinated. (AFAD, 2012) However, one of the key issues is the politics of Eastern Turkey and central government fears that aid might be diverted to the Kurdistan Workers’ Party (PKK). Various commentators have suggested that this has meant that aid, especially support for trade and small businesses, has not been co-ordinated in an effective way. (Tokyay, 2011; Raufoglu, 2012)

Figure 13: Recovery Strategy for Christchurch, CERA, 2011, showing how various plans and programmes fit together

6.2 Regulation

Building codes use engineering and scientific analysis of building performance to define acceptable standards of construction. Planning regulations take risk from natural hazards into account in defining where land can be built on and developed. The effective implementation of codes and regulations reduces building damage and saves lives.

In New Zealand the Department of Building and Housing, with the help of a special Engineering Advisory Group, modified the already strict building codes to take account of greater understanding of liquefaction risk and to provide guidance for foundations in high-risk areas. (Dept of Building, 2011) Planning regulations have also been altered in significant ways to define red zones which will be taken out of use and to impose new height restrictions in the city centre.

Chile also has strict building codes and planning regulations. In April 2011 the Government declared its intent to incorporate tsunami risk mitigation into Chilean urban planning law, but there is little planning experience of how to consider this risk and determine its impact on land use regulations and building codes. Current urban planning law does not define minimum building height and materiality and it is impossible to insist the type of buildings constructed in tsunami run-up areas. Most critical facilities are located in vulnerable areas and it is difficult to move these facilities to safe areas. There is no technical certainty that new tsunami housing and proposed mitigation works can
withstand large magnitude tsunami. The need to rebuild homes is faster than the planning process and people have started to rebuild their homes in the same disaster prone areas. (Bustos Erwenne, 2011).

Figure 14: Christchurch new land use zoning. Grey: low liquefaction risk, normal foundations; Yellow: some risk, more foundation engineering; Blue: elevated risk, specific site design required; Red: land taken out of use

6.3 Consultation

Many commentators have argued that the process of recovery will be more successful if the affected community, residents and business, are involved in strategic decisions about the future of their place (Clarke et al., 2010). But after a disaster many people will be traumatised about what has happened to their families and businesses and may be angry about any delays. This means that effective consultation is not straight-forward.

In New Zealand the level of public engagement was unprecedented. There were 6 weeks of public consultation and 100 meetings with stakeholders. Despite this the authorities felt a lot more communication still needed to be done. In Chile, Master Plans were presented to the community and publicised at various meetings and workshops. This consultation period typically lasted 7 weeks and most plans were approved at the end of October 2010. In Turkey planning recovery is managed centrally by AFAD and there is evidence that that the needs of the local population either in terms of housing or business support were not considered properly. The temporary housing, although erected quickly, is climatically and culturally unsuitable (CEDIM, 2011) and new government houses being built by the Housing Administration of Turkey (TOKI) are regarded as poor value for money and there are concerns that both these housing types will become permanent ghettos with social problems (Jozuka, 2012).
6.4 Plans

In a developed country there is likely to be a range of pre existing and special earthquake related plans and programmes. These should be the starting point for planning recovery. They will, most likely, need adapting in the light of the disaster. For example, land previously zoned for development should be taken out of use because of elevated risk or an opportunity presents itself to improve the transportation network or the amenity of parts of the city.

In New Zealand economic and urban development strategies, and land use and transportation plans were in place before the earthquakes. Although these plans needed modifying, they provided a sound basis for planning.

In Chile there were regional strategic plans in place and the local planning teams focused on devising master plans to guide reconstruction (MINVU, 2011; Cartes, 2011).

6.5 Information

Two types of information are needed after a major disaster. Immediately after the event there is a need for information about damage to buildings, roads and bridges and about the level of relief and shelter required. Almost simultaneously teams of people begin planning the process of recovery at an urban scale and they need a different type of aggregate information about all aspects of the places affected.

In New Zealand extensive engineering and science has gone into understanding the earthquakes, the resultant damage and the development of clear guidance. In particular, a system of zoning land
was devised based on the risk of liquefaction and the type of foundation required (EDC, 2010). Tonkin & Taylor, a firm of consulting engineers collated all the survey data, insurance claim and other information into a GIS and made it available to all the players. (Platt, 2012)

In Chile the ministries and regional governments worked with different data and graphics systems and there was no time to coordinate information, nor were there sufficient trained personnel. The Chilean team working on coastal settlement reconstruction tried and failed to build this database in time to be useful and believe that as a consequence master planning took eight months longer than it would have done with good information (Platt, 2011).

![Figure 16: Orbit GIS Information system used in New Zealand to manage all survey, claims and other data.](image)

### 6.6 Funding

Reconstruction after major disasters is hugely expensive. Losses in New Zealand are about 20% of GDP and in Chile about 13% (Daniell and Vervaeck, 2011). Yet the investment that follows a disaster can be a boost to the economy. In Chile the economy grew by 6-7% in 2011 and commentators attribute some of this growth to reconstruction. In Christchurch it is estimated that NZ$20 billion will be invested in the city and 15,000 jobs created in construction.

In New Zealand the level of insurance penetration is extremely high. Less than ½% of all damaged dwellings are uninsured and most non-residential buildings in the CBD were fully insured. The government insurance scheme will pay losses of more than NZS7 billion and private insurers will pay upwards of a further NZ$10 billion towards the cost of rebuilding Christchurch. The Government expects to spend an additional $8.5 billion. One of the more difficult issues is that authorities are keen to have buildings seismic strengthened, but there is a question about who pays for the enhanced performance.

In Chile the government has assessed damages and losses at US$30 billion, and estimates total public spending for reconstruction will come to $12 billion. The government will fund this spending through moderate tax increases, reserves, budget reallocations, sale of assets and, most
significantly, through concessionary schemes with the private sector. The planners, however, have little control over financial decisions and the exchequer has the final say in approving plans.

In **Turkey** the total cost of disaster relief and recovery is estimated at US$663 million. The insured losses are estimated between US$55 million and US$200 million. There is Government financial support in the form of grants and credit. However, there are concerns that only 20% of people who applied for Government credit have received it. Trades people who have lost everything have difficulty guaranteeing the loan and those with land fear mortgaging it.

### 6.7 Monitoring

There is a need for a systematic approach to monitoring and evaluating recovery that promotes transparency and warns if the reconstruction is not going to plan. Operationally, effective monitoring is necessary to improve coordination, situational understanding and decision-making. Strategically, it would provide accountability to ministers, boards of directors, and the public.

In **New Zealand**, as in many other countries, it is not clear who will independently monitor and evaluate recovery. The authorities in **Chile** recognised the importance of monitoring is important and there were plans to set up a government monitoring unit, but these may not get funded (Platt, 2012).

### 7. Lessons from the three selected earthquakes

**Mitigation**

1. Although losses from the three studied events were severe, evidence from the field investigations shows that, in all three, modern buildings for the most part performed well. In contrast to the three major fatal events of the last 5 years in Kashmir 2005, Wenchuan 2008 and Haiti 2010, the overall death tolls were in the hundreds, rather than tens of thousands, and this is certainly a measure of the mitigation achievements in each of the affected countries.
2. For the future, the lessons for New Zealand, Chile and Turkey and elsewhere are that mitigation through improved building standards is effective. The main improvement needed is to put in place measures that ensure that existing codes and design guidance are adopted.
3. This is particularly a concern for older buildings; and programmes for assessing and strengthening such buildings, or progressively replacing them with more earthquake resistant buildings need to be put in place. This is a concern not just for the rebuilding in the affected areas, but also in adjacent areas at risk of comparable events.
4. There is evidence that recent events (Christchurch and Tohoku, Japan) have produced ground motions which exceed those which were allowed for in the existing codes of practice. Indeed Wyss (forthcoming) has claimed that the macroseismic intensities reported for the last 60 earthquakes with M≥7.5 were all significantly larger than expected. There is therefore a clear need for a review of the return period of the events considered in design within new codes of practice.

**Preparedness**

5. The events have shown that, even where buildings are designed for life-safety and no collapse, the damage can often be so severe that the building needs to be demolished. There is an
obvious need for a new “design for repair” concept to be more widely adopted in codes of practice; the additional costs of such design could be justified against the lower expected lifetime damage.

6. For buildings and areas of historic importance, the Chile and New Zealand events have provided important tests of the effectiveness of a range of strengthening measures adopted. These experiences need to be studied, with a view to an accelerated programme of strengthening; otherwise much important cultural heritage will be lost.

7. The Chile event produced convincing evidence, from the relatively small life loss, of the efficacy of tsunami education of the general public; however there is clearly a need for more robust warning systems, and for tsunami awareness training to be extended to transient populations.

8. In Chile, a breakdown of communications and a changing government caused confusions. Local resilience and cultural awareness on the other hand were clear strengths.

9. In Turkey the hazard is recognised but not communicated. Preparedness is also complicated by the unstable political situation in Eastern Turkey.

Response

10. The New Zealand response was well organised and brought out the local community spirit. They were particular successful in identifying specific target areas for international aid.

11. Chile was hampered by an initial lack of communications and the complacency of the central plus downsizing of local ONEMI offices made matters worse. The event brought to light the need to address transient populations in disaster preparedness. In addition, more involvement of the Chilean Red Cross and extending their responsibilities would also have improved the response outcomes.

12. Turkey was reluctant to ask for international help to start with and delayed the distribution of much needed shelter and supplies to the affected communities. A massive search and rescue operation was deployed with over 4,000 rescuers rescuing 225 people in total. This call to question the effectiveness of resources allocated to response and need to redirect resources to mitigation to save more lives.

13. It is essential to collect all possible data about each disaster when it happens. Many of the consequences of the three earthquakes have not yet been quantified, for example, examining the causes of injuries. Each disaster provides a unique opportunity to learn how society is affected by the events and provide valuable knowledge to support researchers and authorities in eradicating preventable injuries and deaths.

Recovery

14. In New Zealand there have been governance issues and CERA, the temporary earthquake authority, has been criticised for side-lining local authorities, especially in deciding on the programme of demolition in the city centre.

15. Also in New Zealand, science and engineering know-how were harnessed effectively to modify building codes and land use zones and extensive information from surveys, claims and imagery analysis was made available to all parties.

16. In Chile, the planners were hampered by a lack of baseline data and damage information and took 6-8 months longer to produce plans than it might have done.

17. Effective community engagement is crucial. Despite extensive public consultation in New Zealand, authorities feel they could have done more.
18. Monitoring recovery is not sufficiently developed in any of the case study counties and there is a need for a systematic approach to monitoring and evaluating recovery that promotes transparency and warns if the reconstruction is not going to plan.