Disaster Waste Management:

a systems approach

A thesis submitted in partial fulfilment of the requirements for

the Degree

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Abstract

Depending on their nature and severity, disasters can create large volumes of debris and waste. Waste volumes from a single event can be the equivalent of many times the annual waste generation rate of the affected community. These volumes can overwhelm existing solid waste management facilities and personnel. Mismanagement of disaster waste can affect both the response and long term recovery of a disaster affected area.

Previous research into disaster waste management has been either context specific or event specific, making it difficult to transfer lessons from one disaster event to another. The aim of this research is to develop a systems understanding of disaster waste management and in turn develop context- and disaster-transferrable decision-making guidance for emergency and waste managers.

To research this complex and multi-disciplinary problem, a multi-hazard, multi-context, multi-case study approach was adopted. The research focussed on five major disaster events: 2011 Christchurch earthquake, 2009 Victorian Bushfires, 2009 Samoan tsunami, 2009 L'Aquila earthquake and 2005 Hurricane Katrina. The first stage of the analysis involved the development of a set of 'disaster & disaster waste' impact indicators. The indicators demonstrate a method by which disaster managers, planners and researchers can simplify the very large spectra of possible disaster impacts, into some key decision-drivers which will likely influence post-disaster management requirements. The second stage of the research was to develop a set of criteria to represent the desirable environmental, economic, social and recovery effects of a successful disaster waste management system. These criteria were used to assess the effectiveness of the disaster waste management approaches for the case studies. The third stage of the research was the cross-case analysis. Six main elements of disaster waste management systems were identified and analysed. These were: strategic management, funding mechanisms, operational management, environmental and human health risk management, and legislation and regulation. Within each of these system elements, key decision-making guidance (linked to the 'disaster & disaster waste' indicators) and management principles were developed.

The 'disaster & disaster waste' impact indicators, the effects assessment criteria and management principles have all been developed so that they can be practically applied to disaster waste management planning and response in the future.

Disaster waste management: a systems approach
Charlotte Brown

Executive summary

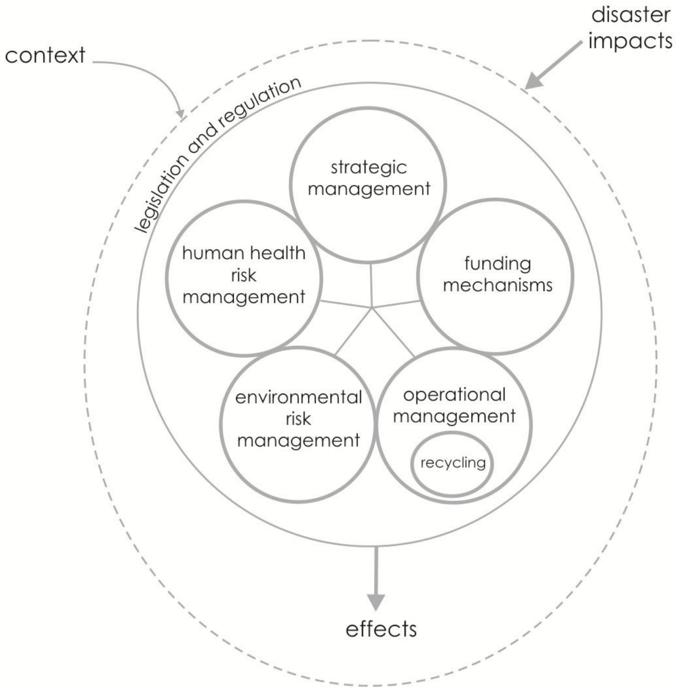
Depending on their nature and severity, disasters can create large volumes of debris and waste. Debris volumes can be the equivalent of many times the annual waste generation rate of the affected community. These volumes can overwhelm existing solid waste management facilities and personnel.

The presence of disaster waste affects almost every aspect of an emergency response, including: inhibiting search and rescue activities and emergency and welfare access to affected populations and potentially posing a public health hazard. In the longer term, poor management of a clean-up can result in a slow and costly recovery. Limited rebuilding / repair can be carried out before the waste is removed, prolonged exposure to the waste is also potentially risky to public and environmental health, and psychosocial recovery may be inhibited by the presence of waste. If managed effectively, debris can become a valuable resource in the recovery and rebuilding process and can have a positive effect on social and economic recovery.

Previous research into disaster waste management has been either context specific or event specific making it difficult to transfer lessons from one disaster event to another. Therefore, the specific objectives of this research were:

1. To develop a robust analysis framework to research disaster waste management.
2. To understand the high level system dynamics of disaster waste management systems.
3. To investigate potential decision-making tools for disaster waste managers.
4. To identify future research needs.

A multi-hazard, multi-context, embedded, multi-case study analysis methodology was adopted. Five case studies were analysed: 2009 Victorian Bushfires, Australia; 2009 Samoan Tsunami; 2009 L'Aquila earthquake; 2005 Hurricane Katrina; and 2011 Christchurch earthquake. A cross-case analysis was carried out using the model presented in the figure on the following page. Each system element (denoted by the circles in the model) was analysed and key principles were developed.



Cross-case study analysis model

Disaster impacts

For the purposes of this thesis five disaster impact indicators have been proposed to describe the disaster impact (relevant to disaster waste management): disaster scale, number of displaced persons, geographical extent, hazard duration and disruption of road network. In addition, five key disaster waste characteristics have been developed: volume of waste, human health hazard, environmental health hazard, movement of waste and waste handling difficulty. The indicators are used qualitatively during the thesis analysis; however, a semi-quantitative assessment approach is proposed such that the indicators can be used in pre and post-event planning and analysis.

Effects

To enable the effectiveness of a disaster waste management system to be qualitatively assessed for cross case analysis, 12 criteria were established (refer to table below). As for the disaster impacts, a semi-quantitative assessment approach has been suggested for future application in pre and post-disaster situations.

Criteria for an effective disaster waste management system

	Criteria
Environmental	
	Adverse environmental effects are minimised.
	Environmentally beneficial strategies encouraged (e.g. recycling).
Economic	
Direct costs[1]	Operational (waste handling and disposal) costs are minimised.
	Regulatory and strategic management costs are minimised.
Indirect costs	Local economy stimulated.
	Potential future costs from environmental remediation and adverse health effects are minimised.
Social	
Psychosocial	Improves community spirit.
	Affected persons are empowered to participate in their own recovery.
	Public understands and accepts disaster waste management strategy.
Human health	Human health (both general public and workers, acute and chronic) risks are effectively managed.
Recovery	
	The recovery is timely.
	The recovery facilitates a community wide recovery.

Strategic management

A strategic management structure, separate from peace-time (or business as usual) roles and organisational structures, is necessary for large scale events. Generally, as the size of the disaster increases, disaster waste should be strategically managed at higher government levels. Strategic management should also be led by the recovery authority with strong collaboration from peace-time waste / environmental authorities.

Funding mechanisms

There are currently a wide range of approaches to funding for disaster waste management. However, in response to the catastrophic events assessed in this thesis, public funding was predominantly utilised, even in contexts where disaster recovery is typically privately funded. In the case studies there was also a trend toward directly facilitated works rather than payment by lump sum or reimbursement. Given the high potential for negative effects from poor disaster

[1] Direct economic costs include those for waste collection, demolition, treatment, and disposal and all the management / overhead costs which relate directly to management of disaster waste.

waste management, the author suggests that disaster waste management (in particular detritus removal and demolition) should be publicly funded and directly facilitated.

Operational management

Between the case studies there were diverse operational management strategies. Generally, it was found that detritus removal activities and debris management of major repair work should be individually facilitated. Debris collection, demolition and disposal, on the other hand, are best carried out collectively in order to manage the collective risks of a poorly implemented clean-up. Ideally centralised management processes should include 'cradle to grave' waste management processes: that is, waste handling facilities should be linked to demolition and waste collection activities. In the absence of an integrated procurement structure, time and cost contracts remove the majority of risk from the contractors and places it with the authority / organisation managing the waste.

Recycling

Several barriers to post-disaster recycling have been identified:

- Time constraints
- Limited resource availability
- The mixed nature of the waste
- Hazards in the waste matrix.
- Displaced population
- Post-disaster market challenges (capacity, availability, disruption, storage space limitations)
- Contractual arrangements
- Availability and feasibility of alternative waste management options

Generally, if recycling is desired and there is an urgency to clear the affected area (and there are suitable waste handling facilities), recycling should be carried out offsite. The likely additional costs for this should be recognised as an indirect cost saving.

Environmental and public-health risk management

Post-disaster, due to the speed and volume of works being carried out, potential environmental and public health risks are undoubtedly going to increase. The increased uncertainty and regulatory and operational resource capacity limitations must be considered when designing appropriate risk management strategies. The author found that stream-lined site-specific approval processes that acknowledge and mitigate against the increased risks are generally a more favourable approach than providing permit exemptions.

Legislation and regulation

From a legislative and regulatory perspective, disaster waste management laws need to: allow for flexibility for adaptation to any situation; be bounded enough to provide support and confidence in outcomes for decision-makers; allow for timely decision-making and action; be collaborative; and focus on responsibility, not accountability.

Future planning

It is envisaged that the concepts in this thesis, in particular, the development of a disaster waste management planning approach and principles, will empower decision-makers to successfully manage disaster waste in the future.

Foreword

I started this PhD research with such objectivity. Academic detachment: to allow for a robust, impartial and (as far as possible in disaster research) repeatable study. I would visit countries and talk to people about waste. I would sympathise with the loss of lives, the damaged structures and the loss and hardship, but not empathise. That is the role of the researcher.

That objectivity and detachment was challenged when my hometown (and place of study) was affected by a series of significant and destructive earthquakes. Canterbury, New Zealand, was struck by a magnitude 7.1 earthquake at 4:35am on the 4th of September 2010. Thankfully, due to the location of the fault rupture, and the time of day, no lives were lost. There was, however, significant liquefaction in residential areas and damage to unreinforced masonry structures. That earthquake triggered a series of even more destructive aftershocks: in particular a magnitude 6.3 earthquake at 12:51pm on the 22nd of February 2011 centred close to the city of Christchurch. This aftershock killed 185 people, and will lead to the demolition of at least 7,500 homes and 1,400 commercial properties. The historic buildings in Christchurch, in particular, were severely affected. The fate of even our most iconic building, The Christchurch Cathedral, was still in question at the time of writing. Along with the destruction, the earthquakes unearthed a powerful sense of community: from neighbours assisting each other to the self-coordinated efforts of the Student Volunteer and Farmy Armies shovelling hundreds of thousands of tonnes of liquefaction silt in the eastern suburbs. Christchurch and New Zealand banded together like never before.

My robust and impartial PhD research now seemed irrelevant. I just wanted to use the knowledge I had gained to help my city regain its feet. Fortunately I was given that opportunity. Helping to manage the waste from a disaster affecting my hometown was bittersweet. From a research and learning point of view the opportunity was invaluable. Once the observer, now I was the observed. What from the outside I thought was important was now insignificant or even impractical. From an emotional point of view, however, as the rubble was being removed, I saw the city I love get swept away along with the lives that were lost.

Beyond the loss and sadness, I see an opportunity for Christchurch and those who live here: an opportunity to 'build back better', do things smarter and build on the sense of community that the earthquakes uncovered. I am looking forward to the journey that we are all embarking on.

Acknowledgements

I would like to thank all the many people who have provided me with wisdom and opportunities along this incredible PhD journey:

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Thank you also to Dave Brunsdon who has given me much advice and believed in me enough to pull me into the Emergency Operations Centre. Thank you, in turn, to everyone who was or is still involved in the Christchurch earthquake response then and now. You all work so incredibly hard and are so incredibly dedicated. Christchurch is very lucky.

Thank you to all the people who allowed me to interview them. Many of you were in the midst of a very challenging time: helping to restore your respective community's sense of normality. I applaud all your hard work and hope that you appreciate that this research was only possible because of your hard work under difficult circumstances. I hope the recommendations in this thesis are useful to you.

This research would not have been possible without the generous support of the University of Canterbury and their doctoral scholarship programme. I would also like to thank the EQC for providing both conference and field work funding.

A big thank you, too, to all my family and friends. Thank you for taking my mind off my PhD, giving me perspective and reminding me about the important things in life. Dad: thank you for taking me in and being a fantastic flatmate.

Last, but not ever least, to my mum: the one who always stocked up the emergency kit and refilled the water bottles. Thank you for everything. I know you would have been very proud of me.

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Name: Mark Milke Signature: [signature] Date: 15 June 12

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Acronym list and glossary

Note that the acronym list and glossary below, relates to the main thesis document only. Additional acronym lists and glossaries are provided for the appendices as required.

Acronyms

BRRP	Burwood Resource Recovery Park [Christchurch, New Zealand]
C&D	Construction and Demolition
CBD	Central Business District
CDEM	Civil Defence and Emergency Management [New Zealand]
CER	Canterbury Earthquake Recovery [New Zealand]
CERA	Canterbury Earthquake Recovery Authority [New Zealand]
CERC	Canterbury Earthquake Recovery Committee
Di.Coma.C	[Government of Italy Department of Civil Protection] Directorate of Command and Control
DPC	Departimento della Protezione Civile [Government of Italy Department of Civil Protection]
DEAO	[Louisiana Department of Environmental Quality] Declaration of Emergency and Administrative Order
ESF	[United States, Federal Emergency Management Agency] Emergency Support Function
EQC	[New Zealand] Earthquake Commission
EWC	European Waste Code
FEMA	Federal Emergency Management Agency [United States]
GAO	[United States] Government Accountability Office
GCRO	[Hurricane Katrina, United States] Gulf Coast Recovery Office
JEU	Joint [United Nations Environment Programme / Office for the Coordination of Humanitarian Affairs] Environment Unit
JICA	Japanese International Cooperation Agency
LDEQ	Louisiana Department of Environmental Quality [United States]
MCDEM	[New Zealand] Ministry of Civil Defence and Emergency Management
MNRE	[Government of Samoa] Ministry of Natural Resources and the Environment
NDMP	[Samoan] National Disaster Management Plan

NRP	[United States] National Response Plan
OCHA	[United Nations] Office for the Coordination of Humanitarian Affairs
OIC	Order in Council
OPCM	Ordinanza del Presidente del Consiglio dei Ministri [Prime Ministerial Decree]
UN	United Nations
UNEP	United Nations Environment Programme
US	United States
USACE	United States Army Corps of Engineers [the Corps]
USEPA	United Stated Environmental Protection Agency
VBRRA	Victorian Bushfires Recovery and Reconstruction Authority [Australia]
WASH	Water, Sanitation and Hygiene
WHO	World Health Organisation
WTC	World Trade Centre

Glossary

Comune	(Italian Government)[Italian] Local (municipal) authority
Peace-time	Periods where there is no disaster. Also referred to as business as usual.
Provincia	[Italian] Local environmental authority

1. Introduction

1.1 Background

Depending on their nature and severity, disasters can create large volumes of debris and waste. In a review of past disasters in the United States (US), Reinhart and McCreanor (1999) calculated that in some cases debris volumes from a single event were the equivalent of five to fifteen times the annual waste generation rates of the affected community. Similar ratios were found by Basnayake (2006) following the 2004 Indian Ocean tsunami. These volumes overwhelm existing solid waste management facilities and personnel. Figure 1-1 shows the enormous volumes of waste on Phi Phi Island one month after the 2004 Indian Ocean Tsunami.

Figure 1-1 Phi Phi Island, Thailand, one month after the 2004 Indian Ocean Tsunami (photo source Erica Seville).

The presence of disaster waste affects almost every aspect of an emergency response and recovery effort. In the immediate response, disaster debris can cause road blockages.

Following the 1995 Great Hanshin-Awaji earthquake in Japan, road blockages prevented building access which in turn impeded rescuers, emergency services and lifeline support reaching survivors (Kobayashi, 1995). Waste presence in a community also poses a potential public health risk. Organic wastes and standing pools of water (potentially caused by debris blocking flow paths) can become vector breeding grounds. Vector-borne diseases are a common form of communicable disease experienced post-disaster, particularly when there are large numbers of people displaced. However, the risk of outbreak is relatively low (Watson et al., 2007).

In the longer term, poor management of a clean-up can result in a slow and costly recovery. First, waste management is on the critical path to recovery. Limited rebuilding and repair can be carried out before the waste is removed. In Haiti an estimated half of the 10 million cubic metres of rubble remained to be cleared some two years after the earthquake (Moloney, 2011). The prolonged exposure to the waste is also potentially risky to public and environmental health, as identified by Srinivas and Nakagawa (2008) in Sri Lanka following the 2004 Indian Ocean tsunami. If managed effectively, debris can become a valuable resource in the recovery and rebuilding process and can have a positive effect on social and economic recovery.

Historically disaster waste management has been managed as a logistical exercise. The main focus was removing the material from the affected area with little thought to the longer term environmental impacts. In L'Aquila, in 1703, a large earthquake severely damaged the town. The debris was deposited in an area behind the Basilica, which now forms the Botanic Gardens. This site has required on-going remediation to stabilise the poorly compacted fill (Stagnini, pers. comm. 2010). In Stuttgart, Germany, following World War II, 15 million cubic metres of rubble from ruined buildings was piled on top of an existing hill. This hill is now a war memorial called Birkenkopf. In Napier, New Zealand, following the 1931 earthquake, the waste management solution was to dump the unsorted debris firstly into a lagoon (Figure 1-2) and secondly onto the beach adjacent to town. The latter disposal site was eventually formed into a 40-50m wide domain that now runs the length of the commercial part of Napier (Johnston et al., 2009). With increasing awareness and concern over potential environmental, social and economic impacts of waste management strategies, as well as the growing size and complexities of disasters, modern disaster waste managers have to take a far more integrated and considered approach.

Figure 1-2 **Following the 1931 Napier earthquake, rubble from collapsed buildings was first dumped into a lagoon just west of the Napier CBD (pictured) and later along the Napier waterfront (photo source Alexander Turnbull Library)**

Improved standards for built infrastructure are decreasing the probable impact of disasters in many communities. However, increased urbanisation and dependence on complex infrastructure networks increases a community's vulnerability to a disaster.

The majority of literature available on disaster waste and debris management comprises one-off case studies and debris management planning guidelines. It is a feature of disaster research that studies are often isolated and event-specific (Chang, 2010). Issues of variability between disasters, time limitations and data access difficulties all make it challenging to conduct quantitative, cross-disaster studies. Table 1.1 lists disaster waste management references specific to individual disasters. The table is ordered first by hazard type and second in chronological order. Debris management planning guidelines (Solis et al., 1995; USEPA, 1995b; FEMA, 2007; USEPA, 2008; Wellington Region Civil Defence Emergency Management Group, 2008; Johnston et al., 2009; UNOCHA, 2011) generally give a range of technical and management options for disaster waste. Technical aspects include: waste collection and transportation; temporary debris storage; recycling; waste disposal; hazardous waste management. Management aspects include: communication strategies; contract management; organisational roles and responsibilities; and record keeping. The guidelines are based on existing institutional frameworks (legislative, organisational and financial) applicable to the given context.

Table 1.1 Disaster waste management references

Hazard type	Year	References
Conflict		
Beirut, Lebanon	Post-1990	(Jones, 1996; Lauritzen, 1996/1997; Baycan and Petersen, 2002; Bjerregaard, 2009)
Mostar, Bosnia	Post-1995	(Lauritzen, 1995; Baycan and Petersen, 2002; DANIDA, 2004)
Kosovo Conflict	Post-1999	(Baycan and Petersen, 2002; DANIDA, 2004; Bjerregaard, 2009)
Earthquakes		
Loma Prieta earthquake, US	1989	(Lauritzen, 1996/1997)
Luzon earthquake, Philippines	1990	(Lauritzen, 1996/1997)
Humboldt County Earthquake, US	1992	(State of California, 1997)
Erzincan Earthquake, Turkey	1992	(Lauritzen, 1996/1997)
Northridge earthquake, US	1995	(USEPA, 1995b; Jones, 1996; State of California, 1997; USEPA, 2008)
Great Hanshin-Awaji earthquake, Kobe, Japan	1995	(Kuramoto, 1995; Lauritzen, 1995; Lauritzen, 1998; Reinhart and McCreanor, 1999; Baycan and Petersen, 2002; Inoue et al., 2007; Hirayama et al., 2009; Hirayama et al., 2010)
Marmara earthquake, Turkey	1999	(Baycan and Petersen, 2002; Baycan, 2004)
Fires		
City of Oakland Firestorm	1991	(State of California, 1997)
Coastal Fires, US	1993	(USEPA, 1995b)
Cerro Grande wildfire, US	2000	(USEPA, 2008)
Cedar and Pines fires, US	2003	(County of San Diego, 2005; USEPA, 2008)
Floods		
Midwest floods, US	1993	(USEPA, 1995b)
Alstead Floods, US	2005	(USEPA, 2008)
Hurricanes		
Hurricane Hugo, US	1989	(USEPA, 1995b)
Hurricane Charley, US	1992	(MSW, 2006)
Hurricane Andrew, US	1992	(Tansel et al., 1994; Meganck, 1995; USEPA, 1995b; Jones, 1996; Luther, 2008)
Hurricane Iniki, Hawaii, US	1992	(USEPA, 1995b)
Hurricane Opal, US	1995	(Reinhart and McCreanor, 1999)
Hurricane Fran, US	1996	(Reinhart and McCreanor, 1999)
Hurricane Georges, US	1998	(Reinhart and McCreanor, 1999)
Hurricanes Frances and Jeanne,	2004	(Solid Waste Authority, 2004)

Hazard type	**Year**	**References**
US		
Seminole Florida Hurricane season, US	2004	(USEPA, 2008)
Hurricane Ivan, US	2004	(USEPA, 2008)
Hurricane Katrina, US	2005	(Harbourt, 2005; LDEQ, 2005a; Pardue et al., 2005; Presley et al., 2005; SWANA, 2005; USEPA, 2005a; b; Brunker, 2006; Diaz, 2006; Esworthy et al., 2006; LDEQ, 2006a; McCarthy and Copeland, 2006; Allen, 2007; Dubey et al., 2007; GAO, 2008; Jackson, 2008; Luther, 2008; Roper, 2008; USEPA, 2008; Cook, 2009; Denhart, 2009; Foxx & Company, 2009; Denhart, 2010; Moe, 2010; HHS.gov, accessed 2010)
Hurricane Rita, US	2005	(LDEQ, 2006a; USEPA, 2008)
Tornadoes		
Central Florida Tornadoes, US	1998	(Reinhart and McCreanor, 1999)
Oklahoma Tornadoes, US	1999	(Reinhart and McCreanor, 1999)
Tsunami		
Indian Ocean Tsunami	2004	(Basnayake et al., 2005; Petersen, 2005; Selvendran and Mulvey, 2005; UNEP, 2005a; WMinE, 2005; Basnayake et al., 2006; Petersen, 2006; Pilapitiya et al., 2006; UNDP, 2006; Srinivas and Nakagawa, 2008; Bjerregaard, 2009)
Typhoon		
Toraji typhoon, Taiwan	2001	(Chen et al., 2007)
Nari typhoon, Taiwan	2001	(Chen et al., 2007)
Mindulle typhoon, Taiwan	2004	(Chen et al., 2007)
Aere typhoon, Taiwan	2004	(Chen et al., 2007)
Tokage Typhoon, Japan	2004	(UNEP, 2005c)
Volcanic eruptions		
Mount St Helens eruption, US	1980	(Markesino, 1981; Dillman and M.L., 1982)
Winter storm		
Lincoln Winter Storm, US	1997	(USEPA, 2008)

In addition there are a limited number of cross case study analyses (Lauritzen, 1995; 1996/1997; Lauritzen, 1998; Reinhart and McCreanor, 1999; Baycan and Petersen, 2002; Petersen, 2004), and technical academic studies (Dubey et al., 2007; Inoue et al., 2007; Rafee et al., 2008; Hirayama et al., 2009; 2010). The US Army Corps of Engineers (Channell et al., 2009) and Ekici et al (2009) give broad reviews, but are still limited to the US context and to technical aspects of debris management. Karunasena (2009) proposes to review disaster waste management in developing countries with an emphasis on the Sri Lankan context. However, the majority of the literature cited is US based and there is no analysis of the contextual relevance of US derived practices in other countries.

The following literature review is divided into nine sections, corresponding to the key aspects of disaster waste management:

- Planning
- Waste characteristics – including waste composition and quantities
- Disaster waste management phases
- Waste handling, treatment and disposal
- Environment
- Economics
- Social considerations
- Organisational aspects
- Funding
- Legal frameworks

In each section, the literature is critically analysed and a summary, in italics, of the missing links and deficiencies in the existing literature is presented. These italicised summaries are later developed into the major lines of enquiry of this research. Last, Section 1.12 outlines the thesis objectives and scope.

This literature review is adapted from a paper written by the author (included in Appendix A):

> Brown, C., Milke, M. & Seville, E. (2011) "Disaster waste management: a review article". *Waste Management,* **31,** 1085-1098.

1.2 Planning

1.2.1 Developed countries

With the increasing frequency and severity of natural disasters, efficient, effective and low impact recovery is becoming increasingly important. One of the first comprehensive plans for disaster debris and waste was prepared by the United States Environmental Protection Agency's (USEPA's) in 1995. The plan was titled "Planning for Disaster Debris" (USEPA, 1995b) and was updated in 2008 (USEPA, 2008).

The USEPA planning guidelines are built from the experience of previous events in the US and are framed around existing legislation, organisational structures and funding mechanisms (referred to here, collectively, as institutional frameworks). In particular, they align with the Federal and Emergency Management Agency (FEMA) debris management guidelines (FEMA, 2007). Both guidelines give a range of technical and management options for disaster waste. Specific disaster waste management plans are the responsibility of individual municipalities and states, for example plans prepared by the State of California (1997) and Louisiana Department of Environmental Quality (LDEQ, 2006a). Recently, FEMA introduced an incentives programme, by way of increased cost share of any future disaster debris management responses, to encourage localities to prepare debris management plans (USEPA, 2008).

In addition to plans, in 2003 the USEPA launched a web-based information tool called USEPA's Suite of Disaster Debris Management and Disposal Decision Support Tools (Thorneloe et al., 2007). The tools are essentially a database for US users with GIS capacities, where the database includes technical information on safe waste handling, disposal options, facilities (including facility waste acceptance criteria, operator contact details), environmental and operational regulations and sample contract documents.

Many authors and government authorities outside the US have also recognised the importance of preparing disaster waste management plans (Skinner, 1995; Solis et al., 1995; Jackson, 2008; Wellington Region Civil Defence Emergency Management Group, 2008; Johnston et al., 2009) but few country or location specific guidelines exist. Many of the recommendations of these documents are based on the USEPA's guidelines and/or take a similar form. While the USEPA's documents are comprehensive from a technical and general management perspective, they are prepared alongside US specific institutional frameworks. When transferring the USEPA guidelines to other contexts, authors do not seem to recognise the influence of these institutional frameworks and the need to assess and potentially develop context specific institutional frameworks for disaster waste management.

These tools and guides also tend to be quite prescriptive. They give little guidance on decision-making and option consideration in different disaster situations.

1.2.2 Developing countries

In 2005, the Hyogo Framework for Action 2005-2015 (ISDR, 2005) was developed to reduce disaster risk, particularly in vulnerable developing economies. Planning for disaster recovery, including management of disaster waste, is part of the disaster risk reduction strategy.

Disaster waste management plans in developing countries seldom exist. In many cases peace-time[2] solid waste management programmes do not even exist – indicating that solid waste management is a low priority. Financial, technical and expert resources in developing countries are generally a limiting, if not prohibitive, factor in achieving disaster risk reduction goals. The Joint United Nations Environment Programme / Office for Coordination of Humanitarian Affairs Environment Unit have recently prepared disaster waste management guidelines specifically for developing countries (UNOCHA, 2011). The guidelines cover many of the technical issues addressed in the USEPA guidelines, and management and implementation strategies are designed for countries with little or no existing infrastructure and/or waste management expertise. Opportunities for livelihood promotion and maximising value from the resources are also emphasised in the draft document.

Two isolated research studies identified a range of technical, managerial and institutional factors that may be limiting factors in the future management of disaster waste. Karunasena et al. (2009) carried out an analysis of Sri Lanka's preparedness to manage disaster waste. Rafee et al. (2008) made an assessment of the likely capability of the city of Tehran to manage earthquake waste.

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[2] Peace-time refers to the times when a community is not affected by a disaster. Also referred to as 'business as usual'.

Apart from the UNOCHA document, there are several documents available to guide first responders in dealing with disaster waste. These include: World Health Organisation "Solid Waste Management in Emergencies" (WHO, 2005); Guidelines for Safe Disposal of Unwanted Pharmaceuticals in and after Emergencies (WHO, 1999); and the UNEP/OCHA Joint Environmental Unit "Initial clearing and debris removal" (JEU, 2006). In addition there are several emergency management handbooks that cover all aspects of emergency recovery including brief sections on waste management. Resources include Engineering in Emergencies (Davis and Lambert, 2002) and the United Nations High Commissioner for Refugees Handbook (2000). All these documents cover solid waste disposal very generally and tend to focus on immediate management of waste generated in an emergency and municipal wastes in displaced populations or where solid waste infrastructure is not functioning. They do not generally cover management of disaster-generated waste.

There are currently numerous guides and tools available for handling hazardous wastes in developing countries that could be applied (in emergencies), including "A Brief Guide to Asbestos in Emergencies: Safer Handling & Breaking the Cycle" (Shelter Centre, 2009), and the Hazard Identification Tool (OCHA, 2009a). Environmental assessment tools and guides are also available such as the Flash Environmental Assessment Tool (OCHA, 2008) and the Environmental Needs Assessment in Post-Disaster Situations (UNEP, 2008). These tools are not currently integrated into the disaster waste management plans / guides discussed above.

As for the planning guidelines in developed countries, these guides are generally limited to technical interventions. They fail to address the managerial and institutional components that influence the effectiveness of a disaster waste management system such as funding, legislative considerations and organisational planning.

Currently disaster waste management guidelines do not consider the impact of existing institutional frameworks on disaster waste management activities. Guidance documents which include not only technical planning advice but also policy development recommendations would be a useful addition to the literature. Research into the effectiveness of prescriptive versus decision-making type guidance would also be valuable.

1.3 Waste characteristics

1.3.1 Waste composition

It is well recognised that different types of waste are generated depending on both the type of built environment affected (e.g. coastal/inland, urban/rural), and the hazard type (Kobayashi, 1995; Solis et al., 1995; Reinhart and McCreanor, 1999; USEPA, 2008). The variation occurs both in composition and manageability (ability to recycle, likely hazardous substances, handling procedures required, etc.). For example, the nature of disaster waste generated from masonry houses will vary greatly from an environment with predominantly wooden houses. Following Hurricane Katrina, waste managers were challenged by the mixture of hurricane and flood-generated debris (Luther, 2008) because each required different management approaches. To date the studies cited only report context specific experiences. The studies also report waste composition in a variety of ways so that it is difficult to make comparisons between cases.

The waste streams generated by disasters generally identified in the literature are:

- vegetative debris or green-waste
- sediment / soil and rock
- house-hold hazardous waste (refrigerant, oils, pesticides, etc.)
- construction and demolition debris from damaged buildings and infrastructure (such as roads, pipes and other services)
- industrial and toxic chemicals (including fuel products)
- putrescible wastes (such as rotting food)
- vehicles and vessels
- recyclables (plastics, metals etc.)
- electronic and white goods
- waste from disaster-disturbed pre-disaster disposal sites
- human and animal corpses

The largest component of urban disaster waste would meet the peace-time classification of construction and demolition (C&D) waste. Some components of this waste stream pose a potential health risk. These include: asbestos, arsenic treated woods (Dubey et al., 2007), gypsum (leaching in disposal sites) (Jang and Townsend, 2001a; USEPA, 2008) and organic pollutants (Jang and Townsend, 2001b).

In addition to disaster generated waste, authors have identified other waste streams that can be indirectly generated post-event, including: excessive unwanted donations such as food, pharmaceuticals and clothing (Ekici et al., 2009), large amounts of health care wastes (Petersen, 2004), rotten food from power outages (Luther, 2008) and emergency relief food packaging (Solis et al., 1995).

Municipal waste must also be managed if the disaster affected community is still living in the affected area. If not collected, municipal waste may be mixed with disaster debris (Jackson, 2008), which: poses a potential public health risk; makes it more difficult to separate the wastes (Baycan and Petersen, 2002); and, in the US, makes the disaster waste ineligible for collection under FEMA regulations (FEMA, 2007).

The terms waste and debris are used differently by different authors. However, in general, debris refers specifically to largely inert building and vegetative materials generated by the disaster, and waste refers to the entire waste matrix, including post-disaster municipal waste.

Some authors use a simple matrix to identify expected waste categories from different hazard types (see Table 1.2 for disasters in the US). Other authors describe not only the types of waste expected but the location and nature of waste expected and how that may affect debris management options. As examples:

- Hurricane storm surges can move private property (including potentially industrial) wastes away from their source site thereby affecting the wider community (Esworthy et al., 2006; USEPA, 2008).
- Hurricane waste is generally more lightweight and with large amounts of vegetative debris (USEPA, 2008).
- Combined flood and hurricane damage means that wastes are mixed beyond the point where separation is practical (Esworthy et al., 2006) (observed following Hurricane Katrina). Similarly, tornado debris in the US is often so twisted it is difficult to separate and, therefore, recycle (Reinhart and McCreanor, 1999).
- Flood events can generate mould problems (Cook, 2009).

- Earthquake debris typically comprises construction material, personal property and sediment (USEPA, 1995b).
- Earthquake debris generally needs to be managed using specialist equipment and personnel (as observed in Haiti following the 2010 earthquake, due to the weight of the collapsed structures) (Booth, 2010).
- Fires typically generate less debris than other hazards (USEPA, 1995b) and the debris is likely to be more difficult to separate and to ensure waste components are contaminant (hazardous or non-hazardous) free (County of San Diego, 2005).

Table 1.2 Typical debris streams for different types of disasters (FEMA, 2007)

		Typical Debris Streams								
		Vegetative	Construction and Demolition (C&D)	Personal Property / Household Items	Hazardous Waste	Household Hazardous Waste (HHW)	White Goods	Soil, Mud and Sand	Vehicles and Vessels	Putrescent
Types of Disasters	Hurricanes / Typhoons	X	X	X	X	X	X	X	X	X
	Tsunamis	X	X	X	X	X	X	X	X	X
	Tornadoes	X	X	X	X	X	X		X	X
	Floods	X	X	X	X	X	X	X	X	X
	Earthquakes		X	X		X	X	X		
	Wildfires	X		X		X	X	X		
	Ice storms	X				X				

1.3.2 Waste quantities

As for waste composition and nature, the quantity of waste will vary based on the type of disaster and the built environment affected. Table 1.3 shows reported waste volumes from some large scale disasters in the last 15 years. As can be seen from the table, waste quantities are reported in terms of both mass and volume. None of the waste quantities reported explicitly stated how they were measured (for example, truck loads or landfill volumes), calculated or estimated (for example waste volumes or mass per house or per affected area). The geographical extents also are generally not reported so it is difficult to give, say, a per affected area or per capita waste generation estimate. Reinhart and McCreanor (1999) have estimated that large scale disasters typically generate in the order of 5-15 years' worth of annual waste generation in a community. The majority of the disaster waste quantity data available is from disasters in the US. This is likely largely due to the established disaster waste management (monitoring and record keeping) processes required for federal emergency funding eligibility, as detailed in the FEMA debris management guidelines (FEMA, 2007).

Table 1.3 Reported waste quantities from previous disasters

Year	Event	Waste Quantities	Data Source
2010	Haiti earthquake	estimated 23 - 60 million tonnes	(Booth, 2010)
2009	L'Aquila earthquake, Italy	estimated 1.5-3 million tonnes	(Di.Coma.C, accessed 2010)
2008	Sichuan earthquake, China	20 million tonnes	(Taylor, 2008)
2005	Hurricane Katrina, US	76 million cubic metres	(Luther, 2008)
2004	Hurricanes Frances and Jeanne, Florida, US	3 million cubic metres	(Solid Waste Authority, 2004)
2004	Indian Ocean Tsunami	10 million cubic metres (Indonesia alone)	(Bjerregaard, 2009)
2004	Hurricane Charley, US	2 million cubic metres	(MSW, 2006)
1999	Marmara Earthquake, Turkey	13 million tonnes	(Baycan, 2004)
1995	Great Hanshin-Awaji Earthquake, Kobe, Japan	15 million tonnes	(Hirayama et al., 2009)

There have been a number of studies that have retrospectively quantified disaster debris volumes following disaster events. The studies have been conducted in an attempt to both improve disaster waste estimation techniques and to aid debris management planning, preparedness and response. In their guide to disaster debris management planning, USEPA (2008) identify that pre-disaster waste estimations are beneficial in both pre-disaster planning and post-disaster response and can be carried out using hazard maps.

The majority of the waste estimation studies carried out have been based in Japan. Studies identified by Inoue et al. (2007) investigated specific gravities of the debris generated by the 1995 Great Hanshin-Awaji earthquake, and found an average specific gravity of 0.59 T/m^3 during transportation, which increased to approximately 0.73 T/m^3 in stockpile due to consolidation processes and water addition for dust suppression. Hirayama et al. (2009;

2010) estimate debris volume on a weight per house or per unit floor area basis. Hirayama et al. use these previous estimates to predicatively estimate likely disaster waste quantities in Japan based on hazard maps. Values of between 30 and 113 T/household are used to account for a range of house and building types and levels of damage sustained.

Outside Japan several studies on disaster waste volume quantification have been carried out. Chen et al. (2007) correlated debris generated from four flooding events in Taiwan with three parameters: population density, total rainfall and flooded area. Chen et al. found a significant non-linear correlation with these variables which could be used to predict future flood waste volumes in Taiwan. A study from the University of Florida quantified arsenic-treated wood following Hurricane Katrina (Dubey et al., 2007). The paper emphasises the potential environmental and public health risk of disposing of such large quantities in unlined landfills. Tansel et al. (1994) present a method of quantifying disaster waste from Hurricane Andrew, US, 1992, based on categorising the size and structural composition of affected houses.

The Federal Emergency Management Agency (FEMA) in the US has developed loss estimation models for disaster events (FEMA, 2009c; d; b). The HAZUS models include debris estimation methodologies. FEMA has also produced a Debris Estimating Field Guide which includes various debris estimation methods (FEMA, 2010).

As for the studies on waste composition discussed in Section 1.3.1, all these studies and guides are context and disaster specific. As noted by Chen at al., the method demonstrated in their study could be transferred to other contexts, but disaster waste data from the different context would be required to generate the correlations. It follows that while estimation methods may be transferred between contexts, actual waste quantities from these studies are less likely to be transferrable.

A cross-context and multi-disaster assessment of waste composition and quantities would be a valuable addition to the literature to enable the development of better waste quantity estimation methodologies. The development of a standard method of reporting disaster waste composition and quantities would be a worthwhile step toward enabling this.

1.4 Disaster management phases

Typically management of disaster waste (and disaster management in general) is described in the literature in three phases (Kuramoto, 1995; Baycan and Petersen, 2002; UNOCHA, 2011):

- Emergency response (debris management to facilitate preservation of life, provision of emergency services, removing immediate public health and safety hazards such as unstable buildings and hazardous materials, lifelines restoration (critical infrastructure) etc.)
- Recovery (building demolition, infrastructure repairs)
- Rebuilding (debris management of wastes generated from and recycled materials used in re-construction).

The phases are not distinct and the duration of each phase varies significantly between disasters. Typically, in terms of waste management, the emergency phase involves the removal of immediate threats to public health and safety, (Reinhart and McCreanor, 1999) and generally lasts between a few days and two weeks (Haas et al., 1977). During this phase there is little scope for recycling and diversion.

The recovery phase is where the majority of the disaster generated waste will be managed and is the focus of this thesis. In past disasters this phase has lasted up to five years (New Orleans, Hurricane Katrina) (Luther, 2008). The duration of the recovery phase for waste managers can be affected by a number of factors outside the control of waste managers including police/coroner investigations which can limit site access for public and waste contractors (Ekici et al., 2009) and slow resident return (New Orleans, Hurricane Katrina) (Cook, 2009).

The rebuilding phase is a much longer process and it is hard to define the 'end' of this phase. According to Haas et al. (1977) the rebuilding phase duration could be in the order of 10 years.

1.5 Waste handling, treatment and disposal

1.5.1 Temporary staging sites

Temporary staging sites for recycling and waste processing are identified as an important element in a disaster waste management system by many authors (FEMA, 2007; Jackson, 2008; USEPA, 2008; Johnston et al., 2009) as they provide extra time to appropriately sort, recycle and dispose of the waste. However, the expense of double handling of wastes and of acquiring land for the staging site can be limiting factors in their use (FEMA, 2007). Figure 1-3 is a photo of a temporary staging area established to manage earthquake waste following the 2009 L'Aquila earthquake, Italy.

Inappropriate location of temporary storage sites can be potentially damaging to the environment and affected people's livelihoods. Following the 2004 Indian Ocean tsunami, waste was disposed of in areas such as playgrounds, swamps and rice paddies (Basnayake et al., 2006; Pilapitiya et al., 2006; UNDP, 2006). Pre-disaster identification of temporary storage sites has been suggested by many authors as a way to avoid these potential adverse effects (Kobayashi, 1995; Skinner, 1995; FEMA, 2007; USEPA, 2008; Johnston et al., 2009). Most of the disaster waste management guidelines reviewed (FEMA, 2007; Wellington Region Civil Defence Emergency Management Group, 2008) provide guidance on temporary staging site selection; however, as identified by Channell et al. (2009), there is potential for more research to be carried out on siting and management aspects of temporary staging sites.

More research on the effective use of temporary storage / staging facilities would be beneficial. Factors requiring consideration include space requirements, environmental factors, noise and dust, pre-disaster site identification, land-use planning issues and costs.

Figure 1-3 Temporary staging area for managing waste following the 2009 L'Aquila earthquake, L'Aquila, Italy. (Photo date: September 2010.)

1.5.2 Recycling

Many components of disaster waste can be recycled. Materials can be used in a number of post-disaster applications including soil for landfill cover, aggregate for concrete, and plant material for compost (fertilisation and slope stabilisation) (Channell et al., 2009). The benefit of recycling disaster debris is shown in many ways and is evident in the analysis of many past disaster clean-ups: Marmara Earthquake (Baycan and Petersen, 2002; Baycan, 2004), Kosovo (DANIDA, 2004), Northridge Earthquake, US, 1994 (Gulledge, 1995; USEPA, 2008), Lebanon (Jones, 1996), Great Hanshin-Awaji Earthquake (Kobayashi, 1995), Indian Ocean Tsunami, Thailand and Sri Lanka (Basnayake et al., 2005; UNDP, 2006). The benefits include:

- Reduction of landfill space used.
- Reduction in the quantity of raw material demand (for purposes where recyclable materials are suitable).
- Possible reduction in waste management costs.
- Reduction in transportation for raw materials and debris.
- Job creation (for developing countries, in particular).

The major component of disaster waste, in most cases, is construction and demolition (C&D) waste. There are many existing articles which address recycling barriers and opportunities to recycling this waste stream in peace-time (Hsiao et al., 2002; Kartam et al., 2004; Blengini, 2009; Kofoworola and Gheewala, 2009). Skinner (1995) and Reinhart and McCreanor (1999) presented peace-time C&D recycling practices and data as guidance for disaster waste recycling. However, little critical analysis was presented for recycling following a disaster event. Other authors have identified potential barriers to C&D recycling after a disaster, including: the time to collect and process the materials; the unavailability of specialised processing equipment (Baycan and Petersen, 2002); the inability to physically separate the materials (Lauritzen, 1998; Baycan, 2004); the lack of desire to offset raw material use in rebuild (Lauritzen, 1998); unavailability of disposal sites (Lauritzen, 1998); cost relative to other disposal methods (Solis et al., 1995); and the unavailability of markets to absorb large quantities of material (Solis et al., 1995; Lauritzen, 1998).

While the literature provides an overview of the advantages and barriers to recycling following a disaster, there have been no quantitative assessments of post-disaster recycling feasibility, and what planning / preparations are possible pre-disaster to make recycling a more viable option

A more comprehensive understanding of post-disaster recycling is required. In particular, factors such as: the effect of large quantities of materials on existing recycling markets; the need for establishment of post-disaster markets (eg. environmental land remediation, land reclamation, waste to energy and housing reconstruction applications); logistical constraints; space requirements and associated land-use issues; and the economics of post-disaster recycling, all require further analysis.

1.5.3 Waste to energy

Waste to energy has been proposed by Yepsen (2008) as a potential disaster waste treatment option. Yepsen noted that there are limiting factors in using waste to energy as a treatment option in the US. These include high shipping costs, limited markets in the US, certification requirements for international movement of the biomass and FEMA emergency funding regulations (which are geared toward lowest cost debris management contracts with no incentives for beneficial use).

Small scale waste to energy has been used in the US in response to Hurricanes Katrina, Rita, Charley, Frances, and Jeanne (USEPA, 2008), but there is no review of the success of these initiatives.

1.5.4 Open burning

Open burning has been used as a disaster waste management option following the Indian Ocean tsunami (Basnayake et al., 2006), and the Great Hanshin-Awaji earthquake (Irie, 1995). While some people accepted open burning as an acceptable management option under the circumstances, others condemned it for adverse health effects and environmental concerns. Petersen (2004) and Lauritzen (Naito, 1995) suggest open burning is a necessary management option in some cases to remove immediate hazards but give little definitive guidance on the situations for which open burning is appropriate.

As for recycling and waste to energy treatment options, no research has been carried out into open burning specifically following disasters.

Guidance on the circumstances under which open burning should be used would assist disaster waste managers to assess and implement appropriate treatment programmes.

1.5.5 Land reclamation and engineering fill

Several disaster responses have used land reclamation as a waste management option. Following the 1999 Marmara earthquake in Turkey, some municipalities used the debris as levelling fill for new housing developments and as land protection against flooding. Baycan (2004) expressed concern over the potential for hazardous wastes to be inadvertently included in the fill but gave no formal assessment of the risk or retrospective analysis on actual contamination. Contamination and/or variability in fill composition could also lead to structural instability of the fill in time.

Following the Great Hanshin Awaji earthquake, existing land reclamation programmes were requested to take earthquake debris. Significant amounts of sorting and waste segregation was reportedly required to ensure the debris was clean enough for coastal reclamation (Irie, 1995; Lauritzen, 1998). As for the Marmara earthquake, the author is unaware of any post-reclamation testing or assessment of effects.

1.5.6 Disposal

In many large scale disasters, waste volumes exceed permanent disposal site capacities (Petersen, 2006; USEPA, 2008). Temporary or low engineered debris and waste disposal sites can be employed. Standards at existing disposal sites have also been reduced after some disasters to increase available disposal sites (for example the expansion of waste disposal criteria at unlined Construction & Demolition landfills after Hurricane Katrina (Luther, 2008)). Authors note the potential for adverse environmental effects at these disposal sites but give little evidence on actual effects.

Disposal of hazardous substances has been identified as problematic following several disasters – Indian Ocean tsunami (Pilapitiya et al., 2006) and Hurricane Katrina (Dubey et al., 2007). Hazardous waste is disposed of in some cases without segregation as part of the overall waste matrix. Apart from the study by Dubey et al (2007) on arsenic quantities in the waste post-Hurricane Katrina, there has been little research into actual effects of disposal of hazardous substances in disaster situations. Channell et al. (2009) identified several problematic substances present in disaster waste of which disposal issues required further research including gypsum and putrescent materials.

Further research would be beneficial investigating the environmental and human health impacts of disaster specific disposal sites and the subsequent development of disaster specific guidance on the effective establishment and operation of these sites.

1.6 Environment

Disasters and the environment are inextricably linked. Disasters cause direct physical damage to the environment and inappropriate environmental management and land use can increase the environment's vulnerability to the effects of disaster events. For example, experts believe that the impact of the Indian Ocean Tsunami would have been reduced by proper preservation and management of mangroves and coral reefs as they would have acted as a buffer against the waves (UNEP, 2005b). In Thailand inappropriate peace-time waste management has contributed to this form of environmental degradation as many waste dumps were located in coastal areas. The suitability, or not, of disaster waste management options will have an effect on the environmental impact of a disaster and in turn may affect the environment's future resilience against hazards. Poor management in general can also induce negative environmental effects. For example, in the past slow clean-up programmes have led to illegal dumping (Baycan, 2004; Petersen, 2004; Jackson, 2008).

The standard peace-time waste management hierarchy of source reduction, recycling and waste combustion / landfilling (USEPA, 1995a) is not always considered possible post-disaster. In fact, sometimes peace-time environmental standards are reduced to expedite disaster waste management activities. For example, as discussed in Section 1.5.6, the expanded waste disposal criteria following Hurricane Katrina.

Despite many of the disaster waste management plans discussed in Section 1.2 emphasising environmentally responsible approaches, there seems to be no critical analysis on what environmental standards are appropriate post-disaster.

In developing countries, disasters are often cited as a potential opportunity for development of waste management systems and/or improvement of existing environmental practices. For example, a United Nations Development Programme (UNDP) Indian Ocean Tsunami waste management programme included a focus on the development of sustainable waste management systems through the collection, recovery, recycling and/or safe disposal of waste materials (UNDP, 2006).

An improved understanding of the need for, and the risks or effects of changes in environmental standards post-disaster is needed.

1.7 Economics

Little information exists on the economic impact, both direct and indirect, of disaster debris management programmes. Table 1.4 provides an overview of the limited published (direct) cost data for debris removal works. Costs reported are variable and sometimes only include one part of the clean-up works, for example: the value of collection contracts; only disposal costs; costs for debris management in one affected region; or just publicly funded clean-ups. Due to the FEMA reimbursement processes (FEMA, 2007) cost data for debris management should be available in the US, however, the author has only located a limited amount of cost data.

Table 1.4 Disaster waste management costs following past disasters

Disaster	Location	Debris quantity	Cost (as quoted in original reference)	Reference
2004 Indian Ocean tsunami	Sri Lanka	0.5 mill tonnes	500-600 million rupees (US$5-6 million)	(Basnayake et al., 2006)
2004 Indian Ocean tsunami	Thailand	0.8 mill tonnes	110 million Baht (US$ 2.8 million)	(Basnayake et al., 2006)
2004 Typhoon Tokage	Tokage, Japan	44,780 tonnes	Estimated US$ 15-20 million	(UNEP, 2005c)
1999 Kosovo Conflict	Kosovo	100,000 tonnes	13.7 millionDKK (building waste management system programme only) (US $2.35 million)	(DANIDA, 2004)
Hurricane Charley	Florida, US	19 mill cubic yards	US$286 million FEMA reimbursed money only	(FEMA, 2009a)
Hurricanes Jeannes & Frances	Palm Beach, US		US$20 / cubic yard pickup-disposal	(Solid Waste Authority, 2004)
1998 Central Florida Tornadoes	Osceola County, US	250,000 cubic yards	US$8 million (debris removal contract only)	(Reinhart and McCreanor, 1999)

In the US, FEMA (2007) estimates that for disasters in the US between 2002 and 2007 (predominantly hurricanes and other storm events) debris removal operations accounted for 27% of FEMA disaster recovery costs. Note that FEMA funds include only for the 'emergency response' activities and do not generally include waste resulting from repairs and rebuilding activities or demolition.

Indirect costs following disasters are more difficult to assess. Indirect costs associated with slow disaster waste management could include: disruption of critical infrastructure; effects on public health (Petersen, 2004); delays to rebuilding processes; affects local industry such as tourism (UNEP, 2005c). Indirect costs also result from a poorly designed disaster waste management programme: reduction in future landfill space; impact of waste trucks on roads (Reinhart and McCreanor, 1999); environmental impact remediation resulting from inappropriate and/or illegal dumping (UNDP, 2006); and increased resource depletion by limited resource recovery.

As for waste quantification (see Section 1.3.2), costs associated with debris management will vary significantly depending on the disaster and the context. Attempts to quantify the direct and indirect costs of management of disaster waste have been limited. The FEMA HAZUS loss estimation methodology (discussed in Section 1.3.2) is arguably the most comprehensive estimation technique available.

Development of an approach to assess the likely direct costs of various waste management options (recycling, waste to energy, landfill disposal, land reclamation, etc.) and indirect costs of those options (slower debris removal, long term environmental degradation, etc.) would greatly enhance disaster waste managers' abilities to respond appropriately to disasters in the future.

1.8 Social considerations

1.8.1 Human health and safety

Human health and safety protection is identified as a goal in many of the case studies and plans (Solis et al., 1995; WMinE, 2004; SWANA, 2005; USEPA, 2008). There are three main aspects of human health and safety relevant to disaster waste management. First, human health hazards presented by the waste matrix itself, such as hazardous substances, vermin and vectors and health care wastes (WMinE, 2003; Petersen, 2004) have to be managed. Second, health and safety risks from waste management options must be considered. For example, following Hurricane Andrew, US, 1992, the use of air-curtain incinerator units drew concern over the potential human health risks from burning commingled wastes (USEPA, 1995b). Lastly, health and safety protection for all those who handle the waste has to be considered. In the aftermath of the 2001 World Trade Centre collapses, medical studies of emergency responders and clean-up workers identified some health effects from dust particles inhaled (Landrigan et al., 2004; Lange, 2004) due to inadequate health and safety equipment. Allen (2007) commented on the inadequate provision of protective equipment for private property owners returning to clean up their properties following Hurricane Katrina. Channell et al. (2009) identified management of fine particulate matter during demolition and debris management processes, as a necessary research area.

Qualitative and quantitative analysis of the likely human health threats will add to the literature, and to disaster waste managers' understanding of waste management options. The assessment should consider the human health hazards from the waste matrix, waste management options and from handling the waste.

1.8.2 Community / psychosocial impact

Many studies state that fast disaster debris removal expedites the community recovery and rebuilding process (Solid Waste Authority, 2004; WMinE, 2004; SWANA, 2005; USEPA, 2008). Unmanaged and visible disaster debris and waste can serve as a reminder to communities of the losses they have endured (DANIDA, 2004; Petersen, 2004). However, most disaster waste management programmes also include environmental and/or health and safety objectives which contribute to a slow debris management process, such as strict recycling targets and hazardous material handling requirements. Luther (2008), for example, identified the time-consuming procedures required for asbestos management following Hurricane Katrina as particularly challenging. The challenge was to minimise exposure to asbestos while not slowing the clean-up. The conflict between a fast waste management process (to facilitate community recovery) and meeting environmental and public health objectives has not been explicitly addressed in the literature.

Allen's (2007) commentary on 'environmental justice' issues relating to Hurricane Katrina highlighted the negative social impact of locating disaster disposal sites near disaster affected communities. Denhart (2009) studied the positive psychosocial impacts of a housing deconstruction (as opposed to demolition) project following Hurricane Katrina. The project allowed property owners to participate fully in the manual deconstruction and resource recovery process of their property. Denhart emphasised the attachment that was felt between people and their properties. Denhart also noted that property owners were able to take control of their properties and were able to "give life" to their damaged properties by donating, selling or re-using the building materials.

It is interesting to note that rubble is often used to commemorate disaster events. Birkenhopf, in Stuttgart (refer Section 1.1) holds a commemorative plaque on its summit.

Rubble from the World Trade Centre collapse has also been used widely (including in New Zealand) to create memorials for those who lost their lives.

It would be beneficial for disaster waste managers to better understand the psychosocial implications of the speed and nature of the debris removal process. For example, effects from personal property salvage and the emotional attachment owners have with their properties. Understanding these factors will enable better planning of disaster waste systems.

1.8.3 Communication

Public perception, understanding and involvement has long been recognised as a factor in successful solid waste management programmes (USEPA, 1995a). However, achieving adequate community understanding in a disaster situation is a huge challenge for waste managers. Authorities after Hurricanes Frances and Jeanne identified pre- and post-disaster communication, through an on-going and consistent education programme, as a key to their successful and efficient debris removal programme (Solid Waste Authority, 2004; USEPA, 2008).

In past events, negative community reaction to disaster waste management options has led waste managers to alter their approaches: consuming time and valuable resources post-disaster as well as generating mistrust in the community. As discussed in Section 1.8.1, community reaction to air curtain incinerators following Hurricane Andrew, led to the abandonment of incineration (USEPA, 1995b). Following Hurricane Katrina, public opposition to the expanded waste acceptance criteria at C&D landfills led to a lawsuit being filed and the eventual closing of one of the landfills. Waste managers were forced to find alternative disposal sites (Luther, 2008). Public consultation during the disaster waste management process may have increased public understanding of the necessary actions for efficient management of the waste, or would have identified publicly unacceptable waste management options before attempts were made to implement them.

Comprehensive guidance on the most effective ways to include communities in post-disaster waste management decision-making is missing from the current literature. Waste managers *need to recognise that communities can be changed by a disaster: their expectations, risk tolerance and needs will likely change significantly. Further research is needed.*

1.8.4 Employment and capacity building

Past disaster waste responses in developing countries and post-conflict situations have included opportunities for post-disaster employment, and for expertise and governance capacity building. Capacity building of local governments, in particular, is identified as a priority by several authors (DANIDA, 2004; Petersen, 2004; UNDP, 2006; Bjerregaard, 2007) and includes development of management systems, budgeting, and technical skills.

1.9 Organisational aspects

1.9.1 Strategic management

Disaster recovery, in general, can be governed by a number of different organisational configurations. Olshansky et al. (2006) comment that generally the establishment of a separate recovery coordination organization is helpful. The management of disaster waste in relation to the overall disaster recovery also varies between contexts and events.

Disaster waste organisational structures are best defined in the US where disaster waste management roles are clearly established by FEMA (2007). Elsewhere, roles and responsibility for disaster waste management are not well established. In Turkey following the 1999 Marmara earthquake, no department was assigned coordinative responsibility for debris which led to a report of haphazard waste management (Baycan, 2004).

In developing countries, in particular, the presence of numerous international aid organisations adds to the complexity of coordination and strategic management. Often, despite coordination efforts by the United Nations or government, inappropriate handling and disposal of debris still occurs (Petersen, 2006; UNDP, 2006). Avoidable administrative delays can also affect disaster waste management activities. For example, there were customs delays at ports in Haiti which delayed the arrival of rubble clearing equipment (Moloney, 2011). Petersen (2004), in a review of several disaster events, emphasised the need for inclusion of waste management activities in international humanitarian responses, and of central coordination for waste management activities.

Organisational structures for the coordination of disaster waste management programmes are likely to be context specific and will need to fit within existing governance structures. However, there would be value in further investigations into how organisational (intra-organisation) structures influence the effectiveness of waste management programmes (for example human and equipment resourcing, work scheduling); and how best to integrate waste management into the overall disaster recovery operation (inter-organisation) (such as coordination with rebuilding activities, allocation of shared resources, works prioritisation).

1.9.2 Operational management

It appears that the physical works associated with disaster waste management operations (demolition, private property clearance, kerbside collection, transportation, temporary staging areas, recycling, disposal) have been implemented in a variety of ways with varying degrees of public and contractor participation and contractual arrangements. For example, the FEMA regulations (2007) generally (unless there is a significant public health and safety risk) require private property clearance to be paid for and facilitated by property owners. Kerbside collection is carried out by contractors or the US Army Corps of Engineers. The organisation of the physical works has implications on the speed of recovery, resource availability and management of environmental and human health hazards.

It appears that certain peculiarities of the disaster and resultant waste may indicate what operational systems are most appropriate. Waste characteristics (as discussed in Section 1.3.1), for example, can influence how the debris is managed and what level of public participation is desirable. For example, heavy earthquake debris (Lauritzen, 1998; Booth, 2010) or hazardous substances such as asbestos after Hurricane Katrina (Luther, 2008), may be too cumbersome or dangerous for private property owners to manage themselves. No author has looked critically at what factors should be considered in the organisational design of the physical works associated with disaster waste programmes.

In the US, disaster waste contracting is a growing industry. Contracting companies are specifically positioning themselves to respond to disaster events including procuring specialised equipment, personnel and pre-arranged contracts (Fickes, 2010). Pre-arranged contracts and rates with contractors has been identified as an important feature in facilitating effective clean-ups (Jackson, 2008) and avoiding price gouging (Jordan, accessed 2010). Mismanagement of disaster waste by contractors, such as illegal dumping observed following Hurricane Katrina, (Allen, 2007; GAO, 2008) may also be avoided by having pre-arranged contracts.

Research is needed into the most effective operational organisational strategies for different disasters.

1.10 Funding

The financial responsibility for disaster waste management varies between and within contexts and disasters. In the US, for example, FEMA funds a kerbside collection service for collection of private property detritus; whereas, private property demolitions are generally the responsibility of the property owner (and/or their insurer) (FEMA, 2007).

The literature includes reference to funding mechanisms used in specific responses; however, it lacks analysis of the most effective mechanism (private, public, insurance etc.) for funding disaster waste management in different contexts.

Disaster response and recovery funding policies commonly stipulate lowest cost options must be used. For example, the FEMA regulations in the US (FEMA, 2008) appear to consider only direct costs and do not consider the longer term, indirect costs and/or benefits, of certain waste management options (refer Section 1.7). That is, the feasibility assessments required by FEMA are cost rather than cost-benefit focussed. In some cases a cost-only analysis does not allow disaster waste managers to meet the goals of long-term (or even current) waste management strategies (Lauritzen, 1995); on the other hand, it could be argued that environmentally preferable management options are too costly in a disaster response situation.

For example, in Los Angeles (LA), following the 1994 Northridge earthquake, FEMA originally denied funding for LA officials to establish a recycling system to supplement its insufficient landfill space, because it was more expensive than landfilling. The city of LA was forced to prove that recycling was part of their long-term waste management strategy and that the additional cost to start up recycling facilities was justified (State of California, 1997). Currently there is no literature on how non-direct costs can be included in feasibility assessments of disaster waste management programmes.

Further analysis of the success or failure of various funding mechanisms relative to the context and the disaster impacts would be beneficial.

1.11 Legal frameworks

Solid waste management, particularly in developed countries, is governed by diverse legislation and regulation to minimise the potentially harmful effects of waste on the humans and the environment. However, in the wake of a disaster these peace-time laws can cause significant delays in the clean-up process. For example, health and safety procedures for demolition of structures containing asbestos meant average structure demolition times of four days in the clean-up following Hurricane Katrina. Authorities elected to relax handling standards to reduce demolition times to one day (GAO, 2008).

As noted by Kobayashi (1995), the greater progress we make toward recycling and advanced waste treatment methods, the more our ability to cope with disaster decreases. Complex treatment and disposal processes with strict environmental standards are not designed for large acute influxes of materials.

Many disaster waste management plans or guides (Solis et al., 1995; Wellington Region Civil Defence Emergency Management Group, 2008) highlight the availability of emergency legal waivers on solid waste regulations such as the Hurricane Katrina asbestos example. However, it is often unclear to what degree and in what circumstances legal or regulatory relaxations are acceptable. In the previous example the relaxation of demolition procedures had the potential to cause long term health effects for waste handlers and the public.

A 2006 report for the US Congress, on Hurricane Katrina, assessed the use of environmental waivers. The report described their effectiveness in the short term for expediently managing debris but raised questions over the implications of their use in the long-term (for example land or water contamination effects) (McCarthy and Copeland, 2006). Overall the report was inconclusive and gave no guidance on future use of legal waivers in the US.

Legislation and regulation has the potential to significantly affect the efficiency and effectiveness of a disaster waste management programme. The impact of legislative provisions on the management of disaster waste will be very context specific. Brown et al. (2010a) present a discussion of the potential legal issues for managing disaster waste in New Zealand. The review found that while there was legal flexibility to facilitate a timely clean-up the complexity of the legislation and organisations involved may make post-disaster decision-making and the assessment of applicability of legal waivers cumbersome. A similar review was carried out by Gerrard (2006) in the US context. Gerrard found that the majority of environmental regulations in the US include emergency exemptions and, despite the propensity following the 2001 World Trade Centre collapse and Hurricane Katrina to expand the existing emergency exemptions post-disaster, further exemptions are not considered necessary.

Waste ownership (salvage rights) was identified as a potential legal issue in a cross case study analysis by Baycan and Petersen (2002). Waste ownership issues are of concern when private property owners are not able to participate in the clearing of their own property, particularly where revenue is then generated from recycling of the debris.

A general investigation and guidance into necessary legislative and regulatory requirements for disaster waste management would be useful.

1.12 Thesis scope

As demonstrated in the above literature review, there are still significant gaps in our understanding of disaster waste management. In particular, existing literature focuses heavily on technical management aspects of disaster waste management and neglects institutional (organisational, legal and financial) frameworks. In addition the literature is generally either based on a single disaster event, single hazard types or has a focus on a single cultural context. As a result it is difficult to apply the recommendations and lessons learnt confidently to other disaster events and in other contexts. This makes planning for disaster waste management challenging.

Therefore, the research aim was to improve our understanding of disaster waste management systems as an element of wider disaster recovery. The focus of the research was on the institutional frameworks that influence disaster waste management system as a function of overall disaster recovery. The analysis included operational aspects of disaster waste management systems from cradle to grave (from demolition / collection to end use / final disposal).

With limited structured research currently in disaster waste management, the author first aimed to develop a robust analysis framework to: 1) enable this research and 2) to provide a clear and repeatable framework for future research. Second, the author aimed to develop a high level, holistic understanding of the disaster waste management system including: the key system elements, the key relationships, the constraints, the behaviour drivers, and the overall system behaviour. Ultimately the analysis framework and the systems understanding were combined to develop a decision-making guidance tool for disaster waste managers which can be transferable between hazards and contexts.

The specific research objectives were:

1. To develop a robust analysis framework to research disaster waste management.
2. To understand the high level system dynamics of disaster waste management systems.
3. To investigate potential decision-making tools for disaster waste managers.
4. To identify future research needs.

The following chapter presents the methodology used for the research and also provides a road map for the remainder of the thesis.

2. Methodology

2.1 Introduction

As discussed in Section 1.1, previous research has been either context specific or event specific making it difficult to transfer lessons from one disaster event to another. A methodology was necessary to enable data to be: 1) gathered from a wide range of contexts and hazard types, and 2) to be analysed such that the analysis results could be transferred between contexts and hazard types.

Therefore, a multi-hazard, multi-context, embedded multi-case study approach was adopted. According to Yin (2009), case study research methodology is appropriate when a researcher is aiming to understand "how" or "why" a certain (social) phenomenon works. In particular case studies are useful where the researcher has no control of behavioural events; the research focuses on contemporary events; and where decisions are the focus of the study: all of which apply to this research topic. As well as increasing transferability of results, a multi-hazard approach ensures that the research is also in line with the majority of emergency research and planning. A multi-cultural approach allows for a wider range of organisational arrangements and institutional frameworks to be analysed. This inclusive approach also increases the number of potential case studies: after all, disasters are, by definition, rare.

The author's aim was to develop a case study analysis framework which could be consistently applied across different and varied disaster events such that common lessons could be drawn and transferred to other contexts. In addition it was desired that the framework could be manipulated so that it could be used as a disaster waste planning tool.

This chapter outlines: why the case studies were selected (Section 2.2.1); how the data were collected (Section 2.2.2); how each case study was analysed (Section 2.2.3); and how the cross case analysis was carried out (Section 2.2.4). A discussion section (Section 2.3) is also included to review the strengths and limitations of the methodology.

This chapter is adapted from the following conference paper presented by the author (refer Appendix B):

> Brown, C., 2011. Disaster waste management: a systems methodology. *International Conference on Building Resilience*, July 2011, Kandalama, Sri Lanka.

2.2 Case study analyses

2.2.1 Case study selection

According to Yin (2009), five or more cases should be investigated if the theory is subtle. Due to time constraints five case studies were analysed. The studies selected were (in the order they were investigated)(*study location in brackets*):

1. Victorian Bushfires (*Victoria, Australia*), 2009
2. Samoan Tsunami (*South eastern coast of Upolu Island, Samoa*), 2009
3. L'Aquila Earthquake (*L'Aquila, Abruzzo, Italy*), 2009
4. Hurricane Katrina (*New Orleans, Louisiana, US*), 2005
5. Christchurch Earthquake (*Christchurch, New Zealand*), 2011[3]

The case studies were chosen for a number of different reasons:

- <u>Access to data</u>: Where possible, cases were selected where contacts and/or relationships already existed, a site reconnaissance was feasible, and/or there was good access to published data (preferably in the author's native language: English).
- <u>Timing of the event</u>: Reconnaissance and interviews were ideally carried out 6 – 12 months after the disaster event to minimise disruption to response activities and to gain benefit from participant reflection.
- <u>Scale of disaster:</u> Cases were selected where waste volumes overwhelmed existing capacities and extraordinary measures, above existing emergency plans and capacities, were taken.
- <u>Multi hazard</u>: A range of (four) hazard types were represented.
- <u>Multi-contextual:</u> A diverse range of contexts with varying institutional frameworks and organisational structures and approaches were included.

[3] Data have been collected since the first Canterbury earthquake on 4 September 2010. While some reference is made to the September earthquake response, the analysis focuses on the 22 February 2011 earthquake.

2.2.2 Data collection

For each case study, qualitative data have been gathered from both pre- and post-disaster literature (government reports, documents and legislation; newspaper; practitioner reports etc.) and semi-structured interviews with professionals involved in disaster waste management. The semi-structured interviews focussed on:

- disaster impacts (number of deaths, number of damaged properties, lifeline disruption etc.);
- disaster waste properties (volume, characteristics, hazards etc.);
- impact and waste assessment processes;
- pre-disaster waste management systems (normal waste volumes, spare capacity in system, future waste strategy);
- pre-existing disaster waste management plans;
- disaster management systems (overall and waste specific);
- property owner participation / responsibilities in clean-up);
- waste collection and transportation process;
- recycling;
- waste disposal;
- waste management timeline and priorities;
- demolition processes;
- reconstruction waste;
- costs;
- economic impact;
- relevant legislation;
- overall effectiveness of waste management approach; and
- any other areas identified by the interviewee.

For all but Hurricane Katrina, face to face meetings were possible with personnel involved directly in the waste management process including solid waste managers, local authorities and emergency managers. Due to funding limitations, a reconnaissance to Louisiana was not possible. Instead data were gathered through three phone interviews with recovery personnel and the review of a considerable amount of published material on the event response. In Christchurch, the author had the opportunity to participate in the first four months of the 2011 February earthquake response and recovery effort, working in the waste management team under Civil Defence and the Canterbury Earthquake Recovery Authority. Therefore, data for the Christchurch case study were primarily collected using an active participatory approach.

A community based survey was also carried out in Victoria to gauge attitudes towards, and impacts of the management of disaster waste. The survey included questions on: community attitude towards debris after a disaster; community perception of insurance and public funding; and the effect of the waste management programme on their overall recovery including timeliness and completeness. Due to language barriers and time constraints, this community survey was not able to be carried out for the other case studies.

The data sources for each case study are summarised in Table 2.1.

Table 2.1 Case study data sources

	Victorian Bushfires	Samoan Tsunami	L'Aquila Earthquake	Hurricane Katrina	Christchurch earthquakes
Date of main data collection	August 2009 (professionals) / March 2010 (community)	April 2010	September 2010	February 2011	September 2010 – date of publication
Time after disaster	6 months / 13 months	7 months	17 months	5.5 years	In parallel with recovery
Number of data sources					
Face to face interviews	8	20	10	-	-
Phone interviews	0	-	-	3	-
Community members surveyed	14	-	-	-	-
Legal documents	2	3	5	10	2
Government document	13	7	8	23	14
Practitioner reports	0	14	0	1	1
Academic articles	1	0	4	12	2
Private enterprise generated documents					2
Newspaper articles	1	11	6	1	24
Websites	2	3	3	4	4

Last, an informal survey of disaster waste management perceptions was carried out amongst largely academics and disaster management professionals. The survey was part of a seminar series by the author and the author's primary supervisor, Associate Professor Mark Milke. As this data collection is supplementary to the main research methodology and data collection, the survey description, results and data limitations are included in Appendix C.

2.2.3 Single case study analyses

For each case study, first a description of the disaster and disaster waste management system was developed. This generally included:

1. Disaster impacts
2. Waste properties (volume, nature, hazards)
3. Organisational structures (strategy and operations)
4. Legislative frameworks and post-disaster legislative or regulatory decisions
5. Funding frameworks (pre and post-disaster)
6. Waste management operations (emergency response; waste collection, transportation, handling and disposal; hazardous waste; health and safety; monitoring and record keeping; public information; and other.)

The general description above provided the background context for which the case study could be analysed and the disaster impacts which may influence the management of the waste.

Next, each case study disaster waste management system was qualitatively broken down into five system elements (note that the system elements have been refined during the course of the research and the full Bushfire and Samoan tsunami case studies used slightly different elements. These were manipulated to the final five elements during the cross-case analysis.):

- Strategic management
- Funding mechanism
- Operational management strategy (including a subsystem of recycling)
- Environmental risk management
- Human health risk management

The effectiveness of each system element was then assessed using a cause and effect model. That is, an analysis as to why the waste management approach was taken and how effective the approach was. The cause or external influences on the disaster waste management system was discussed in a decision-making process section:

- Approach and rationale

The effects were qualitatively assessed by identifying the strengths and weaknesses of the approach, broken down into the following sections:

- Related delays
- Organisational implications
- Legal constraints
- Environmental effects
- Economic effects
- Social effects

The single case studies are summarised in Chapter 3, and the full case studies are included in Appendix D, Appendix F, Appendix H, Appendix J, and Appendix K.

2.2.4 Cross case study analysis

Using the case study analyses described above, a cross case analysis model was developed to enable a consistent and thorough template for cross case analysis. The model is shown in Figure 2-1. The large dotted circle represents the context that is affected by the disaster event. Depending on the context and the hazard generating the disaster, certain disaster impacts are generated. The context and the disaster impacts are the externalities which will determine the nature of a disaster waste management system. These are, in effect, the cause or decision-drivers as to why a disaster waste management system is designed a certain way. The five circles in the middle of the diagram depict the five key elements of a disaster waste management system (as determined above in the single case study analyses). The links between the elements and the touching sides represent the links between the system elements. The elements are in no particular order. The large circle around the system elements represents the legislation and regulation which constrains how the waste management system can be designed. Last, the model includes 'effects'. This system component is important as it represents the effects or effectiveness of a particular disaster waste management approach.

A more detailed discussion of each of the model elements and how the model was used in the analysis is included below (with relevant thesis chapter numbers given in brackets).

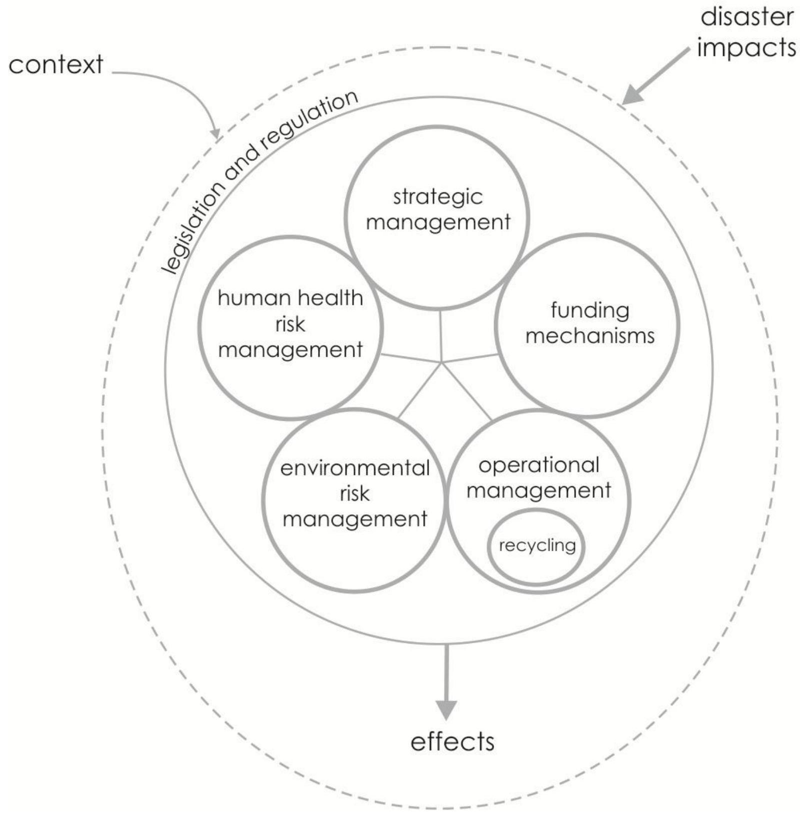

Figure 2-1 Case study analysis model

Disaster impacts (Chapter 4)

To enable cross case analysis, qualitative disaster impact and disaster waste impact indicators were developed using the case study data. The indicators were based on the key motivators and driving factors for post-disaster decision-making. In development of the indicators several definitions and categorisations of disaster waste and disaster waste management activities were developed.

Effects (Chapter 5)

Based on the assessment of effects (environmental, economic and social) for the single case studies, 12 qualitative criteria for assessing the effectiveness of various disaster waste management system approaches were developed. Two criteria specifically reflect typical recovery objectives. A semi-quantitative application for the indicators (as a planning and response tool) is also developed but is not used in the analysis presented in this thesis.

System elements (Chapters 6 to 10)
For each system element (strategic management, funding mechanisms, operational management strategy, recycling, environmental risk management and human health risk management) the data from each case study were combined using a combination of pattern matching, explanation building and logic models (Yin, 2009). All the case study approaches were compared to see which had the most positive impact; the disaster and disaster waste indicators were reviewed to determine why certain approaches were taken or were more successful; and the links to the other systems elements were identified and analysed.

In the thesis discussion (in the interest of brevity), the common links between two system elements have only been fully discussed in one of the respective elements chapters, with a brief reference in the other. The author has elected to only discuss linkages where the linked element has already been presented in a previous chapter. For example links between Strategic management (Chapter 6) and Funding mechanisms (Chapter 7) will only be discussed in the Funding chapter, and so on.

To ensure a fair analysis, wherever possible, the observations were taken relative to the contextual baseline rather than as an absolute. For example, the analysis of the environmental and human health risk management decisions and legislative frameworks (Chapter 10) generally only looked at circumstances where standards had been altered from peace-time standards. It was not the aim of this research to determine the suitability of peace-time standards. This approach was deemed necessary to enable cross case analysis without contextual bias.

Each element analysis (including recycling) is presented in a separate chapter except for environmental and human health risk management which are combined.

Legislative and regulatory framework (Chapter 11)
An analysis on the legislative and regulatory frameworks necessary to successfully manage disaster waste was carried out. As above, this analysis combined all the single case study data

to determine some general requirements and principles for disaster waste management legislation and regulation.

2.3 Discussion

2.3.1 Case study selection

The case studies represented a wide range of disasters and contexts. There was a range of funding mechanisms (full private insurance reliance to full government sponsorship), organisational structures, waste management approaches etc. It was fortunate that the timing of the research and funding availability coincided with such a diverse range of disaster events.

The case studies did not, however, represent a wide range of disaster scales. All events investigated (apart from the 2010 Canterbury Earthquake investigated briefly as part of the 2011 Christchurch earthquake analysis) were catastrophic events involving loss of life and property. Further research including a range of disaster scales would be beneficial.

While variability of disaster events and contexts was desired during case study selection, it was found that the study in Samoa was significantly different to the other studies. The developing country context of Samoa meant that some of the institutional frameworks (legislative structures, environmental standards, public health and safety etc.) that the research focuses on, were not as critical to the management of disaster waste as in developed countries. The case study was still useful, particularly during the analysis of organizational structures and public participation; however, in general, limited comparisons were able to be made between Samoa and the other case studies.

In carrying out the data collection 6-12 months after the event, it was hoped that participants would still have a clear memory of the processes followed, the decision-making rationale, and the outcomes. But also be able to reflect on the approach taken and assess the systems effectiveness. In general, the author believes this aim was met. The major drawback to the timing of the data collection was that, because of the relative proximity to the event, potential environmental, economic and social effects (positive or negative) had not been fully realised. For example, the environmental effects due to mixed waste disposal at a closed landfill site after Hurricane Betsy in 1965, in New Orleans, were not fully realised until 1990 when the landfill site was designated a Superfund[4] site. The site had even already been built on (Allen, 2007). Human health effects on those involved in the clean-up after the 2001 World Trade Centre collapse will need to be monitored for many years with increased risk of respiratory and other illnesses, such as Mesothelioma etc. (Landrigan et al., 2004). Therefore, in some cases the author has had to project, based on the interviewee's responses and her own professional judgment, the possible or likely future effects of certain disaster waste management approaches. It has been noted wherever projections have been made. A longitudinal study of one or more of the case studies presented here would be an excellent way of verifying the robustness of the analysis and the system effectiveness measures.

2.3.2 Data collection

Access to robust, accurate and complete data is one of the major challenges of disaster research. The data in this research relied primarily on individual accounts 6-12 months after the event, supplemented by written documents where available. The quality of the information is limited by: the memory, understanding and interpretation of the situation by the interviewees; language translation (Samoa and L'Aquila); cultural interpretation by the interviewer; the interviewer – interviewee relationship; and the availability of written documents.

The semi-structured interviews allowed for complete, personal accounts of the waste management decision-making and implementation process post-disaster where often published data are not available. However, interviews have a number of limitations. De Vaus (2002) notes that in face-to-face interviews interviewees may be more likely to give acceptable rather than true answers (also known as social desirability). The interviewees here, for instance, as participants and decision-makers in the waste management process have a vested interest in having a positive report on their work.

There may also have been an effect from the cultural difference between the interview and interviewees, or as De Vaus describes it – the effect of observable characteristics. This is where an interpretation of a situation is influenced by one or other's cultural background.

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[4] Superfund is the United States' federal government's program to clean up the nation's uncontrolled hazardous waste sites (www.epa.gov/superfund/).

This may include language nuances, voice tone and body language. The use of a translator in L'Aquila also increased the potential for cultural misunderstanding as it is likely the translator paraphrased and inadvertently added their own interpretation.

There were a number of limitations resulting from forming the Hurricane Katrina case study purely from published documents. These included: presentation of final decisions rather than decision-making processes; data coming from predominantly government documents; inability to clarify unclear statements; and presence of information gaps. In addition the documents were largely written more than 12 months after the event. This allowed authors more time for analysis and synthesis of the data than the other case studies. This may mean fuller and more considered information was available, however this may have meant that motivational bias may have played a part: that is, there was opportunity for unbalanced information to be presented. The data also differed from the other case studies in that the published accounts were generally from an organisational perspective rather than individual (according to the interviews). In general, the author believes that given the range, quantity and quality of documents reviewed for Hurricane Katrina, that a full and fair understanding of the disaster waste management system was achieved.

The active participatory approach following Christchurch presents both more opportunities and challenges than all the other case studies. Participation in the recovery efforts has allowed the author to understand better the decision-making processes in the management of demolition and disaster waste. The author could observe real and perceived decision-drivers and constraints which are often absent in written or first-hand moderated accounts of a situation. The researcher also observed in real time, allowing a greater level of detail to be observed, rather than the snap shot of data gathered during interviews. This 'fly-on-the-wall' aspect of the methodology is a particular strength.

However, the objectivity of the research could be challenged. Because of the author's direct involvement in the design of the waste management process, the author may not be able to critically analyse the actions taken and outcomes achieved. Bias, for example, towards the organisation the author was working for would be a natural tendency. In the interest of future learning, the author has attempted to dissociate herself from the process to allow for a critical analysis.

In all the case studies, except the Victorian Bushfires, no community based data collection was carried out. This presents a significant limitation when attempting to analyse the social effects of the demolition and debris management programmes. In lieu of this information, social impacts have largely been based on observations and the media's portrayal of community response. References are given where possible. It is noted that the media does not always present information that is representative of the whole community and this has been taken into account during the analysis.

Accepting and accounting for these data limitations is an important part of disaster research. Every effort was made here to ensure the data collection and interpretation was consistent across case studies and triangulation of information was carried out. Given the high level information sought during this research it was felt that generally these limitations had minimal impact on the data collected.

2.3.3 Case study analyses

As discussed, the adopted analysis model was an important tool in ensuring consistent analysis both within and between case studies. However, in a complex and dynamic system, such as disaster waste management system, there is a risk of losing the complexities and interdependencies by over-simplifying the system. This is a weakness of the model but a decision that has been consciously made to enable analysis to be carried out in a systematic way.

For the effects analysis, qualitative assessments only were used. Qualitative assessments are subjective; however given all the assessments were made by the author, it is believed that the assessment is valid within the context of this research. In many cases, it is difficult to assess the effect directly related to a specific system element as there are many interdependencies. It is envisaged that the systems approach will provide a conduit to look beyond proximate causes to underlying causes.

2.4 Summary

This methodology allows for a multi-disciplinary and holistic analysis of a complex problem across many different contexts and will enable a greater understanding of disaster waste management systems. The analysis shows how a simple static model can be used to generate more complex, dynamic models. It is envisaged that the methodology will not only assist in the analysis for this thesis but will also be able to be applied to future research in this area and be able to be adapted for future planning of disaster waste management systems. These opportunities are explored throughout this thesis.

3. Case study summaries

3.1 Introduction

This chapter provides a summary of the five case studies included in this research: 2009 Victorian Bushfires, 2009 Samoan Tsunami, 2009 L'Aquila earthquake, 2005 Hurricane Katrina and 2010 Canterbury and 2001 Canterbury earthquakes. The cases are presented in the order in which they were researched. They have been included in this order as the method of analysis and nature of the data collected changed during the data gathering process. This is most apparent in the full case studies presented in the Appendices.

3.2 2009 Victorian Bushfires

The 7 February 2009 "Black Saturday" bushfires in Victoria, Australia, were the most devastating bushfires in Australian history. 173 people were killed in 78 communities. Over 430,000 hectares of land and 2000 properties were destroyed (VBRRA, 2009a).

Due to the intense heat of the fires (up to 1200°C) (Teague et al., 2009), many of the affected buildings were reduced to small piles of debris. The waste matrix included mixed ash, concrete rubble and bricks, partially burnt dimensional timber and fence posts (treated), metal, vegetation and trees, household hazardous wastes (including asbestos), vehicles and corpses (removed by the Coroner).

Due to the scale of the disaster, the Commonwealth and Victorian Governments elected to establish the Victorian Bushfire Recovery and Reconstruction Authority (VBRRA) to "guide the recovery and rebuild process" (VBRRA, 2009b). VBRRA took overall responsibility for the waste management programme.

Two weeks after Black Saturday, the Commonwealth and Victorian Governments also elected to pay for and facilitate demolition and removal of all building related debris in the affected areas. This responsibility would ordinarily rest with private property owners and municipalities. The rationale behind providing this service was to clear debris and hazardous materials from bushfire affected properties and to help start people rebuilding (The Premier of Victoria, 2009) and in turn benefit the economic recovery of the community.

One week later, the State government let a single "managing contract" to facilitate the demolition and debris removal works. The contract included all public and private buildings destroyed in the bushfires. Individual property owners were not required to participate in the works, other than salvaging of personal belongings if desired.

The contract was awarded to an Australian building contractor called Grocon. Approximately 70% of subcontracts (and 50% of the labour) were sourced from the local community.

To expedite debris removal and minimise hazards to people and the environment, the Victorian Environmental Protection Agency and the Department of Human Services, based on limited site testing, elected to classify all bushfire waste as a single waste type: 'Construction & Demolition waste plus other contaminants, including Class B (non-friable) asbestos'. Provisions under Section 30A of the Victorian Environmental Protection Act, 1970 and Section 55 of the Dangerous Goods Act, 1985 (Victorian Government Gazette, 2009) were activated to formalise the classification. These 'emergency' regulations stipulated stream-lined handling, transportation and disposal methods for management of the bushfire waste.

The majority of the bushfire waste went to existing municipal waste landfills a significant distance from the affected area. However, due to several health and safety incidents involving waste-laden trucks travelling on a dangerous stretch of road, an alternate disposal site was commissioned. An area at an existing landfill site, close to the affected area, was identified and a low-engineered landfill cell was designed, consented and constructed in just 10 days.

Overall the demolition and debris removal programme appeared to be successful. The six month demolition programme met the government's objectives of facilitating the rebuilding process. In addition, the community valued the financial and physical contribution towards their recovery. Public health and environmental health risks were generally well managed.

Figure 3-1 shows a typical house demolition site following the Bushfires. Figure 3-2 shows human health protection measures in place to enable private property recovery.

The full length case study report is included in Appendix D. A journal length version of the case study is available in the following publication (see Appendix E):

> Brown, C., Milke, M. & Seville, E. (2011) "Disaster waste management following the 2009 Victorian Bushfires". *The Australian Journal of Emergency Management,* **26**:2**,** 17-22.

Figure 3-1 The remnants of a house in Marysville, following the 2009 Victorian Bushfires. (Photo date: August 2009.)

Figure 3-2 Resident sifting through potentially contaminated rubble following the 2009 Victorian Bushfires. (Photo source: Dr Lachlan Fraser)

3.3 2009 Samoan Tsunami

On 29 September 2009, two tsunami waves, triggered by a M8.3 earthquake centred 200 miles south east of Samoa, hit the south eastern and southern coasts of Upolu Island, Samoa. 143 lives were lost (Samoa Logistics Cluster, 2009) and 4,389 people (2.4% of the total population of Samoa) were affected (Ministry of Health, 2009). Terrestrial, marine, beach, lagoon, coral, mangrove, riverine, marsh and swamp habitats were all heavily affected by the tsunami (Samoan Government, 2009). The majority of affected communities spontaneously relocated inland; leading to a reconstruction task that not only involved personal property rebuilding and infrastructure repair, but also the establishment of completely new infrastructure (water, power, sanitation, schools, shops, etc.) for the relocated settlements.

The waste generated from the Samoan Tsunami mainly comprised green-waste and lightweight building materials (timber and corrugated iron) from the traditional fale style housing (JICA, accessed 2010). There were small amounts of household hazardous materials (pesticides, refrigerants, oils, fuels etc.) and some disturbed oil drums. Excessive and inappropriate relief donations (for example, expired pharmaceuticals and food) were received, and contributed to the waste. Waste from humanitarian aid, such as cans, water bottles and food wrappers, also contributed to the waste volume.

The tsunami emergency response was initially guided by the Government of Samoa National Disaster Management Plan (NDMP) 2006-2009 (Government of Samoa, 2006). However, the extent of the 2009 tsunami overwhelmed the Samoan Government emergency response capacities. Within three days the United Nations (UN) Cluster system was established to help in the response (OCHA, 2009b). Neither the Samoan NDMP nor the UN Cluster system explicitly includes disaster waste management. By default the Ministry of Natural Resources and the Environment (MNRE) assumed responsibility for waste, in line with its peace-time function and the Water, Sanitation and Hygiene (WASH) cluster took the role under the UN system. The UN cluster system was disestablished and disaster administration was handed back to government sector by sector. The WASH cluster was de-activated approximately three weeks after establishment (OCHA, 2009c).

At the time of the tsunami there was no designated disaster fund available for disaster recovery in Samoa. Recovery was heavily dependent on external funds from donors. Following the tsunami, significant amounts of international assistance was pledged to a Samoan Government recovery fund (Government of Samoa, 2006). Funds from the government fund were allocated to recovery activities based on government department recommendations. In addition some funds were pledged to individual organisations (typically non-governmental organisations).

Immediately after the tsunami, many people lit fires to dispose of some of the unpleasant smelling debris (JICA, accessed 2010) likely due to damaged septic tanks and odorous marine sediments. Many villagers salvaged materials from the debris to construct temporary housing, see Figure 3-3, while allegedly others were too traumatised to do anything.

Clean-up activities were initiated and managed by a number of organisations. These are summarised in Table 3.1. Generally the clean-up operations involved community members (paid and unpaid) collecting debris and placing it in piles for contractors to collect and take to the country's only landfill, Tafaigata landfill, near Apia. Some waste segregation (for recycling) was carried out prior to collection (by volunteers and community members) and recyclables were scavenged from the waste at the landfill. Efforts to separate waste at source varied between clean-up operations. There were isolated incidents of debris being disposed of illegally near the affected area. An alternative disposal facility on the south coast was suggested by the Secretariat of the Pacific Regional Environment Programme during the rapid needs assessment process but no action was taken.

Generally terrestrial wastes were prioritised ahead of coastal, marine and wetland wastes. As of April 2010, the majority of the debris had been collected and disposed of. Some targeted clean-ups in wetland areas were still being carried out. The author has no figures on the quantity of tsunami debris or volume to landfill.

In general, the waste management response to the tsunami was piece-meal. There was little overall coordination and subsequently little quality control (public health, environmental standards, programme and completeness).

The full length case study report is included in Appendix F. This case study was also presented at the following conference (see Appendix G):

> Brown, C., Milke, M. & Seville, E. (2011) "Disaster Waste Management for the Samoan Tsunami". *International Conference on Building Resilience, July 2011,* Kandalama, Sir Lanka.

Figure 3-3 A temporary shelter made from tsunami debris, Lalumanu, Samoa. Photo date: April 2010.)

Table 3.1 2009 Samoan Tsunami clean-up activities

When	*Lead agency*	*Funding*	*Scope of Works*	*Reference*
First 2 weeks (October 2009)	Ministry of Works, Transportation and Infrastructure (MWTI)	Unknown	Clearance of debris blocking access roads	
Mid-Oct / Nov	Japanese International Corporation Agency (JICA)	JICA	Pilot project: removal of bulky wastes in Ulutogia, Satitoa, Malaela and Lalumanu Including waste salvage, segregation, recycling and paid community participation.	(OCHA, 2009c)
Start date and duration unknown	MNRE	Unknown	Bulky waste collection. The exact nature and scope of the contract was very unclear. No demolition, no recycling.	
10 November 2009	HMAS Tobruk / Australian Navy	Australian Navy	One day reef and lagoon clean-up operation. Crew and amphibious vehicles were provided. Voluntary community participation.	(Powell, 2009)
March 2010	United Nations Development Programme (UNDP)	AusAid	A one day clean-up for Poutasi village (Falealili District). Voluntary community participation.	(Samoa Observer, 2010b) (Ministry of Health, 2009)
April 2010	Conservation international (CI)	CI	Three day bulky waste removal in the mangroves in Malaela and Saleaumua. Paid community participation.	(Conservation International, 2010)
March 2010 onwards	UNDP	Various	Waste management problems identified by community through Community Centred Sustainable Development Programmes (CCSDP) process.	(Samoa Observer, 2010a)
General	Ministry of Health (MOH)	MOH	Advice on vector control - burning / burying waste and avoiding stagnant pools of water. Some heavy machinery provided to remove waste causing water stagnation.	(Ministry of Health, 2009)
General	Independent church and other groups	Various	Various uncoordinated community level clean-ups by church and other independent volunteer groups.	

3.4 2009 L'Aquila Earthquake

On 6 April 2009, a 6.3 magnitude earthquake hit the Abruzzo region in central Italy. 314 people perished and approximately 70,000 residents were displaced (Dolce, 2009). The largely historic town of L'Aquila, with predominantly multi-storey unreinforced buildings, suffered severe damage. In total approximately 25% of the 72,000 damaged buildings required full demolition (Dolce, 2010). The historic centre of the town was cordoned off and was known as the 'red zone'. The historic centre was still largely closed at the time of writing: three years after the event.

It has been estimated that approximately four million tonnes of waste will be generated from the demolition and repair works. 70-80% of the waste is thought to be aggregate and the intent is to recycle as much as possible. Disaster waste management activities are still continuing at the time of writing and only a small proportion of the waste has been managed.

The Dipartimento della Protezione Civile (DPC) (Civil Protection Department) is responsible for disaster coordination (including recovery) (Dolce, 2010). Under the National Protection Act, DPC has the authority to make special laws to fulfil its emergency response and recovery functions (within EU laws and regulations). All natural disaster damage losses are financially covered by the National Government / DPC. The value of all individual compensation is determined after a given disaster event.

The environmental protection function of DPC Directorate of Command and Control (Di.Coma.C) initially managed the earthquake waste. The unit established and oversaw the waste management strategy and operations until responsibility for demolition and waste management activities was handed back to the respective municipalities (Comunes) in December 2009 (Di.Coma.C, accessed 2010), eight months after the event.

The demolition and waste management works are essentially organised into three categories:

1. *Full demolition works*. Initially full demolition works were coordinated by the Dipartimento della Protezione Civile and were carried out by the National Fire Corps and Army, as shown in Figure 3-4. Temporary staging areas were established to sort mixed wastes brought from the demolition sites. After demolition works were handed to the local municipalities, L'Aquila Comune elected to sort wastes at the

demolition site and take the sorted wastes to temporary staging areas for interim storage. It has been estimated that sorting materials on site has increased the demolition time up to five-fold.

2. *Major repair debris.* Major repair debris is handled by contractors, engaged by property owners, carrying out repair work and who were approved as National Environmental Managers. Contractors are responsible for separating wastes and taking materials to recycling operators or disposal sites as per their peace-time operations.

3. *Minor detritus.* Detritus is dealt with by individual property owners. Central collection facilities have been provided by the municipality. The municipality is then responsible for separating the wastes and taking it to recycling facilities or disposal sites.

The waste management systems under DPC and the Comune are shown in Figure 3-5 and Figure 3-6, respectively.

Figure 3-4 Fire Service and Army personnel carry out demolition of houses in Onna, one of the towns most affected by the 2009 L'Aquila earthquake; September 2010.

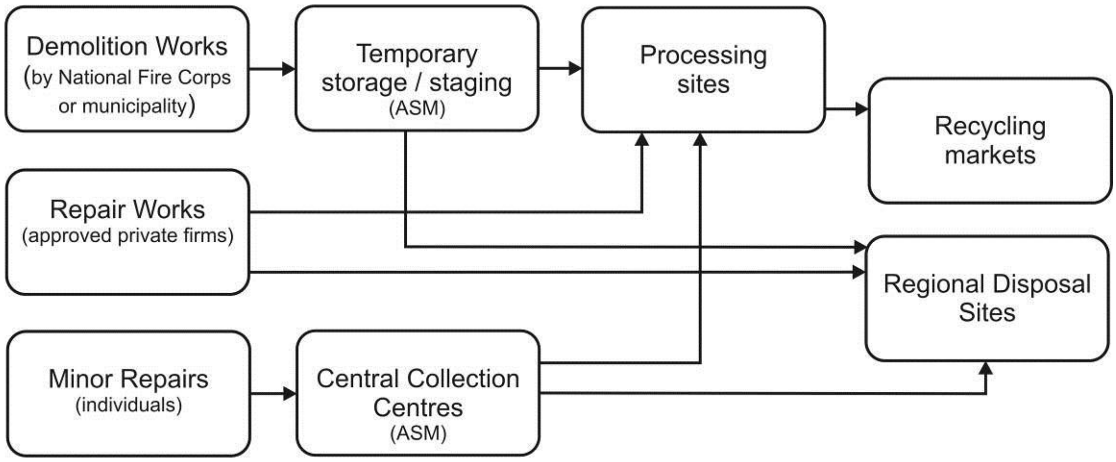

Figure 3-5 **2009 L'Aquila earthquake demolition and waste management flow diagram: as managed by Dipartimento della Protezione Civile (Civil Protection Department)**

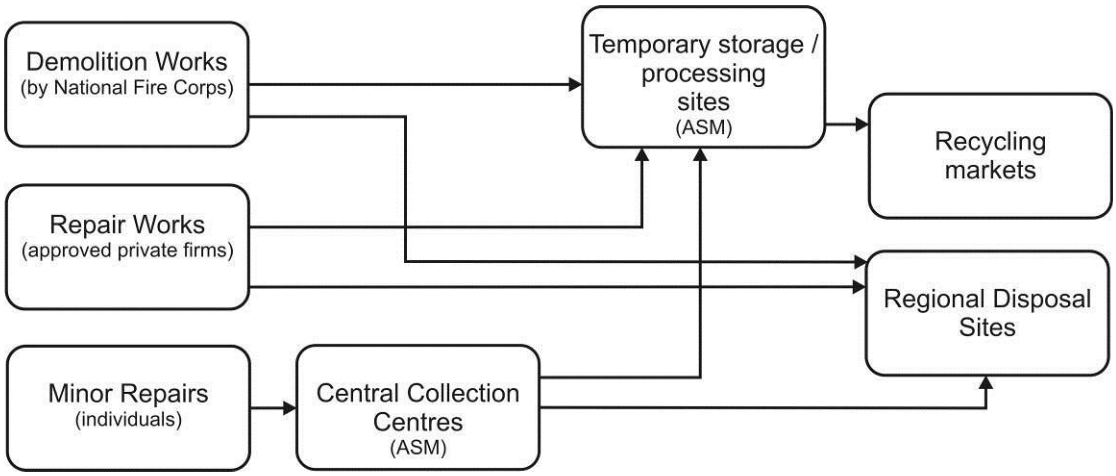

Figure 3-6 **2009 L'Aquila earthquake demolition and waste management flow diagram: as managed by the Comune or municipality**

Existing solid waste disposal and resource recovery facilities were overwhelmed by the waste volumes and new recovery facilities have been sought (Di.Coma.C, accessed 2010). Recycling was identified early as a key component in debris management to reduce environmental impact and save landfill space. Recycled aggregate has been ear-marked for building construction, road reconstruction and environmental remediation works [for example, quarry restoration] (Di.Coma.C, accessed 2010).

Waste management guidelines were established by Provincia dell'Aquila to outline the technical and logistical operation of temporary staging sites. The environmental regulatory bodies (Institute for Environmental Protection and Research, Regional and Local Agencies for Environmental Protection) are responsible for approving recovery and disposal sites. The municipalities are responsible for identifying, establishing and operating temporary storage sites.

There are very strict environmental laws in Italy and the European Union. These have affected the efficiency and effectiveness of the waste management programme. Neither considers environmental procedures and standards for waste or environmental management in response to an emergency. As a result of this, Protezione Civile had to prepare new emergency legislation for waste management (Di.Coma.C, accessed 2010). Legislative and regulatory changes included defining a classification for earthquake waste under the European Waste Code system and expedited procedures for authorising waste management facilities. Despite this, eleven months after the earthquake only some of the many of the temporary and permanent sites needed to process the large volumes of waste had only just been approved (Nardecchia, 2010).

Emergency and recovery managers in L'Aquila have cited debris as a significant hurdle on their road to recovery. As one interview respondent remarked in terms of the recovery: "this [waste management], is not **a** problem – it is **the** problem". The delays in the recovery process have led to some public protests and general community dissatisfaction. Some of the delays in the waste management process have been due to arguably unavoidable circumstances such as management of historic wastes. However, the majority of the delays were, in the author's opinion, as a result of poor organisational management and strict environmental standards.

The full length case study report is included in Appendix H. This case study was also presented at the following conference (see Appendix I):

> Brown, C., Milke, M., Seville, E. & Giovinazzi, S. (2010) "Disaster Waste Management on the Road to Recovery: L'Aquila Earthquake Case Study". *14 European Conference on Earthquake Engineering* Ohrid, Macedonia.

3.5 2005 Hurricane Katrina

Hurricane Katrina hit the States of Louisiana, Mississippi and Alabama, US., on 29 August 2005. In addition to hurricane damage, heavy rain led to levee breaches and flooding in some areas. 80% of New Orleans was inundated by 3-12 feet of floodwaters (Cook, 2009). Over 1800 people died (HHS.gov, accessed 2010) and over 600,000 residential structures were affected – 77% were totally destroyed (Roper, 2008). The disaster resulted in mass voluntary and involuntary evacuations. Four years after Hurricane Katrina some Parishes have still not returned to pre-Katrina population levels (51% for St Bernard and 76% for Orleans) (Brookings Institute, 2009).

Hurricane Katrina generated the most disaster-related debris in the history of the US: more than twice the previous record generated by Hurricane Andrew in 1992. It is estimated that when the demolition of affected properties is complete, approximately 100 million cubic yards [76 million cubic metres] of debris would have been generated and disposed of in the three affected states, with 64 million cubic yards [49 million cubic metres] in the State of Louisiana alone (Luther, 2008). The waste was predominantly construction and demolition (C&D) waste, green-waste and floodwater sediment. There were some significant hazards in the waste matrix, including: flood water sediment contaminated with heavy metals and poly-aromatic hydrocarbons (Esworthy et al., 2006); rotting food or putrescible wastes; household hazardous substances and asbestos (Luther, 2008).

Due to the scale of the disaster, the Federal Emergency Management Agency (FEMA) elected to pay for all debris removal operations. Ordinarily FEMA would pay 75% of the cost for debris removal from public places, and individuals (and their insurance companies) would be responsible for private property waste management. FEMA generally relies on property owners to clean detritus from private properties for kerbside collection (FEMA, 2007); however, the high health risk and level of resident displacement led to FEMA's decision to remove debris and demolish structures declared a public health risk (LDEQ, 2006c).

Many of the local authorities in Louisiana opted for the US Army Corps of Engineers (USACE) to facilitate the FEMA funded clean-up works directly. USACE let four debris removal contacts in the state of Louisiana. The contracts were generally lump sum contracts for the clean-up of a specified area. For legal reasons, demolition of abandoned (later condemned) houses had to be managed by the respective municipalities, not FEMA.

Temporary storage areas were established to sort material collected during kerbside collections. Some recycling was carried out, in particular metals were segregated and sold, and vegetative waste was chipped and used as mulch or for landfill cover. Limited recycling of Construction & Demolition (C&D) waste was carried out, particularly of waste resulting from the FEMA-funded private property demolitions. A regulation change was made to exclude the requirement to remove non-friable asbestos prior to demolition. Many C&D landfills were also permitted to expand their waste acceptance criteria to include wood, carpet and (arguably) most significantly asbestos. Some new landfills were opened (Gentilly and Chef Menteur) and there was considerable public opposition to (including some legal action against) this in areas close to the affected area.

The (simplified) waste management system is shown in Figure 3-7.

The scale of Hurricane Katrina was unprecedented in US history. The extensive planning and funding regulations for disaster debris management in the US had to be adapted to match the scale and complexity of the event. Significant changes to organisation and funding structures were necessary, as well as changes to environmental and public health regulations to facilitate the clean-up. Despite the pre-planning and the extraordinary measures taken, there are still condemned houses waiting demolition five years after the Hurricane (Trethewey, 2010).

The full length case study report is included in Appendix J.

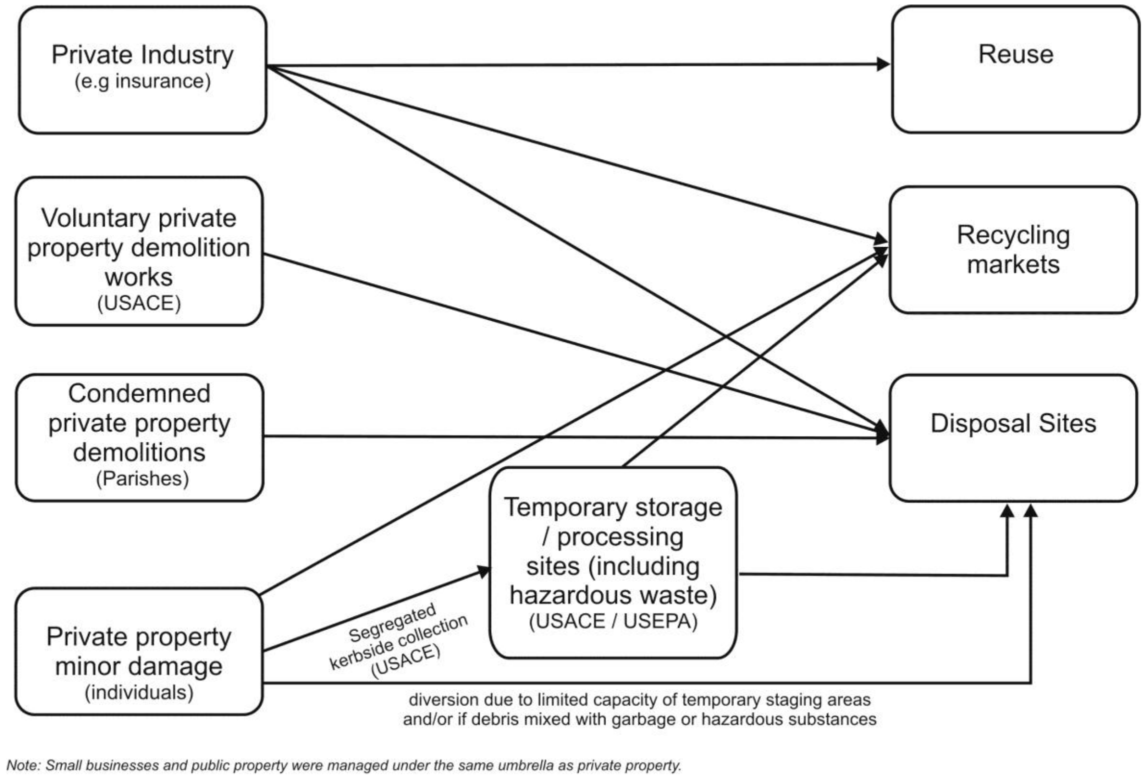

Figure 3-7 2005 Hurricane Katrina demolition and debris management system

3.6 2010 Canterbury and 2011 Christchurch earthquakes

On 4 September 2010, the Canterbury region of New Zealand was struck by a magnitude 7.1 earthquake. The event caused significant damage but no loss of lives. The earthquake, however, triggered a sequence of more deadly and damaging aftershocks that were continuing at the time of writing. In particular, on 22 February 2011, Christchurch was struck by a magnitude 6.3 earthquake, centred within 10km of the central city. 185 people died and 164 were seriously injured (GeoNet, 2011). The central city was significantly damaged and there was widespread liquefaction in the eastern suburbs of the city. At the time of writing an estimated 1400 commercial properties and at least 7,500 homes are facing demolition. As in the L'Aquila earthquake, the central city was cordoned off immediately after the earthquake and was also named the 'red zone'. It is estimated that approximately four million tonnes of building debris will be generated from the demolition and building repair work and up to four million tonnes from the horizontal infrastructure (i.e. roads, water, sewer and stormwater pipes) repair.

The majority of the waste will be construction and demolition (C&D) wastes. Unsafe or already collapsed building debris (i.e. where removal of building contents was not possible) also included building contents such as furnishings, household hazardous substances, food, and whiteware. Asbestos was also present in some buildings. Where possible asbestos was removed prior to demolition, but this was not always possible due to building instability. Some building material had to be stored separately so that it could be used as evidence in various earthquake inquiries.

In addition to the large amounts of construction and demolition, in excess of 500,000 tonnes of liquefaction silt was generated by the earthquakes. This material was largely collected from private properties by an army of volunteers and placed on the kerbside for collection. Local authority roading contractors collected the silt and deposited at one of two designated disposal sites.

The initial emergency response (up to the end of April 2011) was managed by New Zealand's emergency management authority, Civil Defence. The Canterbury Earthquake Recovery (CER) Act was passed in April 2011 to facilitate the recovery. The Act established the Canterbury Earthquake Recovery Authority (CERA) to oversee the earthquake recovery.

Emergency works such as silt clearance and demolition for urban search and rescue, were paid for through the Civil Defence. Demolition and debris management activities in the recovery phase are generally paid for by insurance companies. Commercial properties are insured privately and residential property owners have joint cover between the national insurer, the Earthquake Commission (EQC), and private insurers[5].

Due to the desire to protect public health and safety and to open the city centre as quickly as possible, Civil Defence and subsequently CERA elected to operationally manage commercial property demolitions and later seek financial compensation from insurers and building owners. Building owners had the opportunity to carry out their own demolition as long as they did so within an allocated time. At the time of writing approximately one third of

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[5] EQC covers the first $100,000 of any insurance claim on a residential property and the first $20,000 for contents. Private insurers cover the balance, up to the maximum policy value.

commercial properties (classified as dangerous under the CER Act) had been managed by CERA.

Initially CERA-managed demolitions were carried out with urgency under a cost reimbursement procurement model, allowing for limited material salvage onsite. A large (privately operated) resource recovery site was established to recycle the predicted large volumes of mixed wastes. Metal waste could be taken directly to a metal recycling facility. Inert waste could be taken to Lyttelton Port where a land reclamation (accepting concrete, asphalt, brick, natural fill at no cost etc.) was approved under special CER Act powers two months after the earthquake. As the process continued, lump sum contracts became the preferred procurement approach and as a result contractors began to establish their own, legal and illegal, waste handling facilities to separate and process wastes. Due to the high cost of disposal at the regional landfill[6], a new, low-engineered disposal site is currently being approved to dispose of all, pre-sorted, and unrecyclable demolition wastes. The site is located at the former Christchurch City landfill, Burwood.

Due to the extensive liquefaction in suburban areas, large residential areas are going to be abandoned: that is, the government is buying properties off the residents because of the unsuitable land conditions. These areas are now known as the 'residential red zones'. Demolitions in the residential red zones are being managed by CERA and private insurance companies, depending on whether the property owner has accepted a government or insurance settlement for the property, respectively. All demolitions and major repair works in non-red zoned areas are being carried out by insurance companies or their appointed management company.

The demolition and debris management system is shown in Figure 3-8. Figure 3-9 shows the demolition of the iconic University of Canterbury, School of Engineering, "Mushroom", which was damaged by the earthquakes.

At the time of writing the demolition and debris management programme is continuing. The demolition works continue in parallel with a number of other recovery issues, including establishing new planning and building regulations and securing insurance cover within New

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[6] The regional landfill in Christchurch is a regulated monopoly.

Zealand. At this stage the demolition and waste management works have neither facilitated nor hindered the overall recovery. It has proceeded at a pace which is largely considered acceptable by the public, under the circumstances (Hartevelt, 2011).

The full length case study report is included in Appendix K.

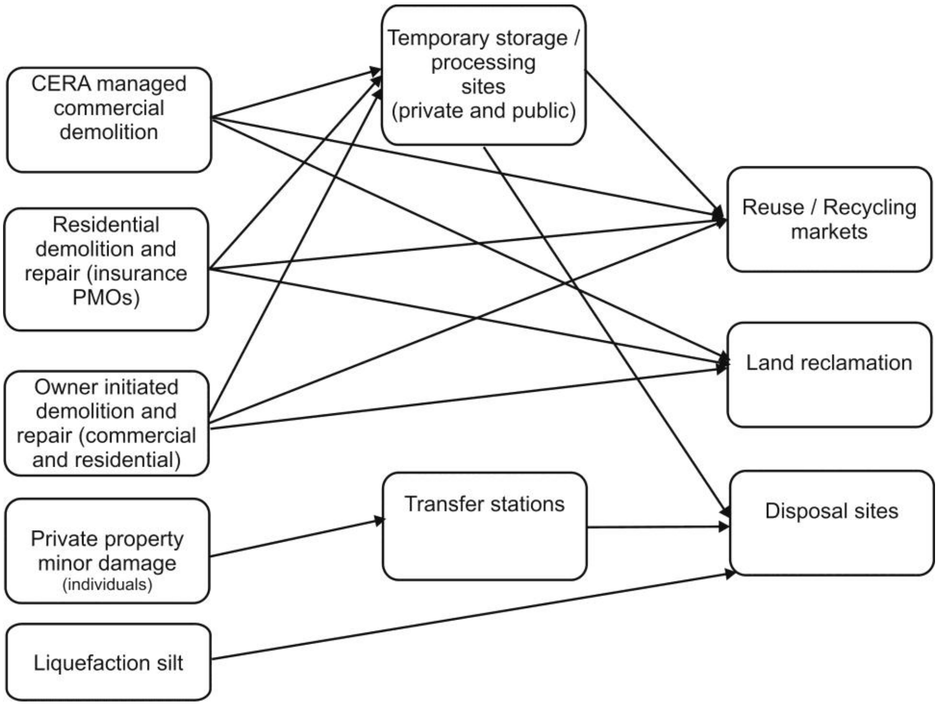
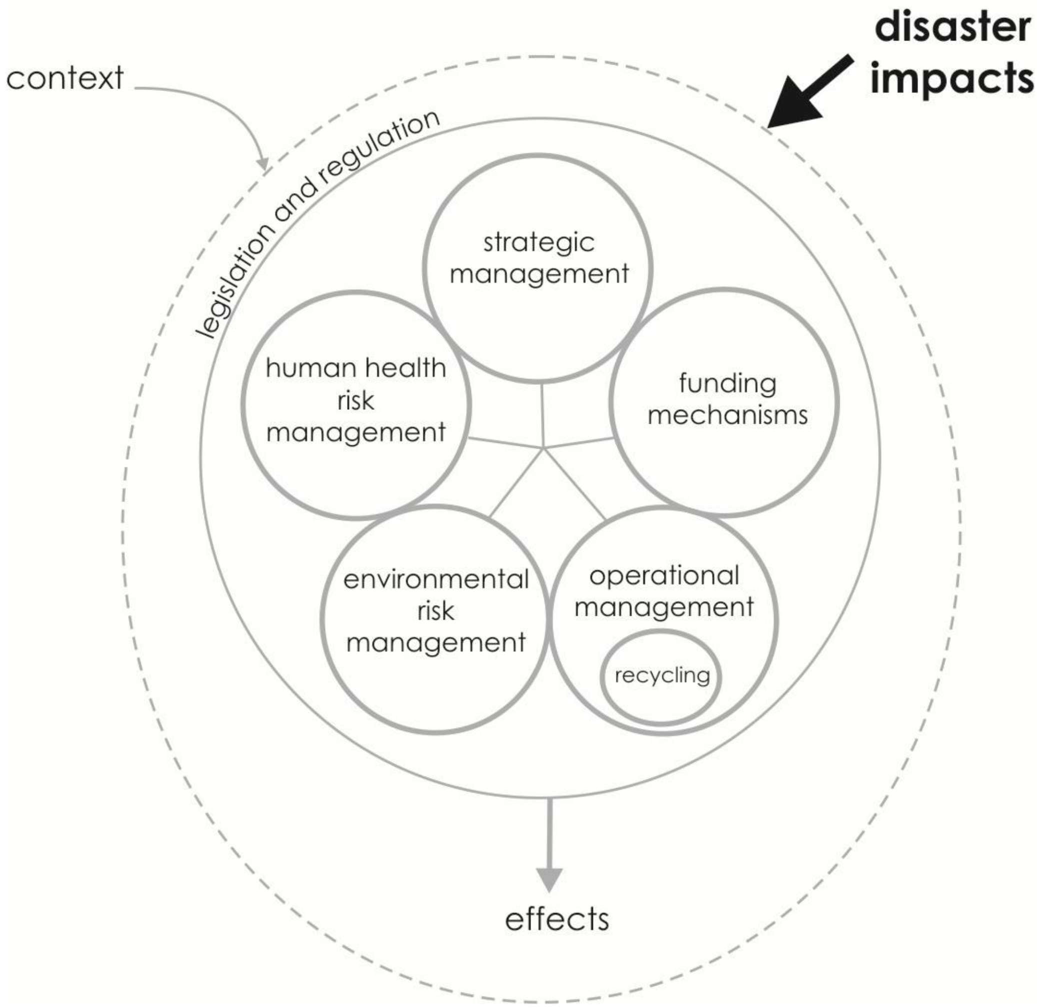


Figure 3-8 2011 Christchurch earthquake demolition and debris management system (simplified)

Figure 3-9 Demolition of the University of Canterbury, Engineering School "Mushroom". (Photo date: December 2011.)



4. Disaster impacts

4.1 Introduction

In order for decision-makers to determine the best approach for managing disaster waste, it is important to understand the disaster impacts that drive decision-making post-disaster. A number of authors have made observations on the nature of disaster waste, see Section 1.3, but generally these observations are event-specific and are limited to a hazard type. This limited analysis makes it difficult to transfer lessons learned from one event, and therefore plan for future events.

The author believes that a generic 'disaster & disaster waste impact' classification system would be useful to enable both post-event analysis and pre-event planning. In this thesis, a disaster & disaster waste impact classification system will enable cross case analysis to be made such that observations are more readily transferable between disaster scenarios. Pre-event, a classification system would assist in planning by allowing predicted hazard scenarios to be translated into disaster & disaster waste impacts which in turn could be used to enable management and operational systems to be planned. Post-event a classification system could be used during rapid assessments and in the initial design of the waste management system.

In this Chapter, disaster & disaster waste impact indicators, developed from the literature review and the five case study analyses, are presented. The indicators will in turn be used during the cross case analyses in Chapters 6 to 10 to determine whether the nature of the disaster impact affects the suitability of various disaster waste management strategies. Last, in Section 12.2, there will be a discussion on how the indicators could be used and/or adapted to aid disaster planning and response.

4.2 Disaster impact indicators

The general impacts of a disaster event will influence the disaster waste management approach taken. The impact of a disaster could be measured in many different ways, using many different measures, including:

- Number or proportion of deaths
- Number or proportion population affected
- Number of persons displaced
- Geographical extent of impact
- Geographical isolation
- Number of buildings destroyed
- Projected recovery time
- Economic impact (direct and indirect)
- Resources required
- Lifeline (critical infrastructure) disruption
- Hazard duration (short, medium, long term) – e.g. continuing aftershocks

During the case study research, several of the above measures, in particular, had a noticeable impact on the management of disaster waste (as will become apparent in Chapters 6 to 10 of this thesis). Therefore for the purposes of this thesis, the above has been synthesised to five indicators which describe a disaster's impact (relevant to disaster waste management):

disaster scale, number of displaced persons, geographical extent, hazard duration and disruption to road network. To measure each indicator the author suggests a semi-quantitative (also referred to as an ordinal scale) rating scale (low, medium, high) could be used.

Semi-quantitative disaster impact indicators are proposed for a number of different reasons. First, in the context of this thesis, semi-quantitative indicators allow for assessments to be made relative to the contextual situation. For example, the 185 lives lost in Christchurch was the second largest loss of life in New Zealand due to a natural disaster (after the 1931 Hawke's Bay earthquake). So relatively speaking, the earthquake was significant in New Zealand terms. That death toll, however, is small in comparison to the 1117 lives lost in the 2009 Padang earthquake, in Indonesia (Vos et al., 2010), which in turn pales in comparison with the 2004 Indian Ocean tsunami and earthquake death toll in Indonesia of approximately 160,000. Thus, based on the number of deaths, the Christchurch earthquake, while considered catastrophic in New Zealand, may have been considered relatively minor in Indonesia.

Second, when planning for disaster events there is great uncertainty over the likely impact or impacts. Using semi-quantitative indicators allows for a range of impacts to be accounted for under a single scenario.

Third, in a post-disaster situation, particularly in the response phase, semi-quantitative indicators allow for rapid assessments to be made so that a picture of the impacts can be developed in the absence of full and accurate data. The gathering and synthesis of data post-event appears to be either 1) infeasible, due to time, resourcing or information access limitations; or 2) impossible, due to the lack of expertise or understanding of how to synthesise and assess risk information for this unique situation. Streamlined post-disaster impact assessment approaches have been suggested by a number of authors: Charles Kelly suggests the balance needed in post-disaster impact assessments is between Speed, Accuracy and Utility (Kelly, 2011); The Impact Measurement and Accountability in Emergencies Good Enough Guide (Emergency Capacity Building Project, 2007) states that "quick and simple" solutions for impact assessment may be the "only practical possibility [given time and resource constraints]". Both Kelly and the Good Enough Guide acknowledge that as the situation changes your assessment approaches may also need to change.

Semi-quantitative ratings are, however, subjective and therefore may be influenced by the assessor's knowledge, experiences and interpretation of the situation. In this thesis, the assessments were all carried out by the author to ensure consistent relative assessments.

For the purposes of this chapter, and as an example, assessment scales have been established. Note, if this assessment approach was to be adopted by a community, context specific assessment scales ideally be established by planning and/or emergency response authorities.

The four disaster indicators and scales are:

1. The general **disaster scale** (e.g. the number of persons deceased, the proportion of the population affected, the proportion of buildings destroyed, the projected recovery time, the economic impact, the resources required to manage the response, lifeline disruption).

Low	Medium	High
Minor level of damage and disruption. Local resources only required to manage the event. Project recovery time: 1-2 years.	Moderate level of damage, possible loss of lives. Regional resources required. Projected recovery time: 2-5 years.	Significant loss of lives and damage to buildings and infrastructure. National and/or international resources required to manage the response. Projected recovery time: over 5 years.

Pre-event, it would be useful for authorities to determine what may constitute a low medium or high scale disaster. Many countries may have a qualitative or quantitative method of doing this already. In New Zealand the scale of an event is largely determined by the resources needed to respond to the event, that is, whether the resources can be found locally, regionally or nationally.

2. The **number of displaced persons** (and desiring to return)

Low	Medium	High
Less than 1% of population displaced.	1-20% population displacement in affected area, with some or all intending on returning to the area.	Over 20% of population in affected area is displaced, with some or all population intending on returning to the area.

Note that, this indicator is specific to displaced persons wanting to return. The reason for this is explained in Section 5.3.

3. The **geographical extent** of the impact (including effects of geographical isolation)

Low	Medium	High
Area of impact is confined to one or two localities, with easy access to unaffected areas.	Regional area of impact. Some or limited access to and from affected areas.	Extensive area of impact, across multiple regions. Difficult access to and from affected area.

4. The **hazard duration**

Low	Medium	High
One off event with short term effects (e.g. presence of floodwaters): up to 1 week.	Multiple, on-going effects of hazard (e.g. on-going severe aftershocks): for up to 1 month.	Multiple, on-going effects of hazard (e.g. on-going severe aftershocks, nuclear incident): in excess of 1 month.

Note that, related to this, is whether or not a hazard is a slow or rapid onset. In a slow onset event (such as an oil spill or potentially a flood) authorities have time to plan, pre-position supplies and people have time to put mitigation measures in place (such as move furniture above group in a flood situation).

5. The **disruption to** the **road network**

Low	Medium	High
Minimal damage to road network.	Roading networks are moderately to severely disrupted for up to one month. Authorities require minimal traffic movement.	Roading networks are disrupted for more than a month. Authorities require minimal traffic movement.

The author has used the above scales to determine the relative impacts of the five case studies. These are presented in Table 4.1 below.

Table 4.1 Disaster impacts for thesis case studies.

		Disaster impacts				
		Disaster scale	Number of displaced persons	Geographical extent	Hazard duration	Disruption to road network
Disaster event	2009 Victorian Bushfires	H	H	L	L	L
	2009 Samoan Tsunami	H	L*	M	L	M
	2009 L'Aquila Earthquake	H	H	M	M	L
	2005 Hurricane Katrina	H	H	H	L	L
	2011 Christchurch Earthquake	H	M	L	H	L
L = low, M = medium, H = high						
* There was a high displacement of persons following the Samoan Tsunami but generally residents elected to move away permanently.						

4.3 Disaster waste impact indicators

4.3.1 General

Typically, as the research literature demonstrated (see Section 1.3), authors have limited their description of disaster waste to debris streams linked to hazard types. As shown in Table 4.2 (a revised version of Table 1.2, based on observations during the course of this research), most hazard types, apart from pandemics, generate most debris streams. This simplistic categorisation, therefore, does not help in understanding why there is such a varied number of disaster waste management approaches both within and across hazard types. A more detailed description of disaster waste is required in order to understand the impact of disaster waste on planning a disaster waste management system and/or measure its effectiveness.

Therefore, it is proposed that disaster waste be further categorised by 1) the waste source and 2) the waste characteristics.

Table 4.2 Typical waste streams for different hazard types: author's adaptation (in bold) of the 2007 FEMA classification

		Typical Waste Streams								
		Vegetative	Construction and Demolition (C&D)	Personal Property / Household Items	Hazardous Waste	Household Hazardous Waste (HHW)	White Goods	Soil, Mud and Sand	Vehicles and Vessels	Putrescent
Types of Disasters	Hurricanes / Typhoons	X	X	X	X	X	X	X	X	X
	Tsunamis	X	X	X	X	X	X	X	X	X
	Tornadoes	X	X	X	X	X	X		X	X
	Floods	X	X	X	X	X	X	X	X	X
	Earthquakes		X	X	**X**	X	X	X	**X**	**X**
	Wildfires	X	**X**	X	**X**	X	X	X	**X**	
	Ice storms	X				X				
	Volcanic eruption	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
	Pandemic				**X**	**X**				
	Industrial disaster	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	

4.3.2 Waste source

The first categorisation is 'waste source'. That is, delineating the wastes depending on where or how the waste originated. A waste source categorisation is useful because the waste characteristics may be different between sources and therefore are likely to be managed differently (as will be discussed later in the thesis, predominantly Chapters 7 and 8). The following categorisations are proposed (waste sources most likely in small scale disaster events are marked with a *****):

Waste sources:

Response phase (prioritised)

1.= Removal of acutely hazardous substances (and other waste posing a secondary hazard e.g. waste blocking flowpaths).

1.= Demolition to enable urban search and rescue.

* 3. Waste clearance for emergency / essential service operation (e.g. access way clearance, removal of damaged stock at food stores).

4. Partial demolition / making safe building for public.

Recovery phase (not prioritised)

* 1. Private (residential, commercial and industrial) property detritus (non-structural material)

* 2. Public property detritus (e.g. liquefaction silt, floodwater sediment, wind blown material, rock fall)

3. Full demolition debris
4. Major repair waste
5. Reconstruction waste
6. Horizontal infrastructure repair (e.g. roads, water, sewer, stormwater)

Within each waste source category there may be sub-categories. For example, in Christchurch following the earthquakes, private property detritus included two waste streams: 1) liquefaction silt and 2) household items such as broken plates, crockery, televisions and carpets. Because of the very different nature and quantity of the materials, they were managed differently (liquefaction was collected by local authority contractors and private residents were responsible for disposal of household items). As will be discussed in the operational management strategies chapter (Chapter 8), each waste stream (and substream) is likely to have a different (but ideally complimentary) management technique and owner / manager.

For the purpose of this thesis cross case-analysis, the waste source classification has only been used in the qualitative descriptions of the disaster waste management approaches. However, it is useful to demonstrate how the waste source classification can be used for 1) post-event assessments (i.e. for research) and 2) pre-event planning (to estimate likely waste sources, relative quantities and composition).

As for the general disaster impact analysis, a semi-quantitative assessment can be used for both pre and post-event applications. Semi-quantitative ratings for the disaster waste sources, and relative quantities, for the thesis case studies are shown in Table 4.3. The scale used is:

Low = 0-10% of the total waste

Medium = 10-50% of the total waste

High = more than 50% of the total waste

Table 4.3 Disaster waste sources for case studies: contribution to overall waste quantity

		Typical disaster waste sources									
		Response				Recovery					
		Removal of acutely hazardous substances.	Demolition for urban search and rescue.	Waste clearance for emergency / essential service operation	Partial demolition / making safe building for public.	Private property detritus (non-structural material)	Public property detritus	Full demolition debris	Major repair waste	Reconstruction waste	Horizontal Infrastructure repair
Disaster event	2009 Victorian Bushfires	L	L	L	L	L	L	H	L	M	L
	2009 Samoan Tsunami	L	L	L	L	M	M	M	L	L	L
	2009 L'Aquila Earthquake	L	L	L	L	L	L	H	M	M	unknown
	2005 Hurricane Katrina	L	L	L	L	M	M	H	M	M	unknown
	2011 Christchurch Earthquake	L	L	L	L	L	L	M	L	L	H
Total contribution to total waste volume (L=0-10%, M=10-50%, H=50-100%)											

For pre-event planning purposes, a slightly different assessment scale is needed. First, the likelihood of the waste being generating from each particular source needs to be scored. The rating scale could be low, medium and high probability. Second, it is useful to indicate the likely relative quantity of the waste stream. The rating scale could be the same as for the post-event analysis (Low =0-10%, Medium = 10-50%, High = above 50%). Thus, a two letter rating system is proposed. The author's ratings for different hazard types are shown in Table 4.4.

Table 4.4 Typical disaster waste sources: the likelihood of them occurring and the likely relative quantity for different hazard types

		Typical disaster waste sources									
		Response				**Recovery**					
		Removal of acutely hazardous substances.	Demolition for urban search and rescue.	Waste clearance for emergency / essential service operation	Partial demolition / making safe building for public.	Private property detritus (non-structural material)	Public property detritus	Full demolition debris	Major repair waste	Reconstruction waste	Horizontal Infrastructure repair
Types of Disasters	Hurricanes / Typhoons	M L	L L	H L	L L	H H	H M	M L	H M	M L	L L
	Tsunamis	M L	M L	H L	L L	H M	H M	M M	H M	M L	H H
	Tornadoes	M L	L L	M L	L L	H M	M M	M M	H L	M L	M L
	Floods	M L	L L	H M	L L	H M	H H	M M	M L	M L	M L
	Earthquakes	M L	H L	M L	H L	H L	M L	H H	H M	H M	H H
	Wildfires	M L	L L	L L	L L	-	-	H H	-	H M	M L
	Ice storms	L L	-	H M	-	-	-	-	-	-	-
	Volcanic eruption	L L	L L	H M	L L	H H	H H	L L	L L	L L	M M
	Pandemic	H L	-	-	-	H L*	-	-	-	-	-
	Industrial disaster	H M	M L	L L	M L	H L	L L	M L	M L	L L	L L

The first letter indicates the likelihood of the waste stream occurring (L=low, M= medium, H= high probability of occurrence)
The second letter indicates the likely quantity contribution to the overall waste matrix (L=0-10%, M=10-50%, H=50-100%).

* Infected waste products possible at household level. Likely most waste will be at medical facilities.

As well as noting what waste sources occur in each hazard, it is useful to consider which waste streams (Table 4.2) are likely for each waste source (Table 4.4). Based on the case studies and literature reviewed, Table 4.5 has been compiled by the author using the same rating system as above. This analysis could be extended to consider the likely debris streams and waste sources for each hazard type[7].

Table 4.5 Typical waste streams for each waste source: the likelihood of them occurring and the likely relative quantity

		Typical disaster waste sources									
		Response				Recovery					
		Removal of acutely hazardous substances.	Demolition for urban search and rescue.	Waste clearance for emergency / essential service	Partial demolition / making safe building for public.	Private property detritus (non-structural material)	Public property detritus	Full demolition debris	Major repair waste	Reconstruction waste	Horizontal Infrastructure repair
Waste streams	Vegetative	L L	L L	M L	L L	H L	H M	L L	L L	-	M L
	Construction and Demolition (C&D)	M L	H L	M L	H L	L L	M L	H H	H M	H M	H M
	Personal Property / Household Items	L L	L L	L L	M L	H L	M L	H M	M L	-	L L
	Hazardous Waste	H L	L L	L L	M L	M L	L L	M L	L L	L L	M L
	Household Hazardous Waste (HHW)	H L	L L	L L	L L	M L	M L	H L	L L	-	-
	White Goods	L L	L L	L L	-	L L	L L	M L	L L	-	-
	Soil, Mud and Sand	L L	M L	H L	M L	M L	H M	L L	L L	M L	H H
	Vehicles and Vessels	M L	L L	M L	-	L L	M L	-	-	-	-
	Putrescent	L L	L L	-	-	M L	M L	M L	-	-	L L

The first letter indicates the likelihood of the waste stream occurring (L=low, M= medium, H= high probability of occurrence)
The second letter indicates the likely quantity contribution to the overall waste matrix (L=0-10%, M=10-50%, H=50-100%).

[7] This level of analysis has not been included here as it is not considered essential to the overall thesis objectives.

4.3.3 Disaster waste characteristics

As well as the relative composition of the waste from each waste source it is useful to know some other physical characteristics of the waste. Based on the literature review and the case studies, five key disaster waste characteristics are proposed: volume of waste, human health hazard, environmental health hazard, movement of waste and waste handling difficulty. The reason for the selection of these characteristics will become evident in Chapters 6 to 10. As for the disaster impacts in Section 4.2, these characteristics have only been used in this thesis to allow qualitative assessment of the disaster waste management system. However, a brief discussion has been included to demonstrate how these indicators may be applied to pre- and post-event planning.

As above, a semi-quantitative rating system is proposed to determine relative impacts for each waste characteristic. Note again that semi-quantitative rating scales specific to different context may need to be defined; those given here are indicative only.

In addition, below each characteristic, a list of possible information sources is noted to enable an impact assessment to be made. The list is divided into data which could be (and should be) known pre-disaster, and which would need to be assessed.

1. The **volume of waste**

Low	**Medium**	**High**
Waste generated is equivalent to 1-2 years' worth of annual waste generation.	Waste generated is equivalent to 5 years' worth of annual waste generation.	Waste generated is equivalent to more than 5 years' worth of annual waste generation.

Information sources (pre-event): local authority building information (building dimensions, material type); land-use data; hazard models.

Information sources (post-event): damage maps, building damage assessments; LIDAR data.

2. **Human health hazard** (physical (e.g. fall hazard) or chemical or biological)

Low	**Medium**	**High**
Hazard poses a weak, chronic threat.	Hazard poses a minor acute or serious chronic threat.	Hazard poses a serious acute and/or serious chronic threat.

Human health hazards can be acute or chronic. As discussed in the literature review (Section 1.8.1), chronic health hazards following the World Trade Centre collapses are being documented on an on-going basis and doctors fear that some effects may be seen for up to 30 years.

Information sources (pre-event): local authority hazardous material databases; hazard models.

Information sources (post-event): air monitoring; water monitoring; expert assessments; building damage assessments.

3. **Environmental health hazard**

Low	Medium	High
Hazard poses a weak, chronic threat.	Hazard poses a minor acute or serious chronic threat.	Hazard poses a serious acute and/or serious chronic threat.

Information sources (pre-event): local authority hazardous material databases; hazard models.

Information sources (post-event): air monitoring; water monitoring; expert assessments; building damage assessments.

4. **Movement of waste** by disaster forces (particularly cross-property or locality boundary)

Low	Medium	High
The majority of the waste remains within the property boundaries.	Some waste is likely to travel across property boundaries.	Significant waste transported across property boundaries.

Information sources (pre-event): hazard models

Information sources (post event): observations

5. **Waste handling difficulty** (e.g. specialist equipment required for demolition, waste separation or heavy material removal)

Low	Medium	High
Persons with little or no skill can manage waste stream. Standard household and garden tools only necessary.	Some basic equipment is required to manage waste. Unskilled workers could be quickly trained.	Waste is difficult and dangerous to manage. Specialist skill and equipment is required.

Information sources (pre-event): local authority building data.

Information sources (post-event): observations; field trials.

These indicators have been applied to the five thesis case studies to demonstrate how the indicators may be used in a post-disaster assessment situation, see Table 4.6. Note that a range of impacts (denoted by a dash or '–') has been given in some cases as the disaster characteristics may vary between waste sources. For example, the difficulty in handling the waste in Christchurch varied from low difficulty for the liquefactions silts (which could be cleared simply by community volunteers) to high difficulty demolishing tall buildings.

Table 4.6 Disaster waste characteristics for thesis case studies.

		Typical disaster waste impacts				
		Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Waste handling difficulty
Disaster event	2009 Victorian Bushfires - demolition	M	L-M	L-M	L	M
	2009 Samoan Tsunami – general clean-up	M	L	L-M	H	L
	2009 L'Aquila Earthquake - demolition	H	L-H	L	L	M-H
	2005 Hurricane Katrina – demolition	H	M-H	L-M	H	M-H
	2011 Christchurch Earthquake – demolition	H	M-H	L	L	L-H
L = low, M = medium, H = high						

For planning purposes, a general rating per hazard may also be useful. While there are definitely waste characteristics that are specific to hazard type (for example trans-boundary movement of waste in tsunami events), there are equally common characteristics (such as human health hazards) which span across hazard types. Generic disaster waste impact characteristics will facilitate cross case analyses across a wide variety of events and therefore, the ability to transfer lessons learnt between different events. Based on the literature review and the case studies in this thesis, a general rating of disaster waste impacts based on hazard type is presented in Table 4.7. As for the analysis in Table 4.6, ranges of impacts have been given due to the likely variation between waste sources as well as disaster impacts for each hazard. Generally this analysis shows that disasters have a wide range of impacts (in terms of waste generation). The most interesting distinction between the disaster events is the hazard types which move privately owned materials or waste across property boundaries (i.e. hurricanes, tsunamis, tornadoes, floods) and those where waste largely stays at its point of origin (i.e. earthquakes, fires, ice storms, volcanic eruptions, pandemics and industrial disasters). This has funding and legal implications which will be discussed in later chapters.

Table 4.7 Typical range of disaster waste impacts for different hazard types

		Typical disaster waste impacts				
		Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Difficulty of handling waste
Types of Disasters	Hurricanes / Typhoons	L - M	L - M	L - M	M	L - H
	Tsunamis	L - H	L - H	L - H	M - H	L – H
	Tornadoes	L	L - M	L - M	M	L - H
	Floods	L - H	L - H	L - H	M - H	L - M
	Earthquakes	L - H	L - H	L - H	L	L - H
	Wildfires	L - M	L - M	L - M	L	M - H
	Ice storms	L	L - H	L - H	L	L - H
	Volcanic eruption	L-H	M	M	L	L-H
	Pandemic	L	H	L	L	H
	Industrial disaster	L-M	L-H	L-H	L	L-H

L = low, M = medium, H = high

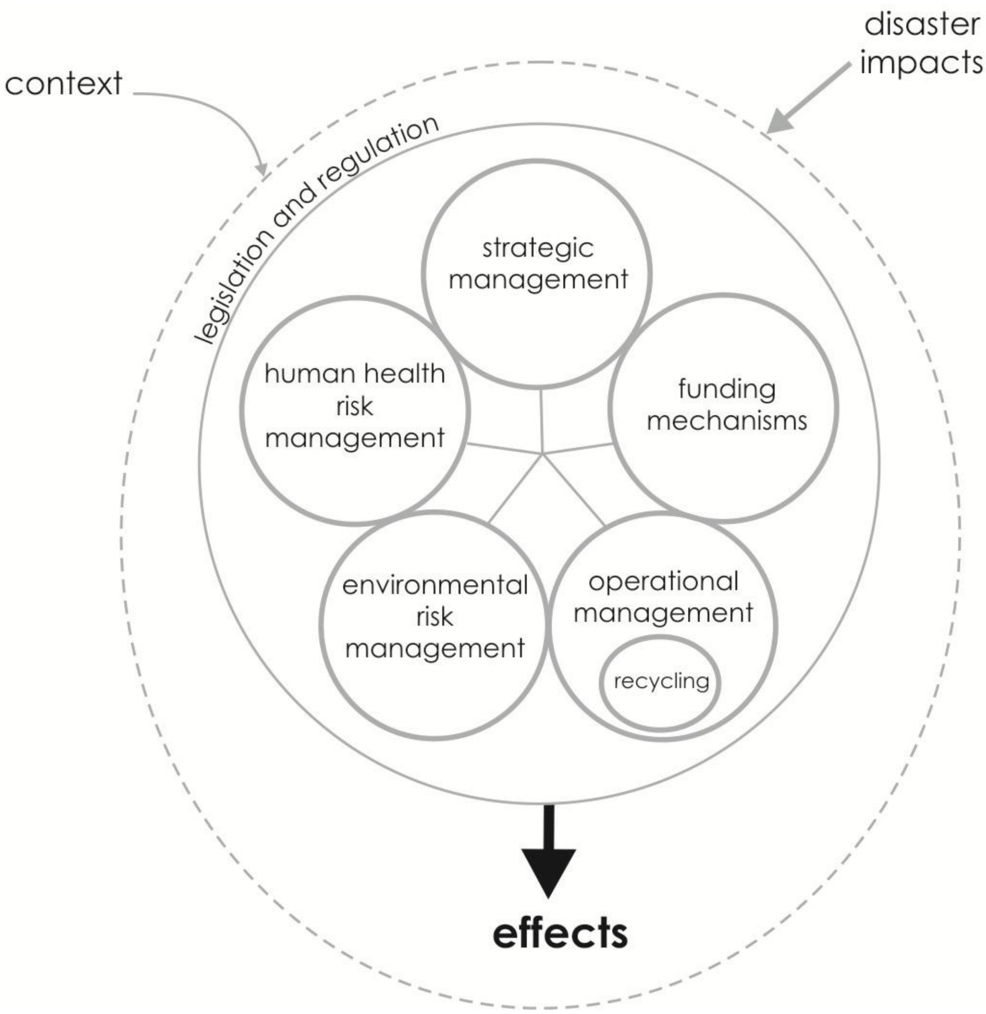
This assessment could be expanded further by evaluating the waste impacts expected for each waste source for each hazard type; and potentially for different disaster impacts within each hazard type. However, that level of detail is not included in this thesis. The aim is to present an approach suitable for further analysis and planning purposes.

4.4 Summary

This chapter presented three key classifications and semi-quantitative assessment techniques which can be used to aid in pre-event and post-event planning and analysis:

- Disaster impact indicators;
- Disaster waste source categorisations; and
- Disaster waste impact indicators.

These classifications will be used qualitatively for the remainder of the thesis to enable cross case analysis.



5. Effects

5.1 Introduction

As discussed in the literature review (Sections 1.6 to 1.8), disaster waste management systems can have wide and varying environmental, economic and social effects. These potential effects need to be better understood to enable disaster waste managers to establish appropriate goals for disaster waste management systems which also meet the objectives of the overall recovery.

The aim of this chapter is to develop qualitative criteria for evaluating the effectiveness of a disaster waste management system. These criteria could also be interpreted as objectives for disaster waste management. The chapter discusses the challenge of balancing these objectives post-disaster, and the impact of the different disaster & disaster waste impacts presented in Chapter 4. There is also a discussion on how these criteria may also be developed for use in future disaster waste management planning. A possible assessment approach and scale is proposed.

The criteria will form the basis for the cross-case study analyses presented in (Chapter 6 to 10).

5.2 The criteria

5.2.1 Environmental

There are a number of widely acknowledged adverse environmental risks associated with managing waste. Environmental risks can include contaminant discharge to air, water or land and can occur at any stage of the waste management process. Generally risks associated with managing waste in peace-time are well recognised and understood. Post-disaster many of these risks can increase intentionally and unintentionally often due to the desired speed of physical works (refer Chapter 10). Disaster waste management systems should ideally aim to mitigate environmental risks.

Examples of negative environmental effects observed in the case studies include: illegal dumping (Hurricane Katrina, Christchurch earthquake, Samoan tsunami) and air pollution from open burning following Hurricane Katrina.

Criterion: Adverse environmental effects are minimised.

In peace-time, waste management systems in developed countries generally successfully manage environmental risks and there is a growing focus on environmentally beneficial strategies for waste management, such as, at times, reuse, recycling and reduction. There is opportunity post-disaster to implement environmentally beneficial waste management strategies and where feasible this should be encouraged.

Criterion: Environmentally beneficial strategies encouraged (e.g. recycling).

5.2.2 Economic

Direct

Waste management is an expensive service. Costs are incurred from management, labour, transportation, plant and equipment, treatment and disposal of waste. Cost control and savings can be achieved through a number of initiatives, including reducing double handling, using in-kind assistance where appropriate, maximising economies of scale, recycling and controlling post-disaster price escalation (see Section 7.3.3).

Criterion: Operational (waste handling and disposal) costs are minimised.

Management costs are incurred both at a strategic and operational level. Costs include administration, monitoring and coordination. These costs can be reduced by selecting efficient contract types, organisational structures and risk management techniques (as discussed later in this thesis). For example, following the Victorian Bushfires, the managing contractor, in agreement with the Victorian Environmental Protection Agency, established a streamlined truck certification and management programme which reduced monitoring requirements.

Criterion: Regulatory and strategic management costs are minimised.

Indirect

As noted by Horwich (2000) in his assessment of the economic impacts of the Kobe earthquake, disaster recovery efforts can have a positive effect on the local economy. In terms of waste management, indirect benefits can be stimulated by use of local labour and services.

Criterion: Local economy stimulated

Indirect costs could be incurred from poor environmental and human health risk management if environmental remediation or medical intervention is needed. Authorities also may face the costs of litigation. This cost is positively linked to minimising adverse environmental effects, above, and human health effects, below. When risks are minimised, potential future remediation costs are also minimised.

Criterion: Potential future costs from environmental remediation and adverse health effects are minimised.

5.2.3 Social

Psychosocial

Many authors, as discussed in Section 1.8, note that the removal of debris aids in the psychosocial recovery of a community. The limited social impact data collected in this research contributed to that assertion. One community member interviewed in Victoria, Australia, described the transformation following the bushfire debris removal in Marysville as having "gone from rubbish heaps to a new housing development"; another described it as "a new beginning". The psychosocial benefits are not just from reducing visual impacts and enabling rebuilding. There are also benefits from facilitating access to and the recovery of social infrastructure such as schools, churches and community facilities. More generally, disaster waste removal is the first physical step towards recovery.

Criterion: Improves community spirit

The author proposes that physically participating in disaster recovery works can contribute positively in psychological terms. Community participation in disaster recovery planning is a well-recognised ideal with many benefits including empowering communities and mitigating potential mental health issues (Sullivan, 2003; Gordon, 2009; Phillips, 2009; Collins et al., 2011; Mooney et al., 2011); the benefits of physically participating has been less well researched. Parallels can perhaps be drawn to the psychological benefits of general volunteerism, under the assumption that similar benefits apply to disaster affected persons. Major benefits of volunteering in a disaster recovery situation cited by Phillips (2009) include decreasing psychological distress and depression, improving mental health and drawing people away from inappropriate means of coping with the disaster. Respondents to a study on community recovery after the 2003 Canberra bushfires in Australia noted that 'having a sense of control and acceptance and engaging in meaningful activities' aided them in their recovery (Camilleri et al., 2010).

Empowering communities during recovery also potentially aids in their future ability to help themselves following a disaster event (The World Bank and The United Nations, 2010).

There was general concern noted, following the Samoan tsunami, that the low level of community involvement in the recovery effort was contributing to aid dependence.

Criterion: Affected persons are empowered to participate in their own recovery.

Public communication and consultation around post-disaster issues, including waste management, is arguably the most important aspect of disaster response and recovery. Communication helps to ensure that the authorities and the community are working toward a common and shared goal. Disconnects between the community and authorities (for example in terms of prioritisation of works, timeliness, fairness, environmental and human health risk management) can lead to erosion of public trust and public opposition which may affect the expedience and quality of the recovery. Following Hurricane Katrina, L'Aquila earthquake and the Christchurch earthquakes, protest and/or legal action has been taken against authorities for various aspects of the waste management system: each time diverting resources from the recovery efforts. It is important to design the disaster waste management programme to maximise public acceptance.

The sensitive management and/or return of personal property should also be considered here. In all the case studies investigated the rightful return and/or sensitive handling of personal property has been an important consideration for community members. Community members all appreciated the opportunity to salvage personal property prior to demolition. In Christchurch there was much disaffection regarding the handling of business effects in the central city – some belongings which were supposed to be unrecoverable (some containing private information) were salvaged by the demolition contractors. This is discussed further in Section 8.3.4.

Criterion: Public understands and accepts disaster waste management strategy

Human health

Management of disaster waste involves the management of various human health hazards. Hazards can be at the demolition site, during waste collection, transportation or at waste handling facilities. Hazards can be chemical or physical, acute or chronic, as described in

Section 4.3.3. Management systems need to be designed to ensure these hazards are effectively controlled.

Criterion: Human health (both general public and workers, acute and chronic) risks are effectively managed.

5.2.4 Recovery

Clear recovery objectives, in the author's opinion, are critical to effective disaster waste management systems and disaster recovery in general. In many of the case studies reviewed in this research, recovery objectives appeared to be either not established, poorly implemented or there was a disconnect between waste management activities and the overall recovery.

In Victoria, Federal and State Officials publicly acknowledged Bushfire recovery objectives and designed the waste management strategy in line with those objectives:

> "Ms [Jenny] Macklin [Federal Minister for Families, Housing, Community Services and Indigenous Affairs] said clearing debris left in the wake of Victoria's bushfires was the essential first step in rebuilding communities. 'We will remove potential hazardous material, such as asbestos, and then clear properties for free, so communities can start to get back on their feet,' she said. 'When you see the scale …[of] the devastation and people sifting through what was their homes, it is clear the pressing priority, both at an emotional and safety level, [is] to start clearing away the debris. We want to help people get started as quickly as we can, and we want to give them the practical assistance they need to make sure the clean-up is done in a safe and sensitive way.' "
>
> (The Premier of Victoria, 2009)

In Christchurch, however, the recovery objectives were rather less well defined. Generally it was understood that time was a critical factor. However, minimising direct cost, social disruption and environmental impact were also proffered as recovery goals by various agencies and authorities.

In a review of disaster recovery programmes, Olshansky et al. (2006) surmised that recovery objectives, while different for every context and disaster, generally focus on time and quality.

In terms of timeliness, expedient demolition and clean-up offers many economic and social benefits. Economically, there are indirect financial benefits from a timely clean-up: reduced business losses, the return and/or non-flight of people and businesses, reductions in government welfare dependence and a faster return to full economic productivity. There is potentially a benefit to faster demolitions from the point of view of a business that has limited or no business loss insurance. For example, the following (fictional) calculation demonstrates the effect of time to demolish on total business losses:

Building value	$1,000,000
Demolition cost (option 1)	$50,000 for 4 week programme
Demolition cost (option 2)	$100,000 for a 2 week programme

Therefore, the additional cost for a faster demolition (option 2) is $25,000 per week. If business losses for the building (or neighbouring buildings unable to open because of the damaged structure) are more than $25,000/week, then, a faster (and more expensive) demolition is justified. Further analysis and research comparing demolition costs and business losses would be advantageous.

Some proffer that a faster demolition reduces the chance of illegal dumping by those frustrated by the clean-up service taking too long to reach them (GAO, 2008) and thus, the risk of cost for future remediation costs is reduced (Section 5.2.2) and human and environmental risks are reduced (Sections 5.2.1 and 5.2.3). From a psychosocial point of view, as waste is removed, community spirits can be lifted (refer Section 5.2.3).

It should be noted that the desired speed of clean-up and demolition may change over time. In fact it could be argued that the urgency to demolish and clean-up, decreases as the recovery period progresses. This is because most of the dangerous buildings are removed, health and safety concerns are reduced, public access may be restored and from a psychological point of view the damage is less visible. Urgency to clean-up could also be reduced when there are delays in the wider recovery planning, including re-build planning and permitting and building code changes observed in Christchurch. It may be appropriate (unless the waste is causing significant disruptions or posing significant hazards) to align demolition / clean-up timing with recovery planning. For example, demolition in the central city of Christchurch (to make safe enough to re-open the area) was scheduled for April 2012 – the same month as the approval of the central city recovery plan.

Criterion: The recovery is timely.

In terms of the analysis in this thesis, the author has assumed that 'quality' is measured by the environmental, economic and social criteria discussed in this chapter.

The author would add to Olshansky et al.'s findings in that recovery objectives also tend to, and need to, focus on community. In many developed countries, a free market paradigm exists which focuses on individual freedoms. It has been observed by the author that this paradigm is not necessarily complementary to community recovery as individual benefits are 'favoured' over the greater community good. Meadows (2009) refers to this systems thinking concept as the 'tragedy of the commons'. Authorities in some of the case studies have modified individual's peace-time market freedoms to ensure community recovery goals are met: generally by increasing regulation. For example, the CER Act in Christchurch, where CERA was given authority to intervene when private property owners did not demolish or make safe dangerous properties in a timely manner.

Criterion: The recovery facilitates equitable outcomes across the community.

5.3 Balancing objectives

The criteria given above are ideal and are not always complementary. It is unlikely that all objectives will be able to be met and compromises will have to be made. That is, when efforts are made to meet one objective, another may be compromised. There are many examples of this need to balance objectives throughout this thesis. For example:

- Recycling all the waste material might be the most environmentally beneficial solution but it might take a long time and can sometimes be more expensive.
- Reducing management and monitoring efforts and costs could have adverse environmental and human health effects.

- Hastening the management of waste could compromise environmental and human health outcomes or lead to community disaffection. For example, the hasty World Trade Centre clean-up led to human health effects (9-11 Research, accessed 2011a) as well as the destruction of forensic evidence (9-11 Research, accessed 2011b); and the fast demolition in Wenchuan, China, following the 2008 earthquake led to accusations of government corruption as some believed bodies were bulldozed away with the building rubble (Demick, 2009).
- Encouraging public participation when there is a public health risk could have a detrimental effect on public health.
- Allowing individual management of waste at demolition sites may empower individuals; but, if poorly managed, may increase the overall economic impact on the community due to prolonged business disruption for neighbouring commercial properties.

Authorities managing each disaster will need to determine how to prioritise the desired objectives. The relative importance of the criteria is likely to be context specific and is for authorities to determine during planning and response / recovery. In terms of this thesis, the author has, where possible, only stated the potential effects of various disaster waste management approaches (rather than the overall balance for a particular case study).

One of the major challenges in balancing objectives is managing the desire to clear debris quickly – referred to here as 'urgency to clean-up' – and the speed at which a quality clean-up can occur - 'speed of clean-up'. Below is a discussion of how some of the disaster impacts, discussed in Chapter 4, affect how urgent the clean-up is and how quickly it can be carried out. The discussion is summarised in Table 5.1.

Disaster scale

Based on the literature review and the five case studies here it appears that the urgency to clean-up increases with the scale of the event. Christchurch in particular is a good example of this, where the response to the September 2010 earthquake was far less urgent than the larger 2011 February earthquake.

Number of displaced persons

The urgency of clean-up activities will depend on whether displaced people intend to return to the affected area or not. If the community intends to return (such as the Christchurch Central Business District), clean-up activities tend to be more urgent than if the community is relocating. Following Samoa the communities elected to move away from the affected area permanently, consequently it appears that, apart from areas related to tourism, there appeared to be slightly less urgency for waste management than in other disaster responses investigated.

In addition, displaced persons are generally not available or willing to assist with clean-up activities. This may have an impact on the speed of the overall clean-up.

Duration of hazard

If the effects of the hazard are prolonged, clean-up activities are less urgent as authorities and funding agencies tend to want to wait until the damage has 'peaked'. However, in some cases urgent action might be necessary to mitigate further effects of the hazard. For example, in Christchurch, demolition of buildings became urgent in the central city, as strong aftershocks continually hit the city to mitigate potential hazards to the public, workers and neighbouring property. However, repair works on houses (and resultant waste management) were delayed until the aftershock activity had reduced to a suitable level to avoid the need to repeatedly repair damage.

Disruption to road network

The higher the disruption is to the road network, the slower the waste management programme will be. If the disruption to the road network is caused by waste or debris then this will also increase the urgency to move the waste. However, if the damage is structural (e.g. bridge collapses, road washouts) this will affect the transportation of wastes and may slow the speed of the clean-up.

Volume of waste

The greater the volume of waste, the greater the urgency to clean-up will be. However, the volume of waste will slow the speed of the clean-up.

Human health risk

The greater the human health risk posed by the disaster waste, the more urgency there will be to clean up. However, it is interesting to note that, generally, the greater the hazard, the slower the waste management processes tend to be. For example, tall buildings that pose a risk of collapse need to be deconstructed in a slow and controlled manner; and if asbestos is present, management techniques need to be in place to protect public and workers during demolition. This dichotomy is explored further in Chapter 10.

Environmental health risk

As for human health risk above, the higher the environmental health risk posed by the waste, the higher the urgency is to clear the waste.

Difficulty in handling the wastes

If waste is difficult to handle and specialist equipment is required, this is likely to reduce the speed of the clean-up.

Table 5.1 Disaster and disaster waste indicators influencing the urgency and speed of a disaster waste management system

	Disaster & disaster waste indicators									
	Disaster scale	Number of displaced persons	Geographic extent	Duration of hazard	Disruption to road network	Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Difficulty of handling waste
Urgency to clean-up	+	+		-			+	+		
Speed of clean-up		-		-	-	-	-			-
+ = positive influence, - = negative influence										

5.4 Systems diagram

To illustrate how the above discussion, a causal loop diagram has been prepared to, see Figure 5-1. Causal loop diagrams are a common method used to illustrate relationships between elements in a system to demonstrate the overall system behaviour. This causal loop diagram shows how the disaster & disaster waste impacts link to the environmental, economic, social and recovery effects. It also demonstrates how the environmental, economic and social effects relate to each other. Between each factor on the diagram is an arrow with a + or a – next to it. This denotes whether an increase in one system element will have a positive or negative effect (respectively) on the adjoining element. The solid links shown are those already developed in the previous two chapters and the dotted links represent the aspects to be developed in later chapters.

Generally the diagram shows:

1) The 'disaster waste system' (as will be developed in the following chapters) is driven by the disaster & disaster waste impacts (left hand side of the diagram). Many of the disaster & disaster waste impacts create an urgency to clean-up the waste quickly and this becomes a decision-driver for disaster waste managers.
2) The 'disaster waste system' is linked to the likely effects. As discussed in this chapter the design of a disaster waste management system will determine how fast the clean-up is carried out and what the likely environmental, economic and social impacts will be.
3) The effectiveness of the recovery is affected by the disaster & disaster waste impacts. Generally the disaster & disaster waste impacts will negatively impact how fast the clean-up can be carried out.
4) The effects relate to each other. As the feedback loops on the diagram show, the effects generally positively reinforce each other. The social, environmental and economic recovery is affected significantly by the speed at which the clean-up is carried out. In particular, a more expedient clean-up has positive economic and social effects which also positively reinforce each other. Thus, it can be inferred that carrying out an expedient clean-up would be very positive for the recovery.

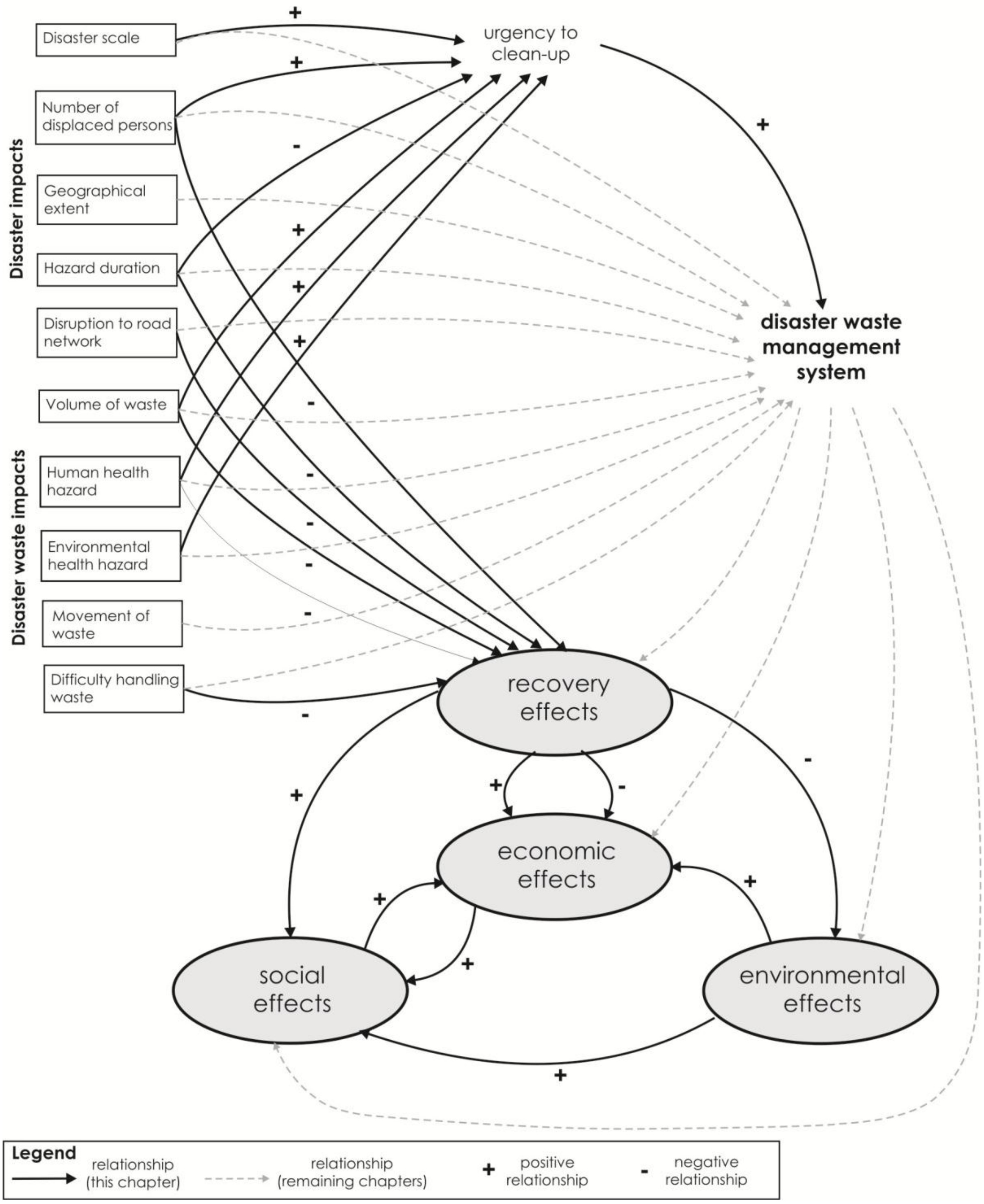


Figure 5-1 **Causal loop diagram: for measuring the effectiveness of a disaster waste management system.**

5.5 Criteria application

As for the disaster & disaster waste impact indicators (Chapter 4), the disaster waste management system effectiveness criteria are only used qualitatively in this thesis to support the conclusions drawn. However, as stated above, these criteria could be used to assess the likely effectiveness of the proposed disaster waste management systems – either pre- or post-event. To enable this, a semi-quantitative scale (such as that used in Section 4.2) could be applied to the criteria. To allow for the criteria to be balanced, a weighting should also be given to each criterion.

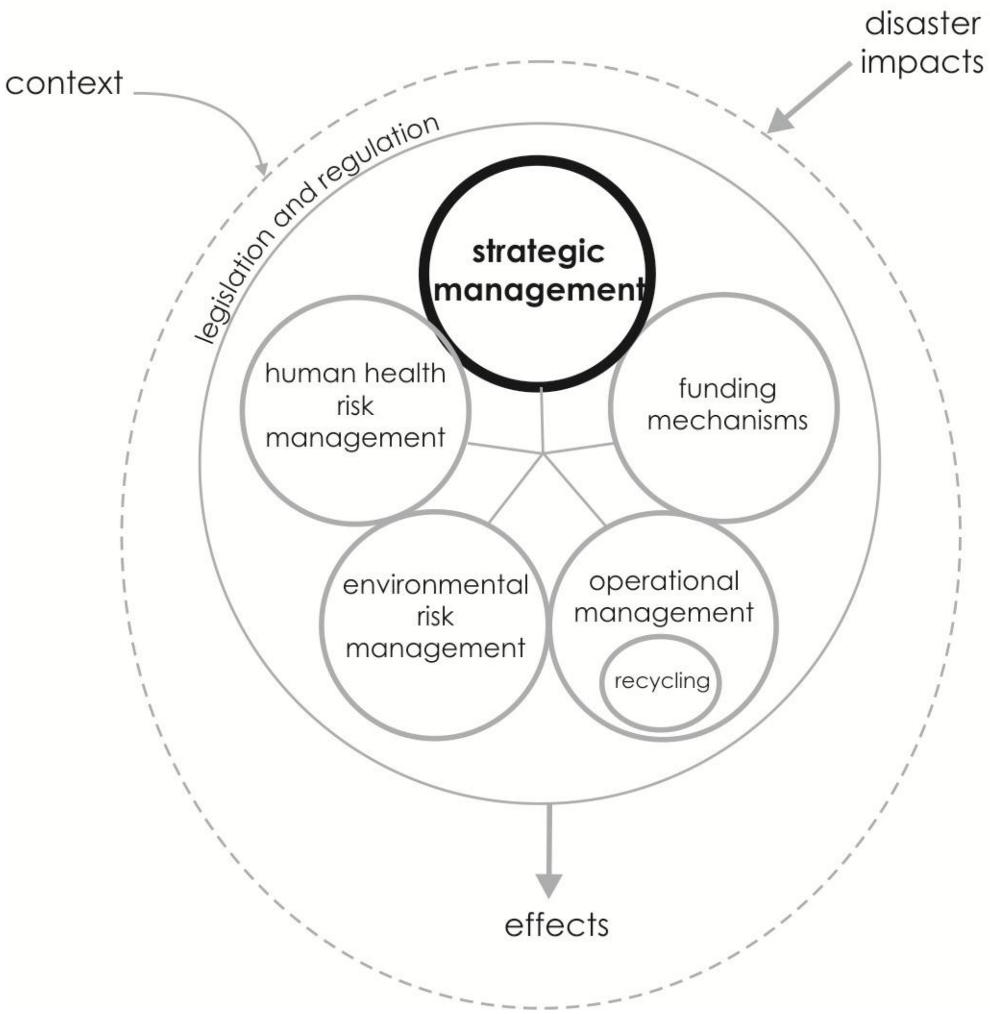
5.6 Summary

The challenge in this thesis is to determine the best design for the 'disaster waste system' to ensure an effective and efficient demolition and debris management programme. This chapter has outlined a set of 12 criteria, as listed in Table 5.2, to enable the assessment of the environmental, economic, social and recovery objectives likely in a disaster waste management system. These criteria will be used, qualitatively, in this thesis to support the discussion on the effectiveness of certain approaches to disaster waste management (see Chapters 6 to 10). It is envisaged that these criteria could be adapted as objectives to enable future planning for disaster waste management (Section 12.2).

Table 5.2 Criteria for an effective disaster waste management system

	Criteria
Environmental	
	Adverse environmental effects are minimised.
	Environmentally beneficial strategies encouraged (e.g. recycling).
Economic	
Direct costs[8]	Operational (waste handling and disposal) costs are minimised.
	Regulatory and strategic management costs are minimised.
Indirect costs	Local economy stimulated.
	Potential future costs from environmental remediation and adverse health effects are minimised.
Social	
Psychosocial	Improves community spirit.
	Affected persons are empowered to participate in their own recovery.
	Public understands and accepts disaster waste management strategy.
Human health	Human health (both general public and workers, acute and chronic) risks are effectively managed.
Recovery	
	The recovery is timely.
	The recovery facilitates equitable outcomes across the community.

[8] Direct economic costs include for waste collection, demolition, treatment, and disposal and all the management / overhead costs which relate directly to management of disaster waste.



6. Strategic management

6.1 Introduction

As described in Section 1.9.1, disaster waste managers have developed and coordinated disaster waste management programmes using a number of different organisational structures. The responsibility for this strategic management can be assigned to: local, regional or national authorities; waste management or emergency organisations; or the need for strategic management can be neglected altogether.

This chapter analyses the strategic management of the five case studies in the context of their respective wider disaster recovery governance.

The general aims in the chapter are to understand:

1) Why strategic management is important

2) Where responsibility for strategic management should lie (local, regional or national; waste management or disaster management authority); and
3) What general principles a strategic management organisational structure should adhere to.

As discussed in the methodology chapter (Chapter 2), both the disaster impacts and system effectiveness criteria have contributed to, and will be referred to during, the analysis.

Also included in this chapter is a brief discussion of public communication and consultation around disaster waste management.

6.2 Case studies

6.2.1 2009 Victorian Bushfires

Due to the scale of the event, the Commonwealth and Victorian Governments elected to establish the Victorian Bushfire Recovery and Reconstruction Authority (VBRRA) to "guide the recovery and rebuild process" (VBRRA, 2009b). As part of this, VBRRA took overall responsibility for the waste management programme. Thus, VBRRA became the focal point for waste management issues. VBRRA initiated the coordination of the appropriate regulators and contractors to implement the project and consistent quality / implementation standards were established across the entire affected area. VBRRA acted as a coordinator for the three levels of government and had limited direct decision-making authority. Legislative authority remained with peace-time authorities. Given the scale of the event, the approach was generally sufficient.

In general, the inter-agency communication was ad-hoc (due to the absence of a plan) but seemed effective. Post-disaster, roles and responsibilities were undefined and overall responsibilities for various aspects of the waste management process were unclear. Community consultation was absent during the planning of the demolition and debris management plan. Some public consultation was carried out during implementation but the communication was largely one-way: that is, information provision to communities.

6.2.2 2009 Samoan Tsunami

Overall the coordination of the waste management process was weak. The UN Cluster system response and Samoan government emergency response systems were not integrated and neither system explicitly recognised waste management as a specific recovery activity; consequently expected roles and responsibilities were ill-defined. No one agency, national or international, took responsibility for a strategic and integrated approach to waste management.

There also did not appear to be a clear mechanism for cross-organisational collaboration. While the Ministry of Natural Resources and the Environment was directly responsible for waste management works, waste management issues were identified as a need by at least two government agencies (Ministry of Health and Ministry of Agriculture and Fisheries). The mechanisms to alert relevant authorities of given recover needs, however, was unclear and there was reliance on existing pre-disaster relationships.

A lack of strategic management led to varied programme effectiveness. Organisations formed their own waste management strategies and policies with varying degrees of recycling and disposal standards. Doubling-up on, and omission of, recovery activities also occurred.

There were some public communication attempts, via the media (radio, newspaper), to notify people of the potential toxins in the lagoon area due to the debris. This appeared to be effective. However, poor community understanding and participation in the clean-up planning and process led to many villagers managing their own waste haphazardly on site: including open burning and burial.

6.2.3 2009 L'Aquila Earthquake

Emergency management in Italy is the responsibility of Departimento della Protezione Civile (DPC) [Government of Italy Department of Civil Protection]. Although DPC was not specifically prepared for management of disaster waste, the environmental arm of DPC (established in 2006 following the Campania waste crisis) assumed control of establishing and operating the waste management system for the first eight months. Following that, the local authorities (Comunes), who have normal operational control of waste management activities in Italian towns, assumed control of waste issues. Legislative changes were enacted by DPC, in consultation with Provincia dell'Aquila, to enable waste management activities.

The initial coordination by DPC appeared to be effective in that it provided an umbrella for coordination of all stakeholders and the joint establishment of waste management procedures. The body also allowed for linkages to other recovery activities. However, once DPC withdrew and individual Comunes assumed responsibility for waste management within their locality, the regional approach appeared to be lost. A regional commissioner and round table forum were established to oversee the recovery and ensure a regional approach; however, their effectiveness appeared to be limited, as critical decisions (such as identification of disposal and waste handling sites) were not forthcoming.

The uncoordinated approach contributed to delays in waste management which increased public health and environmental risks (due to the presence of the unmanaged waste); led to community dissatisfaction (particularly due to slow progress in the historic city centre or red zone); and affected the economic recovery of the area.

Some efforts were made by Provincia dell'Aquila to communicate waste management issues and procedures (Bonanni and Stagnini, accessed 2010), including press conferences and meetings with citizens' committees and all municipalities to outline waste management practices. No information on communication efforts of other authorities was obtained by the author.

6.2.4 2005 Hurricane Katrina

The general approach to overall coordination of the waste management programme following Hurricane Katrina was as prescribed in the National Response Plan (NRP). The NRP clearly outlines specific operational roles, delineated into Emergency Support Functions (ESFs), to be enacted in response to a disaster. Each ESF has a government department as lead and they are responsible for facilitating any legislative and organisational measures necessary so that the operational roles can be carried out. In the case of waste, the primary lead agencies were the US Corps of Engineers and US Environmental Protection Agency (USEPA). Generally ESF mandates are operationally focussed.

In response to Hurricane Katrina, the Gulf Coast Recovery Office (GCRO) was also established to coordinate FEMA / NRP activities across all affected States. Generally, it appears that: (1) USEPA set minimum standards for waste management; (2) LDEQ ensured State laws were met, established minimum standards for clean-up operations and streamlined regulatory processes where necessary; and (3) local authorities identified disposal sites and ensured that contractors had sufficient disposal, staging and recycling sites. However, it is unclear who oversaw the efficiency and effectiveness of the disaster waste management system.

Overall, based on the data gathered, the strategic management and coordination of the waste management process was missing. Established operational roles worked well, as did organisations working within their peace-time capacities. However, there was a distinct lack of coordination across federal, state and local authorities with respect to waste management activities. It is unknown how effective the GCRO was and the exact linkages (if any) between the GCRO and the ESFs roles, functions and personnel. There was also, perhaps as a result, minimal strategic direction given to implementing organisations in terms of how specific streams of waste should be handled. This led to a slow clean-up operation which was inconsistent between localities.

The large number of displaced persons made public communication difficult. USEPA provided some information on their website and gave general guidance on how to deal with certain aspects of the waste following Hurricane Katrina, including asbestos, storage tanks, polychlorinated biphenyls, hazardous materials and demolition material (USEPA, 2005a). However, the Government Accountability Office (GAO, 2007) determined that USEPA's public communication of the health and safety risks involved in residents returning home, was inadequate. The reports were issued too late (3, 6 and 11 months after the disaster) and much of the early data did not clarify that the risk assessments were based on short term exposure to the hazardous waste components.

6.2.5 2011 Christchurch Earthquake

Emergency response and recovery in New Zealand is managed by Civil Defence under the Civil Defence and Emergency Management (CDEM) Act. The provisions under the CDEM Act (and related plans and organisational structures) were sufficient to enable emergency response following the earthquake; however, the legal mechanisms and organisational structures allowed for under the CDEM Act were not sufficient for recovery from an event as large as the Christchurch earthquakes. Thus, a new law was passed (the Canterbury Earthquake Recovery or CER Act) and a new government department, the Canterbury Earthquake Recovery Authority (CERA), was formed to strategically manage the recovery of Christchurch in partnership with local and regional authorities. CERA also had some operational responsibilities, in particular with respect to demolition and debris management in the commercial and residential red zones.

Waste was not explicitly included in the Civil Defence pre-event plans or legislation. A demolition and debris management team evolved during the emergency response phase, under Civil Defence. Representatives from local and regional authorities, Civil Defence, project management consultants and contractors were brought together to develop and implement the demolition and debris management system. The team was largely operationally focussed but some effort was made to strategically plan for waste management in collaboration with local councils. This team carried over during the transition from Civil Defence to CERA. This carry-over occurred out of necessity as much as with a strategic intent for continuity. By five months after the earthquake, the waste team was reduced to one consultant working, primarily, in an operational capacity. Environmental regulation and enforcement was carried out by the local and regional councils according to their peace-time functions.

At the time of writing, there appeared to be no role developed for strategic management and coordination of the overall waste management process. Debris and waste management issues have been officially divided between CERA (debris management – demolitions) and the local authority (Christchurch City Council) (water and waste issues) (CERA, 2011) such that no organisation appears to be overseeing the whole waste management system, from 'cradle to grave'. Thus, no organisation is actively identifying bottlenecks, capacity limitations, risks or developing integrated protocols & strategy.

Public communication during the response was largely reactionary. The high number of media enquiries and limited human resources meant that proactive messaging was not always possible. Public consultation efforts were limited to those required under law and some of these had been stream-lined by provisions under the CER Act, see Section 11.2.5.

6.2.6 Case study summary

As demonstrated above, there are a diverse range of approaches to strategic disaster waste management. Table 6.1 indicates what types of organisations (national, regional, local, emergency / recovery or waste/environmental management) were responsible for the strategic management of the waste for each case study. Note that responsibilities shown in the table are those beyond their peace-time organisational mandate.

Table 6.1 Disaster waste strategic (overall) management responsibility (beyond peace-time responsibilities) during response (E) and recovery (R) phases

	Governance level			**Authority type**	
	National	Regional	Local	Emergency / Recovery	Waste / environmental
2009 Victorian Bushfires		E+R		E+R	
2009 Samoan Tsunami	E+R				E+R
2009 L'Aquila earthquake	E		R	E	R
2005 Hurricane Katrina		E+R			E+R
2011 Christchurch earthquake	E			E	

The survey results presented in Appendix C, indicated that there was no obvious choice for assignment of responsibility for disaster waste management activities. 49% indicated that the emergency / recovery agency should have responsibility for the waste; while 23% and 28% indicated local and national waste management authorities respectively.

The spread of the survey responses and the range of organisational structures used in the case studies, perhaps, is indicative of the complexity of contextual factors that can potentially influence strategic disaster waste management approaches.

6.3 Discussion

6.3.1 Importance of strategic management

It is important to acknowledge that disaster waste management is a separate function to peace-time. In peace-time, organisations have existing mandates for dealing with various peace-time waste streams. Roles and responsibilities are well defined and consistent. However, as discussed in Chapter 4, disasters generate different waste streams with unique characteristics and, by definition, the waste is generally managed under time and resource constraints. As a result (as discussed in Chapter 5) peace-time waste management objectives are also likely to have shifted. These factors dictate that, unless the disaster is small, a specific management approach, distinct from peace-time is required.

If a central authority had not been established in Victoria, Australia, following the bushfires, it would have been unclear where the overall responsibility for and strategic management of the bushfire waste would have rested amongst the diverse range of private, state and local government bodies involved in daily waste management in Victoria. A single authority allowed for a strategic and centralised approach to waste management. VBRRA was responsible and ultimately accountable for ensuring the clean-up works were complete and implemented effectively and efficiently.

A strategic management approach, distinct from peace-time structures is generally required to ensure recovery objectives are met.

A strategic management organisation (or group of organisations) is, therefore, necessary to manipulate peace-time roles and responsibilities to ensure new post-disaster objectives are met. In L'Aquila, where strategic management was lacking, peace-time mandates and silos interfered with meeting recovery objectives. While it was the local environmental authority's role to advocate for recycling processing sites and to minimise landfilling, they had no mandate to establish sites to facilitate this; that had to be done by the municipality (Comune). However, it was not necessarily in the municipality's interest or their priority to establish these sites, as their primary aim was to remove the debris from the streets to facilitate recovery of the city. Thus the common goal of regional recovery (both social and environmental) was lost as no one organisation was driving the waste management process. In Christchurch, the local authority focusses much more on social disruption, whereas the regional authority focusses on the environmental impact. Decisions appeared to be being made independently within each organisation to meet their organisational mandate. Unless there is good overall leadership, different organisations are likely to make decisions based on their understanding of the context and peace-time processes and responsibilities. They are unlikely to consider wider recovery goals – either unintentionally or due to legislated limitations in their organisational mandate. In systems terms, this is known as bounded rationality: "each actor in a system may not lead to decisions that further the welfare of the system as a whole" (Meadows, 2009).

The appropriate legislative framework (including mandate and authority) is required to ensure strategic management is possible. Conversely, inadequate strategic management structures can increase the possibility of poor legislative and regulatory decisions. This is discussed in detail in Section 11.3.1.

An entity must be given the responsibility and mandate to lead disaster waste management activities toward community-wide recovery goals.

6.3.2 Responsibility for strategic management

As shown in Table 6.1, overall responsibility for management of disaster waste in the case studies investigated here rested with a range of different agencies. Some were fairly well defined in emergency response and/or recovery plans (Hurricane Katrina), others emerged during the recovery (Victorian Bushfires, Samoan Tsunami, L'Aquila earthquake) and others never fully eventuated (Christchurch earthquake). A key decision, is determining 1) which type of organisation (emergency/recovery or waste/environmental) and 2) what level of governance is best to strategically manage the waste.

Organisational function (emergency / recovery or waste / environmental authority)

As discussed above, existing organisations are often constrained by their peace-time mandates and/or mentalities or they suffer from 'bounded rationality'. Bounded rationality was evident during the author's involvement in the response to the Christchurch earthquakes where existing local authority functions, at times, did not adapt to match the new working environment and some decisions were being made using peace-time assessment processes and considerations. In L'Aquila, authorities were bounded by their peace-time approach to identifying waste handling and disposal sites, such that insufficient sites were identified. Assigning responsibility for disaster waste management to an organisation which is not constrained by peace-time protocols, such as an emergency / recovery authority, may be beneficial to the recovery. The author suggests, therefore, that:

If there is an urgency to clean-up, responsibility for strategic management should be delegated to the recovery authority.

At the same time, the disaster waste system must also utilise the existing systems and facilities as far as possible and ensure that the proposed intervention does not adversely affect future peace-time waste management. Emergency / recovery authorities may not give enough consideration to the effects beyond the duration of the recovery. The key is to design a strategic management structure which utilises these local waste management personnel but does not overwhelm or supersede them. In Samoa, the UN Cluster system appeared to completely usurp the Samoan National Disaster Management Plan organisational structures and peace-time waste management functions and worked almost completely independently from existing governance structures. This was not ideal as the capacity and knowledge of the government was lost during that time. Existing peace-time organisations have a wealth of knowledge in their given area as well as, data systems, monitoring and enforcement capacities, regulatory tools etc.

It is vital that the strategic management structure has strong links with those with vested interest and long-term responsibility for waste management facilities and operations.

If strategic management does rest with a peace-time waste authority, then measures need to be implemented to minimise the effects of bounded rationality. That is, the organisational objectives need to be changed. For example in some cases an organisational directive may be adequate to alter people's perspectives; in other cases, however, a formal legal mandate or legislative change may be necessary to ensure an appropriate approach is taken.

If peace-time waste authorities are responsible for strategic management of disaster waste, appropriate authority and mandate must be given to the organisation for the purposes of the recovery.

Where waste management activities are likely to affect wider recovery activities, it would be beneficial to strategically manage the waste under the recovery organisation. In particular there is greater need for synergy (between waste management and recovery governance) where there are a high number of displaced persons, there is high disruption to the road network and there are high human health impacts. For example, the waste presence in New Orleans, following Hurricane Katrina, had a significant impact on the willingness and ability of residents to return to the affected areas and recovery efforts were difficult to achieve when the population was missing. In this situation waste and recovery managers must work together closely to identify priorities and strategies for moving the waste and returning people to the area.

Waste activities should be managed under the recovery organisation where waste management activities have a strong interconnectedness with other recovery activities. This is particularly relevant where there are a high number of displaced persons, high disruption to the road network and high human health impacts.

Governance level (Local versus Regional versus National)
By definition of a disaster, resources of a community are overwhelmed and external assistance is needed. Determining the relative disaster scale will help to determine how affected local authorities are and whether they have sufficient resources to strategically manage the waste.

The emergency response arrangements in the US are based on a bottom-up approach. The lowest level of governance is delegated authority where possible and is required to request assistance from higher levels when their capacities are overwhelmed. However, according to Weaver (2006), the almost complete collapse of low level government structures following Hurricane Katrina meant authorities were neither in a position to lead the recovery nor ask for assistance. Weaver suggests a federal "push" model (that is a top-down approach) as opposed to the existing "pull" model would be preferable.

In New Zealand, the emergency plans are also based on a "pull" model. However, this broke down at times following the February earthquake and a number of decisions were made at national level without requests from local civil defence authorities. One example was the approval to reclaim land at Lyttelton Port with inert demolition materials. It is arguable whether or not this national intervention was necessary (to enable the port to continue operating or as a waste management solution) or not in this case, however, national authorities clearly believed that the reclamation would contribute to the successful recovery of Christchurch. Local authorities following the Victorian Bushfires stated that they were relieved not to have to manage (strategically and operationally) the Bushfire waste as they were largely overwhelmed by the event.

FEMA's 2011 National Disaster Recovery Framework (FEMA, 2011) acknowledges the effect of scale on management structures. It recommends that plans are scalable and adaptable: "[a] tiered leadership structure helps to accommodate the rapid surge of Federal resources that may be needed to assist in large-scale or catastrophic incidents".

The <u>disaster scale</u> (and resultant economic and social impact extent) will inevitably determine what level of government strategic management should occur.

Strategic management organisational structures should be tiered and modular such that they can be adapted to different disaster scales.

Local authorities generally have a better understanding of the existing capacities of their waste management system. However, local authorities tend to focus on operations. Capacity to quickly and effectively strategically plan and design a waste management system many times larger than their existing system may not be available. In L'Aquila waste removal rates reduced from 600 tonnes / day to 100-200 tonnes/day following the handover from the Civil Protection Department to L'Aquila municipality.

In addition, as above, local authorities (as discussed for organisational functions) may be restricted by their peace-time operation mentality and mandate. Regional and national authorities arguably have more capacity to step back, and, using information from local authorities, develop an objective view of the situation. The capacity and objectivity of an organisation to manage disaster waste should be considered.

Strategic management personnel must have the capacity to think strategically and objectively (outside their peace-time roles and avoiding silo mentality), therefore, regional and national authorities may be more appropriate than local authorities.

The geographic extent of the waste will generally indicate whether or not waste should be managed at a local, regional or national level. More than one locality was affected in all the case studies in this thesis. Each presented opportunities for regional solutions, including sharing resources and waste handling facilities. The management of waste at local authority level in L'Aquila (rather than regionally as per the extent of the disaster effects) almost certainly contributed to the difficulties in identifying sufficient waste handling facilities in L'Aquila. However, note that if waste volumes are small but widespread, there may be little benefit in strategically managing the waste beyond local levels.

The geographic extent of the waste should generally determine the level of government response (i.e. strategic management should, at a minimum, correspond to the physical extent of damage).

The geographic extent may also indicate what organisations need to be involved in the waste management works. In a tsunami situation, such as in Samoa, wastes were both in the marine and terrestrial environment invoking different organisational responsibilities. This in turn increases the number of governmental and non-governmental organisations to coordinate. Management of marsh debris following Hurricane Katrina required consultation with eight different stakeholders (LDEQ, 2006a).

The geographic extent of waste will trigger involvement of different organisations, in particular where waste extends into different environments (terrestrial, marine, wetland etc.).

It is important to note that if a regional or national approach is adopted, consideration must be given to the potential differences in legislative and regulatory frameworks (refer Section 11.3.1).

Summary

As discussed above, the most suitable organisation to lead strategic management of disaster waste may differ depending on the disaster & disaster waste impacts. This is summarised in Table 6.2.

The structure (and effectiveness) of various strategic management approaches can be dependent on the funding mechanism. This is discussed in Section 7.3.3.

Whatever organisation is given responsibility for strategic management of waste (as discussed above) it is beneficial for the organisation to have decision-making power, as discussed in Section 11.3.1.

Table 6.2 Indicators for selecting an appropriate disaster waste strategic management lead organisation.

	Disaster & disaster waste indicators									
	Disaster scale	Number of displaced persons	Geographic extent	Duration of hazard	Disruption to road network	Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Difficulty of handling waste
Level of Governance										
National	H	-	H	-	-	-	-	-	-	-
Regional	M	-	M	-	-	-	-	-	-	-
Local	L	-	L	-	-	-	-	-	-	-
Authority type										
Emergency / recovery	-	H-M	-	-	H	-	H-M	-	-	-
Waste / Environmental	-	L	-	-	M-L	-	L	-	-	-
L=low, M=medium, H=high, - = no impact										

6.3.3 General principles

Roles and responsibilities

Strategic managers must provide clear guidance to enable quality operations that meet the recovery objectives. In Christchurch there was limited formal direction given to contractors on how waste should be managed to meet recovery goals. For example, individual contractors were left to their own devices to determine how much recycling should be practiced and whether it should be carried out onsite or offsite. The only limitation was a time constraint using powers under the CER Act. It is interesting to note that this also occurred in Hurricane Katrina. LDEQ called on contractor knowledge and judgement to determine waste management options for the debris (LDEQ, 2005a; 2006a). In taking this 'hands off' approach, LDEQ essentially allowed the contractors to determine the overall recovery goals. Given a contractor's primary objective is generally to generate profit; this can lead to risky behaviour. Indeed, a high number of regulatory violations relating to debris management were recorded in Louisiana and Christchurch, indicating contractors were not behaving responsibly.

Strategic managers must provide operational guidelines to ensure waste is handled appropriately.

One of the primary responsibilities for a strategic management organisation is to prioritise works appropriately. In Samoa, the strategic management efforts were weak. As a result the waste management works were not prioritised particularly effectively. Rather than a risk based approach, the works were seemingly prioritised on an as identified basis and/or based on proximity to people. Some priority was given to tourist areas; however, largely the works were not prioritised in any particular way to contribute to the recovery. CERA in Christchurch has been integral to the timely opening of the Red Zone, as demolition works (and resources) have been prioritised to enable a systematic reduction in the cordon extent.

Strategic management structures must prioritise resources to meet recovery objectives.

Another important role for strategic managers is to anticipate and mitigate potential problems. Anticipating potential problems, through allowing more time to consider effective solutions, will reduce the likely delays and associated negative effects. For example, in Louisiana, if the shortage of disposal space had been identified sooner, more consultation and environmental impact assessments could have been carried out prior to the opening of Chef Menteur and Gentilly landfills. This may have avoided the controversy and legal action and site clearance that followed.

Strategic managers must anticipate and mitigate potential problems.

Strategic managers are responsible for ensuring quality control of disaster waste management works. In particular, they are responsible for managing environmental and human health risks. Generally, in peace-time, strategic responsibility for monitoring risks associated with waste management is well defined. Post-disaster these roles and responsibilities may change, particularly if a new organisation for strategic management is established. Any new structure must clearly identify the responsibility for environmental and human health risk management. Following the Christchurch earthquake, there was confusion around the responsibility for public health protection, in particular with regard to asbestos and dust emissions from demolitions. Under New Zealand law, work place health and safety is governed by Department of Labour. It is their responsibility to monitor and mitigate worker exposure. However, if emissions are released from the worksite, it is unclear who is responsible for monitoring effects and protecting the public (if necessary). Public complaints regarding dust and asbestos were fielded by at least four different authorities. Many of those authorities indicated that they believed it was the recovery authority's (CERA's) role to address these concerns as they were disaster-related issues. Yet CERA did not necessarily have the skills or expertise to do so.

Strategic management structures must assign responsibility for, and oversee, post-disaster environmental and human health risk management.

In order to monitor risks, as well as to assess the overall disaster waste management systems efficiency and effectiveness, data gathering is important. Strategic managers, in coordination with peace-time waste managers, need to ensure appropriate data gathering mechanisms are in place to enable planning. For example, in Christchurch there is no regulatory or legislative mechanism to gather data from demolition sites where buildings are three storeys or less. This means that monitoring operations for quality and anticipating waste management demands is difficult. Some have attributed the increase in illegal dumping post-earthquake to this lack of monitoring, authority and visibility. Strategic managers must ensure that appropriate mechanisms (organisational or regulatory / legislative) are in place to facilitate monitoring and to enable planning. Data such as location of demolitions, waste generated, amount of waste diverted, disposal sites being used etc. would allow for waste managers to build a picture of how much waste is expected and whether facilities have enough capacity to deal with it. Olshansky et al. identify information as a crucial resource in recovery in general (Olshansky et al., 2006).

The operational management approach adopted can significantly affect the ability of strategic managers to access information. This is discussed in Section 8.3. Risk management approaches adopted can also affect the ability to gather data / monitor works. This is discussed in Section 10.3.1. Legislative issues around monitoring are discussed in Section 11.3.1.

Strategic managers must ensure appropriate monitoring systems are in place to enable effective strategic management and planning.

Cross-organisational coordination

Good cross-organisational coordination is an important function of strategic disaster waste management. As noted by Kobayashi (1995), based on experiences managing waste generated from the Kobe earthquake, our waste management systems are becoming more complex and specific which reduces our capacity to respond to disaster waste events. With increasing technical complexity comes increased organisational complexity. Asbestos management in New Zealand, for example, is governed by more than five organisations. In addition to the high number of organisations typically involved in waste management in peace-time, emergency / recovery authorities must also be included. A strategic management organisation must enable clear and efficient organisational relationships across these wide ranging authorities.

Cross-organisational coordination is critical even within emergency / recovery organisations. Emergency and recovery systems are often compartmentalised to enable fast responses and to simplify organisational structures. In the US, for example, the emergency response structure is based around 14 Emergency Support Functions: three of which relate to debris management. This approach enables activities to be broken into manageable sizes, and helps to ensure suitably qualified people are working on areas within their expertise. Good cross-organisational coordination is essential in this environment to ensure that there are no needs gaps or double ups.

Poor cross-organisational coordination had been identified as a weakness of the UN Cluster system (ActionAid International, 2007) prior to the Samoan tsunami. Despite waste management being identified as a need or priority by two clusters following the Samoan tsunami (Health and WASH) (OCHA, 2009b) neither cluster actively directed waste management activities. As discussed in Section 6.2.2, the Cluster system also did not merge well with the existing Samoan National Disaster Management System.

In addition, decisions in other recovery functions will directly affect the amount of debris that has to be managed. The decision to demolish or repair, for example, could significantly reduce or increase the volume of waste produced. Some authors have suggested that incentives should be provided for repair as it aids in the speed and effectiveness of community recovery (Olshansky et al., 2006). From a debris point of view this would also significantly reduce the volumes of waste. Coordination across recovery functions is important.

Good cross-organisational coordination is essential for making risk management decisions, particularly where peace-time standards have to be compromised to meet the recovery objectives. For example the decision to open a new landfill cell in Victoria meant that environmental standards were compromised to mitigate health and safety concerns relating to truck travel (refer Section 10.3.1).

Strategic waste management structures need to include protocol for cross-organisational coordination and collaboration across both waste and recovery functions.

Typical organisations that need to be involved in a strategic waste management organisational structure include:

- Waste management authorities and industry (including demolition)
- Emergency management / recovery authorities
- Environmental authorities
- Health and safety authorities
- Public health authorities
- Hazardous substance authorities and industry
- Lifelines authorities (particularly with respect to demolition works)

- Marine authorities (for events with debris in marine environmental)
- Transportation authorities and industry
- Non-domestic agencies (e.g. international governmental and non-governmental groups)
- Community groups (including ethnic minorities and indigenous people)

In some cases, where peace-time functions and organisations are integrated into the post-disaster strategic management structure, existing cross-organisational coordination structures may need to be streamlined. For example, in New Zealand, the Department of Labour usually sits above operational activities and acts merely as an enforcement agent and standards authority. However, during the CERA managed demolition works, a Department of Labour representative was based at the CERA demolition headquarters and worked proactively to mitigate against potential health and safety issues. Similarly, a representative from the Auditor General's Office worked with the CERA Demolition team to help to ensure that all processes were robust during process design – rather than acting as an after-the-fact process check.

Organisational relationships may need to be streamlined to meet the needs of the recovery.

Transition from response to recovery

In three of the case studies investigated there was noticeable disruption caused by the transition from response to recovery organisational structures. Disaster waste management is a unique aspect of disaster recovery in that it commences during the response but endures long into the recovery phase.

In Samoa there was very little consistency between UN Cluster system and the Samoan National Disaster Management structure, as mentioned in Section 6.3.2. The author is unaware of any formalised transition between the two structures. In L'Aquila the transition between the Department of Civil Protection and the municipality resulted in a slowing of the demolition process (Section 6.3.2). Following the Christchurch Earthquakes there were issues relating to the validity of contracts let during the emergency phase which carried on to the response phase (see Section 8.3.5).

When designing a strategic management structure, care needs to be taken to ensure a smooth transition between response and recovery. However, distinction also needs to be made between the different goals or objectives of the response and recovery plans. During the response phase, little strategic management tends to be carried out. The focus is largely operational. There is an urgency to save lives and property. The recovery phase requires more considered balancing of objectives (as discussed in Section 5.3). Carrying the Emergency Support Function structure and operational mandate in Louisiana following Hurricane Katrina for approximately 18 months, was, in the author's opinion, too long to have emergency structures (and mandates) in place. Legal frameworks governing response and recovery consequently need to be written with these factors in mind (see Section 11.3.1).

Strategic management structures for waste need to bridge between emergency and recovery structures as far as possible while recognising that each structure needs a different approach.

Human resources

When planning it is important to recognise that a number of personnel will be brought into strategic management and operational roles from outside the affected area. Following the Christchurch earthquakes, many of the persons involved in the recovery were working in an unfamiliar environment. Many local, regional and national government staff were unfamiliar with the Civil Defence arrangements, so there was much confusion over roles, responsibilities and protocols etc. The author herself had no experience working in the Civil Defence framework. In addition, the author, having not worked as a professional in Christchurch, found it challenging to learn and adjust to the systems of the respective authorities. When the recovery agency, CERA, was established, all entities had to learn to operate in a new institutional arrangement. Strategies need to be employed to mitigate the effects of new people entering the emergency systems and changes in peace-time organisational systems. Preparing plans in terms of positions, not individuals is one useful approach (Auf der Heide, 1989).

Training and refresher courses are one mechanism for achieving this preparedness. However, there is a limit to how many people can reasonably be expected to be trained for these events.

Organisational structures and protocols in plans need to account for a range of potentially untrained persons needing to be involved.

Public Communication

An important aspect of the whole waste management system is communication. Communication is included in: gathering information to assist in decision-making; facilitating decision-making (inter-agency communication); sharing information with the public (to gain buy-in); educating on environmental and public health risks; and facilitating community participation, if desired (e.g. personal property detritus removal in the US). Communication is also an effective risk management tool. If carried out effectively it can mitigate against risks such as community dissatisfaction and human health and environmental effects.

Communication, it seems however, was not carried out particularly well in any of the case studies. In Victoria, the community survey revealed that there was generally a lack of understanding of the waste management system. This included: health and safety procedures, waste disposal options for individual clean-up efforts, funding, recycling efforts, procedure for awarding the managing contract, and local labour use. Interestingly, there appeared to be a low level of public concern over waste management operations once the waste had been removed from private properties. In Samoa many communities were unaware of and/or did not understand the waste management process. Many individuals managed their own waste haphazardly, for example open burning and burial. One community elected to manage its own waste because they believed the government appointed contractors were making a profit on the sale of recycled goods. In L'Aquila, the local environmental authority made concerted efforts to communicate waste management issues and procedures (Bonanni and Stagnini, accessed 2010), including press conferences and meetings with citizens' committees and all municipalities to outline waste management practices. However, the Department of Civil Protection and the municipality did not appear to make significant communication efforts.

Communication is identified as an important part of the debris management process in the US (O'Connell, 2005; USEPA, 2008) and in previous disaster responses in the US as the most critical part (Solid Waste Authority, 2004). However, significant difficulties were faced in Louisiana following Hurricane Katrina dealing with the significant number of people who were displaced. The large community frustration experienced during the clean-up and subsequent illegal dumping can be partly attributed, in the author's opinion, to the lack of communication.

Strategic waste management arrangements officially assign responsibility for disaster waste management activities: both within waste management / recovery agencies and for the community. It is the responsibility of strategic managers to become a focal point for all communications. They must ensure clear and consistent messages that build public confidence. If strategic management is ineffective or absent, it is likely that multiple agencies will be disseminating conflicting information which may distress the public. In Christchurch the author was aware of four different authorities issuing advice on human health risks associated with asbestos.

Strategic waste managers must become a focal point for all communications.

Within the strategic management team, responsibility for public communications must be assigned. In Christchurch, there were communications or public information teams involved in both Civil Defence and CERA. The communications teams primarily operated in isolation, outside the operational groups. Generally media or public enquiries were received and the public information representatives would seek answers from operations. There were several occasions where information was misinterpreted and the full and necessary information was not gathered because of this segregated arrangement.

From an organisational perspective, ideally a communications person should be embedded in the waste management (and other recovery functions) team, and linked to the overall recovery authority. This would enable the public information representatives to fully understand the issues involved in demolition and waste management and to be able to proactively identify the emerging issues before they become a problem. This would also enable more 'good news stories' to be told which will have positive effects on both the community and the staff of the organisation.

Communications personnel should be embedded within the disaster waste management team.

Being proactive, in itself, is an important communication principle. Due to pressure from the media and the limited number of communications personnel, the response in Christchurch was initially reactive. Some public messages that may have been useful were not disseminated until media requests came through. Some public messages around waste also appeared to be missed because they were not considered to be the responsibility of CERA. The lack of clarity around roles and responsibilities not only created gaps in planning, as discussed above, but also gaps in public communication. Management of asbestos, for example: at least four different authorities have monitoring responsibility for asbestos depending on the location of the asbestos, management stage (e.g. manufacturing, demolition etc.) and/or persons exposed. No organisation appeared to take responsibility for pro-active messaging around the relative risks and mitigation strategies in place in the post-disaster environment. It is possible that this is attributed to the perceived risks involved with asbestos. This reactive approach changed as the media requests reduced and forward communications planning was possible.

A pro-active public information campaign would have had a number of benefits, including allaying community fears, developing a community wide understanding of the demolition process and likely risks, providing information for people to protect themselves if necessary, providing a united front of all organisations and enabling community feedback by identifying a single point of contact for future queries, concerns or complaints.

Strategic waste managers should develop a proactive public communications strategy.

Community Consultation

In most of the case studies examined, including those discussed in the literature review, it appeared that few disaster waste management systems were actively designed in a collaborative process with the community. Some elements of the disaster waste management system may have included limited community consultation (for example: selected consultation carried out in Christchurch prior to approving certain waste handling facilities; community consultation during the Community Centred Sustainable Development Programme development in Samoa); however, the majority of waste management decisions were made by authorities alone. The author cites several possible reasons for this:

- Disaster waste management decisions tend to be made during the response and early recovery phases when governance structures are typically command and control (and therefore consultation is not expected and can be seen as a hindrance to the recovery process).
- Post-disaster waste management does not appear to be perceived by the public as a high priority or a high concern (Victorian Bushfire public survey).
- Waste management systems post-demolition/waste collection, have a direct effect on a limited number of people (predominantly those living on transport routes and adjacent to waste handling facilities).
- Authorities may consider that, as a reasonably complex technical service, the public may not understand some of the technical constraints.
- The waste management system is a temporary measure and public acceptance is not necessarily essential.

It is the responsibility of strategic managers to determine the desired level of consultation to match the recovery objectives. Authorities need to recognise what decisions are immediately urgent (that is, the activities where the effects of non-action outweigh the effects of public objections) and those decisions which can be delayed to allow for consultation. Authorities also need to consider how willing and able community members are to participate. Olshansky et al. (2006) note that citizen participation in recovery planning in general (predominantly regarding land-use and rebuilding decisions) is crucial.

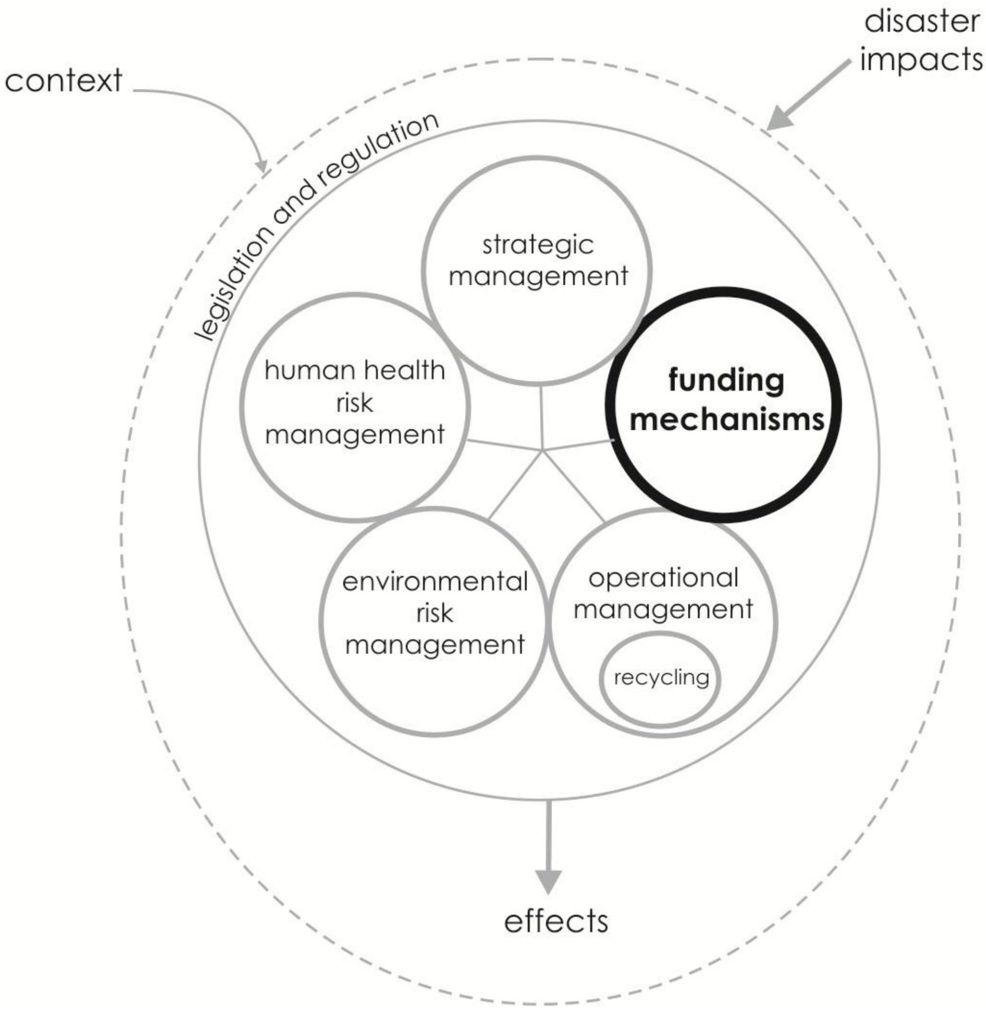
Regulatory requirements for consultation may need to be changed to reflect the post-disaster situation (such as absent population) (see Section 11.3.1).

6.4 Summary

In all the cases investigated, generally strategic management of the waste could have been better designed and implemented. In none of the cases does the author believe that any one or group of agencies had a full understanding and control of the waste management system. The primary lessons learned from the case studies are that: roles and responsibilities across organisations need to be clearly established; structures must be able to be adapted (and authorities must be prepared to do so) depending on disaster impacts; and strong collaboration is required.

Strategic management should include: identifying bottlenecks; predicting and advocating when legislative changes may be necessary; directing a waste management strategy in line with recovery objectives; carrying out good cross-organisational collaboration with appropriate legislative and operational bodies.

Determining the lead authority for strategic management (including both organisation type and governance level) of disaster waste will be context specific. However, the author suggests that decision-makers should be prepared to develop a tiered and modular strategic management structure that can be adapted depending on the disaster impacts. Generally, if the disaster scale is high, there are a high number of displaced persons, there is a large spread of waste, there is significant disruption to the road network, or there is a human health hazard, higher level governance and more recovery focussed management structures are desirable.



7. Funding mechanisms

7.1 Introduction

Disaster recovery activities are significantly affected by funding mechanisms. The timeliness and quality of recovery activities are not only affected by the extent of the funding but also the mechanisms with which funding is delivered. As demolition and debris management activities are on the critical path to recovery, it is essential that they are effectively funded to minimise disruption to the recovery and rebuilding process.

In this chapter the suitability, constraints and implications of different funding mechanisms for disaster waste management activities are assessed. It should be noted that this chapter does not address how disaster funds are accumulated, managed or how much funding should be allocated. Instead it looks at how different kinds of funding mechanisms affect the quality of debris and demolition management programmes. A brief discussion on valuing the costs of post-disaster demolition and waste management is also included.

For the purposes of this thesis, 'funding mechanisms' is divided into two parts: funding source and funding delivery:

Funding source

In a given community, there is generally an expectation that financial preparedness is either a private responsibility (individuals, households or businesses) or it is a publicly provided service (that is, it is managed by a public entity and theoretically all affected persons have access to the funds). Thus, funding sources will be divided in this analysis into Public or Private sources.

Funding delivery

The method by which financial assistance is distributed to the affected population varies based on the context and the funding source. The primary mechanisms for delivering disaster recovery funding discussed in this thesis are:

1. Direct facilitation (delegated organisation(s) carry out the works collectively).
2. Reimbursement (individuals facilitate the work and present receipts for reimbursement).
3. Lump sum (value of recovery works is estimated and paid as a lump sum to the affected person – who is, in turn, responsible for facilitating the necessary works).

This chapter used information previously presented in the following conference paper (see Appendix L):

> Brown, C., Milke, M., & Seville, E. (2011), "Disaster Funding Mechanisms: a demolition and debris management perspective". *Ninth Pacific Conference on Earthquake Engineering.* 14-16 April 2011, Auckland, New Zealand.

7.2 Case studies

7.2.1 2009 Victorian Bushfires

In an effort to speed-up the recovery and eliminate potential health threats from burnt house remains (The Premier of Victoria, 2009), and in turn benefit the economic recovery of the community, the National and State governments elected to pay for and directly facilitate the demolition and debris removal of all affected properties. Ordinarily debris and demolition works are the responsibility of homeowners and their insurance companies.

Overall the clean-up was a success. All (approximately) 2000 properties received the same demolition and debris removal services and the process was completed within six months; leading the way for the reconstruction. Delays experienced in other disasters due to insurance settlements were avoided.

7.2.2 2009 Samoan Tsunami

The funding system for the Samoan tsunami was very different to the other four case studies. Both the Samoan government and Samoan population had and have limited capacity to financially prepare for disaster events. As a result, the tsunami response heavily relied on humanitarian donations. The majority of the funds were either donated to the Samoan government, for general use, or were donated directly to a humanitarian organisation, primarily for use on specific projects. The government disseminated the funds, in lump sums, to Ministries and individual agencies / organisations based on rapid needs assessments and individual project funding requests.

Communities had very little input into what funds were delivered to them and what the funds would be used for. It was not until six months after the tsunami when UNDP initiated its Community-Centred Sustainable Development Plan programme that communities were involved in identifying and prioritising recovery activities.

Overall, the funding was piecemeal. This led to incomplete clean-up and a varied quality of disaster waste management programmes.

7.2.3 2009 L'Aquila Earthquake

In Italy, the government provides funding for national disaster response and recovery activities. Debris management works are covered under this scheme. The government establishes different payment schemes depending on the damage level. In response to the L'Aquila earthquake, repairs (including debris management) were reimbursed up to a maximum value based on property size and damage level. For properties requiring full demolition, demolition and debris disposal was directly facilitated and a reconstruction entitlement was paid.

Overall, the government funding scheme was a good foundation to build the centralised demolition and debris management plan on (see Chapter 8). All costs of the system from demolition to recycling to disposal were covered by the government. Everyone, in theory got full and equal access to funds to enable appropriate waste management, and recovery managers could prioritise works as necessary. This has a positive community wide impact as there is no dependence on individuals to action their own clean-up works. The extent and source of funding appeared to be clear from early in the recovery process.

7.2.4 2005 Hurricane Katrina

The US has well established debris management funding mechanisms. FEMA administers federal funding for collection of debris from public property, including collection of debris removed from private property and placed on the street for collection. This work is generally directly facilitated by the local authority or the US Army Corps of Engineers (on behalf of the local authority). Private property demolition is generally the responsibility of property owners and, where applicable, their insurers. However, due to the large scale of Hurricane Katrina, the high public health risk from toxic flood sediments, the large number of displaced persons and low level of insurance, FEMA funded debris removal and demolition on private properties where there was a public health risk.

Overall, increased federal funding provided a platform for a comprehensive debris management system to be built on (see Chapter 8). The funding ensured equal and full access to clean-up resources to ensure a community-wide public health threat was eliminated, and therefore enabled recovery. Had the recovery relied on individuals and insurance companies there would have been significant organisational difficulties and delays and the environmental and human health risks may have been harder to control.

7.2.5 2011 Christchurch Earthquake

There were primarily two funding mechanisms relating to demolition and debris removal: central emergency funding for emergency works and an individual property level insurance system for recovery.

Emergency funding, from the government (via civil defence) paid for activities primarily to support life and prevent further loss in accordance with the CDEM Act. In this case those activities included emergency building demolition. It was unclear whether demolition and debris management costs had been forecast for in this fund. The CDEM Act does not include for cost recovery for works, such as dangerous building demolition, carried out on behalf of building owners. Emergency funds were also used to facilitate collection of liquefaction silt placed, by residents, on the kerbside for collection.

For the recovery works, the majority of demolition and debris management works on private properties were covered by insurance. In New Zealand, natural disaster damage on residential properties is covered by a dual private / public insurance funding system. All private property owners with insurance are also covered by the National Insurer, the Earthquake Commission (EQC), for damage up to $100,000 and any land damages. The EQC is a government entity; however, it manages residential insurance like a private insurer. Private insurers cover individuals for damage above $100,000. Commercial property owners generally hold private insurance.

Insurance coverage theoretically ensured that building owners would eventually recover most of their losses (both direct capital and indirect business loss). However, many residents felt frustrated by the slow actions of some insurers and the 'unexpected' exclusions of policies (for example asbestos removal).

Operational organisations were established by both EQC and private insurers to collectively manage the claims and the physical works. This enabled a shift in funding delivery mechanism from lump sum payments to direct facilitation.

The dual EQC / private insurance system created some organisational and logistical complexities for residential properties with land damage. In many cases the damage was above $100,000 and the property would need to be handed between EQC and the private insurer as the recovery works moved from demolition (private), to land remediation (EQC) to rebuilding (private). The decision to retreat from large affected areas (rather than remediate) has considerably reduced this organisational problem. It is understood that there have been significant delays in the residential demolition programme resulting from a slow property settlement and cost share agreements process between the EQC and insurers.

Overall, there were significant organisational and logistical deficiencies with the private funding mechanisms. While some organisational changes post-earthquake mitigated the complexities of the dual and private funding system, a more considered analysis of operational implications or a completely transformed funding system is needed.

7.2.6 Case study summary

Table 7.1, below, summarises the funding mechanism (source and delivery) for the five case studies used in this thesis. The table uses the waste source categorisations presented in Section 4.3.2. Note that public property detritus management and infrastructure repair has been left out due to insufficient data and because it is assumed they are largely the responsibility of public authorities both operationally and financially.

Table 7.1 **Case study disaster debris management funding mechanisms summary**

	2009 Victorian Bushfires	2009 Samoan tsunami	2009 L'Aquila earthquake	2005 Hurricane Katrina	2011 Christchurch earthquake
Funding source					
1. Private property detritus* 2. Full demolition debris 3. Major repair waste 4. Reconstruction waste	1. n/a 2. public 3. private 4. private	1. public 2. public 3. public 4. public	1. private / public 2. public 3. public 4. public	1. private / public 2. private / public 3. private 4. private	1. private / public (silt) 2. private 3. private 4. private
Funding delivery (DF = directly facilitated, Re = reimbursement, LS = lump sum, n/a = not applicable)					
1. Private property detritus 2. Full demolition debris 3. Major repair waste 4. Reconstruction waste	1. n/a 2. DF 3. LS 4. LS	1. DF 2. DF 3. unknown 4. LS	1. Re 2. DF 3. unknown 4. unknown	1. Re / DF 2. unknown / DF 3. ** 4. **	1. ** / DF 2. ** 3. ** 4. **

* Note where a private / public split is denoted this generally means that individuals cleared their own property but that a public service was provided for collection and/or disposal.

** Payment mechanisms varied depending on the insurance policy and could be either DF, Re or LS.

7.3 Discussion

7.3.1 Funding source

In very simple terms – whoever holds the purse, holds the power. The ability of an authority to strategically manage the demolition and debris management activities (as discussed in the previous chapter) is considerably improved if they are also in control of, or have considerable influence over, how the funds (and subsequently resources) are distributed, prioritised and managed. For example, in L'Aquila, the government funded works were prioritised by the local authority such that smaller repairs were carried out first to enable large numbers of the community to return to their home and to 'normal', while larger repairs and demolitions were a lower priority. This, in turn, had an impact on the type and volume of waste being generated over time. In Samoa, the number of individual entities bringing funds into the area and independently implementing projects, created a piecemeal approach to waste management. There were some double-ups and many omissions in recovery works as a result. This piecemeal approach was also noted in Thailand after the 2004 Indian Ocean Tsunami (Petersen, 2006). Information flows between insurance companies and recovery planners in Christchurch, were not always smooth as insurance companies were bounded by privacy issues and commercial sensitivities. Without good information, planning (e.g. estimating the number of uninsured persons, estimating the total volume of waste to be generated and subsequently what waste management facilities are required) is difficult (as discussed in Section 6.3.3). Thus, public funding models offer advantages over a private funding model as there is much greater control over the nature of the works, prioritisation and information management and monitoring. In the absence of a centralised funding source, strong organisational structures and legislative authority (Section 11.3.2) would be required to manage the different funding sources.

Public funding mechanisms generally enable more effective strategic management.

As discussed in Chapter 5, different disasters and contexts have different recovery objectives. Generally the objectives focus on a quality, timely, and community-wide recovery. Funding mechanisms, both in terms of source and delivery, inevitably contribute to how effectively these objectives can be met.

In terms of time, in the case studies investigated here, publicly funded disaster waste activities were generally carried out in a timelier manner than privately funded activities. Private insurance claims, for example, take time to settle: it took approximately 11 months to complete EQC assessments for the February 2011 Christchurch earthquake event and longer for private insurers. Claim settlements are still continuing at the time of writing. Delays due to slow insurance settlements were also observed following Hurricane Katrina (The World Bank and The United Nations, 2010).

Second, publicly managed funds generally allow for disaster waste works to be implemented with a community focus. This is a particularly important consideration for funding waste management activities as waste can pose environmental and human health hazards as well as affect the ability of a community to return to normalcy (from an economic and social perspective). Private mechanisms, such as self-funding or insurance, tend to have an individual focus. As a result, funding decisions, and subsequent actions, are made without consideration to the wider community. In Christchurch, there were several instances where property owners were significantly affected by inaction of neighbouring property owners. For example, one building posed a fall hazard to a neighbouring building and rendered it uninhabitable. Fortunately, provisions under the CER Act allowed for CERA to intervene and facilitate the works necessary to mitigate some of the wider impacts of individual's actions or non-action. There were also cases where building owners chose to demolish buildings very slowly (generally to reduce costs through increased recycling (see Chapter 9)) and in doing so, increased the business losses for neighbouring buildings. For example, following the 2010 Canterbury earthquake, demolition of one building initially estimated to take six weeks took more than 11 weeks. One neighbouring business owner estimated that their turnover was reduced by 50% during the works (Sachdeva, 2010).

Public funding, in general, more readily allows for a macro (community wide) rather than micro (individual property) level approach to demolition and waste management.

If a private funding mechanism is preferred, measures need to be in place to ensure adequate coverage for a community wide recovery perspective (including residential, commercial, public properties and infrastructure). In the US an attempt was made to make the National Flood Insurance Programme compulsory for all homes in the 100 years flood plain as a condition of their mortgage. However, due to poor enforcement and an absence of flood events, approximately two-thirds of homeowners in Florida had cancelled their policy within five years of it becoming compulsory (The World Bank and The United Nations, 2010). As a result of the low level of insurance discovered after the Bushfires, some experts are calling for a national disaster insurance to be established in Australia (Sexton, 2010).

If private funding approaches are preferred, mechanisms must be in place to ensure there is adequate cover across the community, including for residential, commercial and infrastructure.

While it is generally believed that public funding is more advantageous for the recovery as a whole, there are several circumstances (categorised by the disaster & disaster waste impacts presented in Chapter 4) which indicate that it is critical that a public approach is taken.

First, the number of displaced persons may indicate a public approach will be necessary. In the US, FEMA expects property owners to clear detritus from their own property (to kerbside for collection) at their own or their insurer's expense. The large displacement of people after Hurricane Katrina (Brookings Institute, 2009) meant that many properties were not cleaned and the kerbside collection was highly ineffective and inefficient (Cook, 2009). Due to this and the hazardous nature of the debris (see below) FEMA elected to fund private property detritus removal and demolition. The FEMA funded clean-up facilitated the return of thousands of families (Louisiana Homeland Security and Emergency Preparedness, 2007) that otherwise might not have had the means to pay for or facilitate the debris removal. Public funding was necessary to expedite the clean-up and to subsequently encourage people to return to the area.

Where there is a high <u>number of displaced persons</u> and there is a desire to repopulate the affected area, <u>public funding</u> may be needed to ensure work on private property is completed where owners are absent.

Second, the degree of human health hazard needs to be considered. In Louisiana, it was determined that in some places the floodwater sediments posed a public health and safety threat. Subsequently (and due to the higher displacement of persons (above)) FEMA elected to pay for private property clearance. The FEMA policy stated that debris removal on private property would only be performed to "address an immediate threat to life, public health, safety or property" (FEMA, 2005).

High human health hazards affect not only the private property owner but all neighbouring properties. Presence of unmanaged hazards can have a severe impact on public health, as well as the psychosocial and community recovery of the area. A publicly funded system in this case can help to remove the hazard more efficiently and mitigate against negative effects.

Where there are significant <u>human health hazards</u> in the waste matrix, a <u>publicly funded</u> approach is preferable.

Similarly, and third, if the waste poses a high environmental hazard, it may be desirable to maintain control of the waste stream so that adverse environmental effects, caused by inappropriate waste handling, are minimised.

Where there are significant <u>environmental health hazards</u>, a <u>publicly funded</u> approach may be desirable.

Fourth, suitability of funding mechanisms is affected by trans-boundary movement of waste. When waste has moved away from its origin, 'waste ownership' (or responsibility for the waste) becomes difficult to assign (see Section 11.3.3). A significant quantity of debris from the 2011 Japanese tsunami is, at the time of writing, floating across the Pacific Ocean (NOAA, 2011). Waste that has moved across property boundaries will inevitably, regardless of original 'ownership', need to be managed by a public funding body, rather than private.

Communities susceptible to hazards that can cause trans-boundary <u>movement of wastes</u> should consider <u>public funding</u> mechanisms for debris management.

Last, where there is a high disruption to the road network, public funding is likely to be essential. Authorities are likely to be trying to minimise traffic movements on a heavily affected road network, therefore, it will likely be necessary to provide a consolidated waste management service, which will inevitably have to be publicly funded.

Public funding for waste collection will be necessary where there is a high disruption to road networks.

A summary of the relationship between the disaster & disaster waste impacts and the preferable funding source is shown in Table 7.2.

Table 7.2 Indicators for preferable funding source

	Disaster & disaster waste indicators									
	Disaster scale	Number of displaced persons	Geographic extent	Duration of hazard	Disruption to road network	Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Difficulty of handling waste
Public funding	-	H-M	-	-	H-M	-	H-M	H	H-M	-
Private funding	-	L	-	-	L	-	L	M-L	L	-
L=low, M=medium, H=high, - = no influence										

7.3.2 Funding delivery

In terms of funding delivery, direct facilitation of the works can be an effective way of contributing to the recovery objectives. Direct facilitation has the same benefits and drawbacks as a centralised operational management strategy, as discussed in Section 8.3.3. Benefits include the ability to: reduce initial assessment times; prioritise works; achieve economies of scale; mitigate disruptive effects of property owners who are slow to act. Lump sum and reimbursement delivery mechanisms leave the responsibility of timely and effective action with individuals; individuals with a likely focus on their own recovery rather than the wider community.

Funding mechanisms that directly facilitate the waste management works are more effective at achieving recovery objectives than lump sum or reimbursement delivery mechanisms.

Where there is a significant human health hazard or environmental health hazard, direct facilitation will more likely ensure that the works are carried out to completion, meeting necessary quality standards and with the necessary expedience. This is elaborated on in the discussion on centralised management of operations in Section 8.3.3.

Where there is a significant human health hazard or environmental health standards, direct facilitation of the works is beneficial.

In lieu of direct facilitation, reimbursement offers an opportunity for some quality control by restricting what works are eligible for reimbursement. For example reimbursement could be limited to management of waste at approved facilities only; or payment only on confirmation of asbestos removal code compliance. Lump sum payment mechanisms offer none of these checks and balances on quality as money is paid irrespective of the action taken by the recipient. In some cases, owners may elect not to spend the money on waste removal and any hazards and visual nuisance could remain unmanaged at the property. This affects the wider recovery.

A directly facilitated programme also assumes the risk of cost overruns. Cost overruns are a possibility following a disaster where price escalation is sometimes observed (see Section 7.3.3). If costs inflate and property owners have been given a lump sum to complete the works, low quality works (to reduce costs) may be a result. Preferably, demolition and debris management funds should be delivered using a structure that reflects the actual costs faced post-disaster, rather than an estimated pre-disaster value (that is, reimbursement or direct facilitation). This will ensure adequate funds are allocated to demolition and debris management and are not diverted for private interest or gain.

Direct facilitation reflects the actual costs post-disaster and therefore offers greater quality control. Reimbursement and lump sum offer less and the least quality control, respectively.

Funding strategies where funds are delivered as a reimbursement or lump sum, lead to waste management facilities operating under a high risk and highly uncertain environment. Waste handling facilities, under these funding delivery schemes, inevitably have to operate independently from the demolition, collection and transportation aspects of the waste management process and therefore charge an upfront gate rate (or disposal fee, usually based on weight). Gate rates are difficult to accurately establish in an uncertain post-disaster environment where waste type, volume and potential hazards are difficult to predict. If the venture charges too little, it is possible that insufficient funds will be collected to appropriately manage the waste and an environmental legacy may be left. It would be preferable to include the waste handling facilities in the demolition and debris management system to increase the facilities ability to anticipate future waste demand and set their pricing structure accordingly. It would be simplest to achieve this using a directly facilitated funding mechanism. This idea is developed further in Section 8.3.3.

Direct facilitation reduces the uncertainty in operating waste handling facilities and consequently reduces the potential for environmental legacy issues.

As will be discussed in Section 8.3.5, maintaining cash-flow for contractors and affected persons during a disaster response is sometimes a challenge. The choice of funding delivery mechanism can reduce cash-flow issues, particularly for residents. For example, direct facilitation and, to a degree, cost reimbursement if implemented well, reduces (or eliminates) costs which the affected persons has to carry before receiving payment for works, as the funder can pay the service provider directly.

7.3.3 Funding mechanism principles

Form and scope

For individuals and governments to be adequately prepared for a disaster, funding mechanisms (both source and delivery) need to be flexible in their design such that they can be applied to different scales of disaster. FEMA funding mechanisms are well established in the US. The systems work well for most 'medium scale' disasters; however, the extent of Hurricane Katrina required extra-ordinary measures and increases in funding. In 2007, permanent changes were made to the FEMA funding guidelines to reflect the measures necessary following Hurricane Katrina. One important change was the inclusion of a policy and protocols for private property demolition. Following the Victorian Bushfires, the planned privately funded demolition and debris management system (insurance-based) was replaced by a publicly funded approach.

Funding mechanisms need to be scalable / adjustable to match the <u>disaster scale</u>.

It is essential that whatever funding mechanisms exist, that the funds are sufficient to meet the overall recovery objectives. In particular, it is necessary to ensure that there are no significant gaps. Following both the Victorian Bushfires and the Canterbury Earthquakes, a number of concerns were raised regarding the insufficient or non-existent allowances for demolition and debris management in insurance policies. Despite demolition being funded by the government, following the 2009 Victorian Bushfires only 43% of homes were rebuilt with insurance money due to high levels of under or no insurance (Sexton, 2010). One early estimate in Christchurch was that 50% of the commercial buildings were underinsured for demolition: insurance policies either excluded demolition or the value allocated to the demolition was less than the actual post-disaster cost. The author believes that under-insurance was a contributing factor to the reported incidences of illegal dumping following the Christchurch earthquake (Sachdeva, 2011; The Press, 2011; Williams, 2011b; Wright, 2011) as individuals attempted to make cost savings.

As discussed in the previous section, if there are insufficient funds, some property owners may take short cuts in demolition and debris management activities to allow for rebuilding activities. This could leave environmental and human health legacy issues. It is, therefore, advantageous to delineate demolition and debris management activities from other recovery aspects (in private or public policies) to ensure that funds are not diverted from these activities, resulting in low cost (and subsequently low quality) approaches.

Some believed that the perceived under insurance was actually due to post-disaster price gouging by demolition contractors. It is the authors understanding however, that demolition and waste prices, post-earthquake, while higher than peace-time, were not substantially higher. The author suggests that the original insurance generated estimates of demolition costs may have been based on national demolition and waste management costs, which in this case are significantly lower than the local costs[9].

Price escalation is an expected unknown in disaster response and recovery. The author is unaware of any data on the change of waste management prices after disasters, however, price gouging (Pelling et al., 2002; Jackson, 2008) and market fluctuations (Chang et al., 2010)

[9] There is a significant difference in the waste management costs between landfills in New Zealand's largest city Auckland, for example, (multiple landfill, high value market for recycled materials such as crushed concrete) and Christchurch (single landfill, limited recycling market capacities and values).

for services and resources is well recognised in post-disaster situations. This indicates that market fluctuations and service prices are likely to change in the deconstruction and waste management sectors as well. The author believes that there is a current market reality: when demand outstrips supply (there is a resource constraint), prices will increase. Demolition and debris management costs are particularly sensitive, not only to the cost of labour and plant but to the value of the recycling markets which can become flooded after disasters (see later discussion in Section 9.3.1). Demolition and debris management costs can also increase when buildings need to be taken down quickly, without opportunity for peace-time practices for cost savings (i.e. stripping building interiors and maximising recycling). Conversely, following some disasters, waste management costs can decrease. As examples: free inert material disposal at Lyttelton Port of Christchurch, and relaxation of landfill disposal standards and subsequent disposal cost reduction in Louisiana (Katrina). However, the author believes that in general there is a net increase in waste management costs. This post-disaster 'premium' needs to be accounted for.

Disaster funding mechanisms, public or private, must routinely include allowances for demolition and debris management, preferably as an item separate from rebuilding. Estimates for post-disaster demolition and debris management costs need to:

- *Be updated regularly*
- *Be priced to match the local market*
- *Include a post-disaster premium (due to time and/or resource constraints and recycling market changes)*

The discretionary nature of some funding mechanisms is difficult to manage. In particular, some authors have alleged that the political climate has a significant influence on funding distribution (Olshansky et al., 2006). It has been shown that flood disaster declarations in the US are more frequent in re-election years (The World Bank and The United Nations, 2010). FEMA reimbursement in the US, for example, is not guaranteed and is subject to change depending on the current political environment. The increase from 75 to 100% cost share for example post-Hurricane Katrina may not have been implemented by another government or at another time. Disaster compensation in Italy is also undefined pre-disaster. Values are set post-event and are vulnerable to the political environment. Disaster victims and local authorities relying on public funds are therefore very vulnerable to the political dimensions at the time which makes strategic planning difficult. The more established and certain the funding scope is, the easier it will be for strategic managers to plan and determine the recovery objectives.

Funding sources that determine funding amounts post-disaster need to establish these as soon after the disaster as possible.

Funding policies

Funding policies can restrict the management options for demolition and waste management. In San Diego after the 2003 Cedar and Paradise Firestorm, the majority of the debris management programme was declined reimbursement by FEMA. Bins to collect waste, for example, were put on private properties in some cases due to space restrictions on roads and driveway lengths; however, FEMA only reimburses for bins located on public property. The county also deemed that a private property clearance was necessary due to the hazards in the waste; however they did not meet FEMA's criteria for private property removal. In addition, FEMA has very rigid record keeping and monitoring requirements which local authorities must meet to ensure cost reimbursement. Authorities in San Diego were unable to sufficiently monitor the waste management programme (due to poorly regulated waste facilities) and as a result were not successful in receiving FEMA reimbursement (County of San Diego, 2005). In a situation such as this, authorities are in a position where they must choose to either 1) fit within the regulations (and design a less efficient debris management system); or 2) design the most effective system (from a cost, environment, economic and social point of view) possible and risk not being able to recover the funds from the funding provider. Assessing eligibility for funds can consume many resources which could instead be used to improve the recovery process.

It is not only publicly funded schemes that have restrictive policies: in New Zealand, insurers have a 'one shift' policy for waste. That is, they will only pay for one movement of the waste. Thus, any costs for the management of the waste need to be estimated upfront (as discussed in the previous section for lump sum funding delivery mechanisms). This can have perverse consequences by increasing the cost of waste management activities as contractors increase their costs to reflect the risk that are assuming (see Section 8.3.4). In turn it limits the ability of creative waste management systems (such as temporary staging facilities).

The contract types stipulated in some funding policies can also counteract wider recovery objectives. For example, the FEMA regulations favour lump sum contracts, which, as discussed in Section 8.3.4, is not necessarily the most effective.

Funding policies often have legislative requirements that need to be met. Where these requirements exist, authorities must be careful that legal waivers, aimed at expediting the recovery, do not exclude waste management programmes from receiving funding. The FEMA funding policy, as established under the Stafford Act (FEMA, 2007), sets out statutory requirements that debris management operations must meet to be eligible for funding. In particular, it states that federal laws must be met. There was some concern that one of the legal waivers used in Louisiana - the expansion of the waste acceptance criteria at C&D landfills - may have excluded the disposal activities from funding. It was later determined that the legal waiver met the statutory requirements (GAO, 2008). Following Hurricane Katrina, FEMA was also moved to alter its policy on requirements for legal approvals for removing debris from private properties as the process was lengthy and caused a bottleneck. In L'Aquila, disaster waste management funding was dependent on managing the waste in accordance with European and Italian waste laws, in particular the European Waste Coding (EWC) system. However, there was no code suitable for the mixed earthquake waste. It was not until a decision to specially code the waste was made that surety of funding was provided.

The often strict rules around funding mechanisms can have unintentional consequences. In systems thinking this is referred to as Rule Beating (Meadows, 2009). In the US, if debris was contaminated with garbage or it was suspected the waste was not disaster generated, then the piles would be missed, as these 'contaminated' loads were not eligible for payment by FEMA. It is understood that this was not the intent of the FEMA regulations and contractors were using this as a front to reduce the work required in their lump sum contracts. The regulations were established to try to educate people on what they can and cannot put out for collection, however, it was expected that all waste collected within a specific time frame could reasonably be expected to be disaster waste. FEMA also wanted waste removed to mitigate secondary hazards caused by piles of debris, such as blocked flow-paths, vermin and vector (mosquitos, rats, flies etc.) breading, and fire hazards etc.

Some funding policies can significantly restrict the environmental outcome of the operations or indeed can increase the environmental risks being taken. For example, the Federal Emergency Management Agency (FEMA), in the US, stipulates that lowest cost solutions must be used. Following the 1994 Northridge earthquake, the city of Los Angeles was running short of landfill space and needed to start recycling the disaster waste. Recycling was, however, a more expensive option. FEMA initially resisted the move but eventually accepted it on the understanding that recycling was in the long term waste management strategy for Los Angeles (State of California, 1997). If recycling had not been allowed, the recovery may have been stalled, or a low cost (with potentially high environmental risk) landfill may have been required. In Louisiana, following Hurricane Katrina, the lowest cost option was landfilling, however to facilitate landfilling, environmental standards were relaxed significantly.

The lowest cost approach, stipulated in many funding policies, does not always have a positive social impact. For example, following Hurricane Katrina, demolition was favoured over deconstruction as the lowest cost option. Denhart (2010), however, observed that deconstruction (allowing material salvage) provided a more positive psychological end to a house for some property owners. The lowest cost policy also removed the ability for building owners to determine the fate of their own building.

While funding policies are understandably strict, some flexibility needs to be incorporated into the policies such that the desired recovery outcomes can be achieved. The current situation where the funding mechanism and policy drives the response needs to be reversed, such that the system objectives can be met. One option would be to have *outcome targets* rather than have *process constraints*. The outcome targets could reflect cost as well as environmental, social and economic goals. The drawback to this is the reduced certainty in receiving funding when designing the disaster waste management plan. This concept needs further development and has been recommended for future research in Chapter 12.

As discussed in Section 6.3.3, data and information monitoring are necessary to facilitate strategic management. Requiring data collection in funding policies is an effective way of ensuring the necessary data are collected to enable planning.

Funding mechanism policies need some flexibility to allow for effective and efficient waste management options.

Funding policies should not only consider direct costs, but also environmental, social and economic effects (and must avoid perverse outcomes).

Funding policies should include provision for data collection.

Exclusions in funding policies (private or public) can mean that some aspects of the demolition and debris management, in some cases critical to the wider recovery, are not managed. In New Zealand, one notable omission to most insurance policies is compensation for asbestos removal. This exclusion is not surprising as the extent of asbestos in most properties is unknown and removal costs are very expensive. However, this can create organisational complexities where direct facilitation is being used to deliver the funds. Demolition sites need to be transferred between contractors engaged (by the owner) to remove the asbestos and contractors engaged by the funder. Policy exclusions like this can increase the financial burden on property owners and, as described above, this can lead to low quality approaches for cost reimbursement or lump sum delivery mechanisms. Illegal dumping of asbestos was observed in Christchurch (Wright, 2011). In the case of asbestos, poor quality management approaches can have significant human health risks.

Where possible, policy exclusions which may affect implementation, or have significant environmental and human health effects, should be avoided (e.g. asbestos).

If, for whatever reasons, exclusions are unavoidable, significant efforts need to be made to ensure individuals have the right tools, information and incentives to manage the 'exclusions' themselves. In Victoria, Australia, individual property owners were responsible for any clean-up works outside the scope of the government funded and facilitated clean-up works (which was generally limited to the building footprint). There was a general reluctance to carry out the work due to an expectation that the government should or would provide additional funding. Some even noted that they felt neglected by the government. As a result, there were reported instances of illegal dumping from residents unwilling to pay high disposal costs. Limited systems were put in place to ensure residents were aware of their responsibilities and were in a position to manage the waste in an appropriate manner.

Having appropriate risk management strategies that account for limited funding availability will also reduce the risks and potential negative effects (see Chapter 10).

If funding scope is limited, efforts need to be made to provide education, assistance and incentives for individuals to appropriately deal with that waste.

Overall funding system

Multiple funding sources can introduce funding gaps and overlaps. During Hurricane Katrina, for example, a large number of boats sank. Under the law at the time, the Coast Guard (sponsored by FEMA) was responsible for clearing all debris in the (public) shipping channel (Stafford Act). However, no one was responsible for waste outside the shipping channel. It is unlikely private property owners or their insurers would have interest in salvaging the boat. Thus no funding was provided. In contrast, the combined hurricane and flood damage on land created confusion between responsibilities of flood and hurricane insurance companies. Insurance in the US is by hazard. Private insurance generally is required for hurricane damage and the National Flood Insurance Programme covers flood damage. Flood damage caused by levee breach in Louisiana led to many insurance companies denying hurricane insurance claims. Unfortunately, as a compounding factor, most people in these hurricane zones had insurance for hurricanes; however, many people did not have flood insurance. It is not uncommon for disaster events to occur simultaneously (fires induced by earthquakes, floods induced by hurricanes). Extreme care is needed in determining respective funding scopes and how this may affect the completeness of works and the operational systems. As discussed previously, there are currently significant delays in the residential red-zone demolition process in Christchurch as EQC, private insurers and the government agree cost share arrangements prior to any demolitions taking place.

Where multiple funding sources are relied upon, efforts must be made to ensure there are no funding gaps, or overlaps.

The number of funding mechanisms contributing to recovery efforts can create organisational complexities. For example, in New Zealand there is a dual insurance scheme for residential properties. The national insurer EQC covers the first $100,000 damage (within eight metres of the footprint of the building) and any land damage; and the private insurer covers any additional cost. Generally for works under $100,000 EQC facilitates the works and over $100,000 is managed by the private insurer. However, for properties requiring land remediation, the private insurer would facilitate demolition, then EQC would take over the land repair (generally in coordination with neighbouring properties all with different private insurers) and then the private insurer contractor would remobilise on site for the reconstruction. All these works also have to be coordinated to minimise the disruption to the property owner[10]. As well as organisational complexities, multiple funding sources can reduce efficiencies in the operations (such as timeliness, completeness and recycling opportunities) and can increase costs (from coordination and site de-mobilisation and re-mobilisation).

Organisational complexities also arise out of apartment or buildings with multiple owners and insurers, as was noted in Christchurch. In some buildings there were multiple owners and tenants all with different insurers. The author is aware of one such building which involved eight insurance companies. Single funding sources would inevitably reduce the complexities of management. It should be noted that despite the public funding source in L'Aquila, decisions regarding buildings with multiple owners were inevitably slower than single ownership properties. This has been observed in disaster recovery (generally: not specifically attributed to disaster waste) in Kobe and Los Angeles (Olshansky et al., 2006).

More generally, funding mechanisms and operational strategies (Chapter 8) are inextricably linked. Either funding mechanisms must be designed with desired operational strategies in mind, or vice versa. If the systems are not designed together, logistical challenges and operational inefficiencies, such as those described above, are likely. Legislative measures can be implemented to manipulate the funding to the desired operational approach (such as in

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[10] It should be noted that the original intent of the EQC threshold ($100,000) was to cover the value of an average house. This value has not been revised since the figure was set in 1993. If the figure had been raised accordingly, the number of properties having to deal with both EQC and their private insurer would have been reduced.

Christchurch where private funding sources were managed centrally courtesy of the CER Act) (discussed further in Section 8.3.3 and 11.3.3).

Funding mechanisms and operational organisational strategies should be designed together to ensure systems can be effectively implemented and there are no funding gaps.

A single funding source for each property / building is preferable to avoid organisational complexities and improve recovery efficiencies.

Liability

Funders must also be aware of possible liability issues. The potential for liability of disaster recovery funders was noted in the US following Hurricane Katrina. USEPA found they could not clear FEMA of any liability should there be adverse environmental effects due to activities that they funded (such as the expanded waste acceptance criteria at construction and demolition landfills) (Luther, 2008). According to one report, many jurisdictions have sued FEMA for reimbursement post-disaster for compensation over the loss of landfill space due to disaster waste management operations and the restrictions placed on authorities in post-disaster situations by the FEMA regulations (County of San Diego, 2005). Liability issues in general are discussed in Section 11.3.5.

Funding providers need to consider the potential for liability due to adverse effects resulting from the disaster response.

Strategic management

As discussed in Chapter 6, strategic management structures are beneficial to the quality of the recovery efforts. However, establishment of strategic management structures for waste (or any other recovery function) incurs costs - whether the function is embedded in existing organisations or whether it is part of a new entity specific for the recovery. Potential costs for this need to be accounted for in funding mechanisms. Where private funding is being relied upon for physical recovery, additional public funding may be required to enable strategic management functions as private organisations may not believe it is their duty or responsibility to ensure that the wider recovery objectives are met. Payment allowance also needs to be considered for central management of operations (if desired) (see Section 8.3.3).

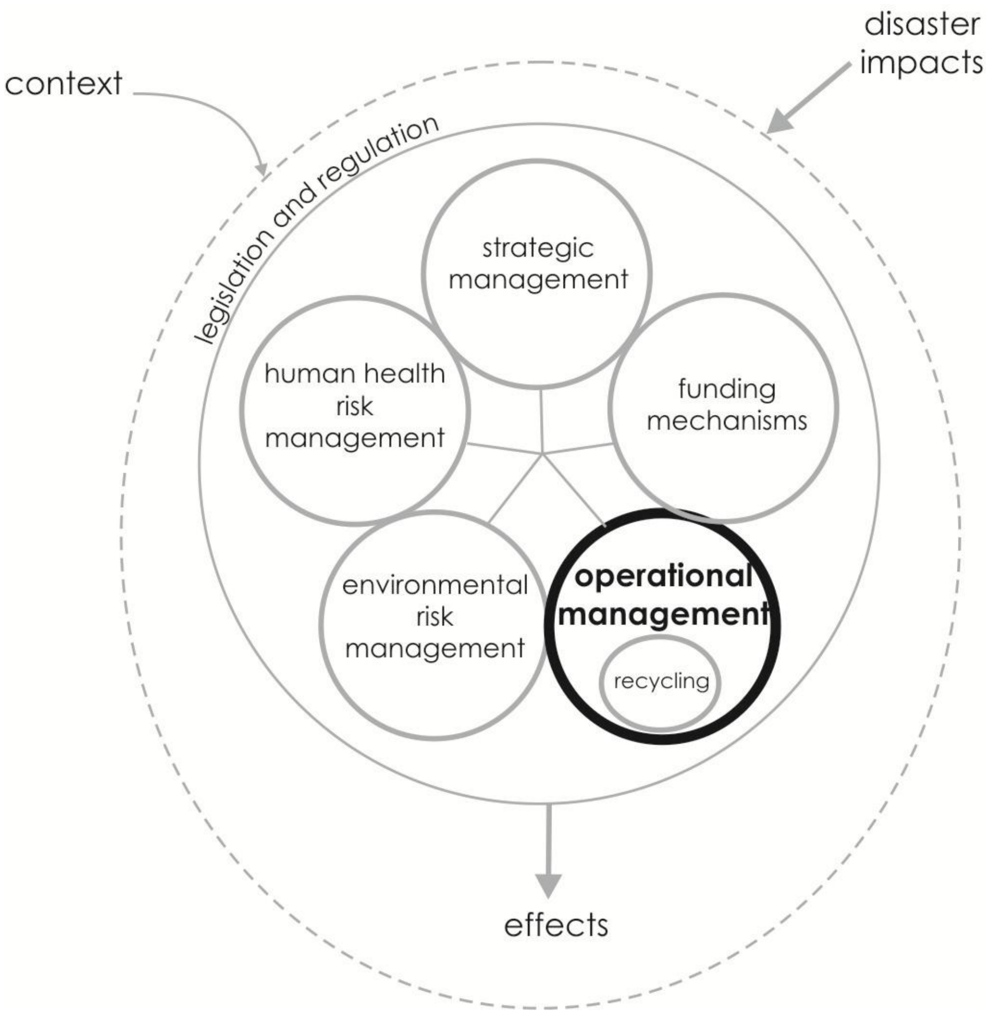
Funding mechanisms for large scale disasters needs to include a strategic waste management function.

7.4 Summary

As discussed in this chapter, there are currently a range of approaches to funding of demolition and debris management works. Funding mechanisms can be categorised into the funding source (public or private) and the delivery mechanism (lump sum, cost reimbursement or direct facilitation). Demolition and debris management funding often piggy-backs onto general response, recovery and reconstruction funding and is not always considered as a specific task with unique requirements and impacts on the wider recovery.

The presence of disaster debris can have a significant and community wide impact, therefore having appropriate funds to enable an efficient and effective recovery is imperative. Generally, where the risk (likelihood and consequence) of mismanagement of waste is high, then a low risk (quantity, quality and timeliness) funding source and delivery mechanism should be used. High risk of mismanagement of waste may occur when there is: a high number of displaced persons, disruption to the road network, high human and environmental health hazards and movement of waste across property boundaries. The lowest risk funding mechanisms, in the author's view, are those which are publicly held and are directly facilitated. Low risk funding approaches offer more control over how funds are managed and distributed and, therefore, the impact of demolition and disaster waste activities on the recovery.

Funding policies need to avoid being too restrictive so that they do not inhibit innovative debris management options which contribute to meeting the wider recovery objectives.



8. Operational management

8.1 Introduction

The success of a disaster waste management system is dependent on effective operational management. That is, the physical works need to be carried out using organisational structures and procurement strategies that facilitate the overarching recovery objectives being met. Ineffective operational management (as discussed in Section 1.9.2) can significantly affect the timeliness and quality of the recovery.

The aim of this chapter is to:

1. Summarise the operational management strategies (organisational and procurement) used in the five case studies,
2. Define typical operational strategies, and

3. Propose basic principles for operational management (organisational and procurement) for disaster waste systems.

The chapter includes discussion on both the operational organisational structures and the procurement strategies. The following definitions apply:

Operational organisational strategy

Based on the case study findings basic operational organisational structures can be divided into the following two categories:

1. Centrally managed works (large quantities of work managed collectively as a single body of work).
2. Individually managed works (works managed by individuals).

Procurement strategies

In terms of this thesis, procurement strategies are the contract conditions under which the operations are carried out. This thesis will focus on contract conditions for centrally managed works. The procurement strategies included in the analysis/discussion are:

1. Lump sum.
2. Cost reimbursement (also known as time & cost or time & material).

The chapter includes material from the following conference paper (see Appendix M):

Brown, C., Milke, M. & Seville, E., 2011. *Implementing a disaster recovery programme: a demolition and debris management perspective.* International Conference on Building Resilience, July 2011, Kandalama, Sri Lanka.

8.2 Case studies

8.2.1 2009 Victorian Bushfires

In an effort to speed-up the recovery, and eliminate potential health threats from burnt house remains, the National and State governments elected to facilitate, through a centralised contract, the demolition and debris removal of all affected properties. The contract was awarded to a large national contractor who engaged a number of subcontractors (70% local) to complete the works. All works were carried out on a cost reimbursement basis. Individual property owners were not required to participate other than to salvage personal belongings if desired. Waste was primarily disposed of at existing, privately owned landfills. A landfill cell was constructed to support the recovery efforts. The landfill cell construction and operations were integrated into the central demolition and waste management contract.

Overall the clean-up operations were a success. The centralised demolition and debris removal contract allowed for efficient removal of waste. All waste was removed within six months – leading the way for reconstruction. Effective prioritisation of works was practiced. Streamlined and consistent health and safety and environmental procedures were also implemented across all affected areas. Organisational structures were simple and economies of scale for the physical works were also possible. Some affected persons, however, felt that more labour and contractors should have been sourced from the affected community and more consultation could have been carried out. Some claimed their exclusion reinforced the victim mentality and contributed to mental health problems.

8.2.2 2009 Samoan Tsunami

The tsunami response and recovery programmes were primarily implemented through central government and non-governmental organisations (NGOs). Clean-up projects were generally ad-hoc and piece-meal. Primarily waste was collected and segregated at the affected site by the community (both paid and unpaid) and contractors were employed to collect and transport the waste to the disposal site or recycling depot, see Figure 8-1. The effectiveness of the contractors, generally paid on a cost reimbursement basis, was dependent on the degree of supervision. The JICA programme, for example, monitored works to ensure recycling and reuse was maximised and that full truckloads went to the landfill. This had environmental benefits and provided cost savings. The government programme was not so effectively supervised and limited waste segregation was practiced.

The majority of the work did not require specialised skills and was conducted effectively and efficiently by community labourers. Paying for community members to assist in the clean-up operations was a boost to the economy of the affected area. Some, however, suggested that by paying the community members, an increasing dependence on humanitarian aid was being fostered. Participation in the clean-up also reportedly helped support traumatised persons and allowed the community to participate in their own recovery, including salvage of wastes where desired.

Figure 8-1 Contractors collecting bulky metal for recycling

There was some difficulty in recruiting community members to participate in the clean-up, in particular where no monetary or in-kind compensation was provided. Some attributed this to the need of individuals to concentrate on their own recovery rather than participating in community clean-up. The author suggests that the mass movement of people from the affected area reduced the perceived need of and desire to participate in the clean-up.

A community level, centralised response was suitable following the tsunami, given that waste materials were moved from their point of origin and ownership of and responsibility for the waste was difficult to determine.

8.2.3 2009 L'Aquila Earthquake, Italy

The organisation of the demolition and debris management operations in L'Aquila was essentially aligned with the government funding. Demolition works were carried out as a centrally managed programme which allowed for economies of scale and prioritisation of works and resources. Army and fire personnel were used for a large portion of the demolition works. Reasons given for using the army and fire personnel over private contractors included: 1) it was a cost saving strategy, 2) it was to avoid laws and regulations around hiring private contractors, 3) they were the only organisation with available capacity and equipment, and 4) legal requirements around dealing with collapsed structures (where criminal investigations were pending). The building repair works and associated debris management was carried out by private contractors (certified as environmental managers). Private property owners were responsible for managing detritus (up to one tonne) from their own properties. Central debris collection centres were established for residents to dispose of their waste. The provision of central collection facilities for private property detritus empowered residents to manage their own waste. The majority of the waste handling facilities (including community drop-off centres, temporary storage and recycling) were operated by locally appointed contractors. No data were collected on the procurement strategies for the works.

Overall the centralisation of the demolition works offered opportunities for efficiencies and economies of scale. However, there were a number of other factors (criminal investigations, regulatory bottlenecks, shortages of waste management areas, insufficient capacity / resources within the Comune) that limited the effectiveness of the operational organisational strategy.

8.2.4 2005 Hurricane Katrina

The US, pre and post-Hurricane Katrina, has well established debris management processes including operational strategies. Generally clearance of private properties is carried out by private property owners. Private property detritus is placed on the kerb for collection by local authority or FEMA appointed contractors. Demolitions (and the associated debris) are also the responsibility of individual home owners or their insurers. However, due to the large scale of Hurricane Katrina, the high public health risk from toxic flood sediments, the large number of displaced persons and low level of insurance, FEMA funded and facilitated all debris removal and demolition on private properties. The works were awarded as lump sum contracts to large contracting and demolition firms. Waste was handled in accordance with standard debris management procedures developed by the Louisiana Department of Environmental Quality.

Waste and debris was taken to existing private recycling and disposal facilities. Some additional disposal facilities were required and they were generally managed by as private endeavours (according to the local approach to waste management).

Because of the lump sum contract approach to demolition and debris removal, contractors aimed to minimise costs for their particular contract. Contractors did not necessarily view the benefits for the recovery and community as a whole from approaches that minimised disruption to communities or minimised waste to landfill. LDEQ, in fact, issued a directive that contractors were responsible for determining the most appropriate waste management approach based on cost.

Overall the centralised approach to debris removal and demolition works allowed for streamlining of the clean-up operations. The high level of displaced property owners, and high degree of health hazard present in the waste matrix, made necessary a coordinated and large-scale response. It was not feasible to rely on a conventional FEMA response where private property owners participated in the clean-up. The centralised approach allowed for expedient management of environmental and public health risks and for stream-lined mitigation procedures to be put in place. However, the lump sum contract approach allowed contractors opportunities to adopt risky behaviour and waste management approaches not necessarily beneficial to the overall recovery. Limited use of local contractors was a community complaint noted.

8.2.5 2011 Christchurch Earthquake

Despite the individually-oriented funding mechanisms in Christchurch (see Section 7.2.5), a centralised demolition and waste management approach was adopted by most insurance companies (residential property repair and demolition) and CERA (commercial and residential red zone property demolition). A centralised approach had been trialled on a small earthquake event in Te Anau, New Zealand, in 2003 and was noted to present opportunities for efficiencies and quality control (Rotimi et al., 2006). However, following the Christchurch earthquake, it was not compulsory to participate in the insurance nor the CERA commercial property centrally managed programmes. Many individuals accepted cash settlements with insurers and elected to manage their own works. This led to many independently managed projects, particularly within the city centre. Under the CER Act, CERA had some control over independent demolitions (as the CER act allowed CERA to intervene when works were not being carried out in a timely manner). However, because CERA was not managing the contracts it was not possible to have complete control over the works programme. As a result, the ability to prioritise resources and timeliness of demolitions was lost and as a consequence the demolition times increased.

CERA developed a selective demolition procurement strategy for its centralised demolition works. The strategy allowed for simple, low risk jobs to be carried out quickly and efficiently using cost reimbursement contracts. A cost reimbursement approach was adopted as it allowed a greater opportunity to efficiently share resources across the city. The higher risk jobs (e.g. tall building demolition) were tendered, as lump sum projects, to ensure prices were competitive and the risk of cost overrun rested primarily with the contractor. As the works progressed, however, pressure from insurance companies to maintain a competitive tender process (for commercial red-zone properties being demolished by CERA but being paid for by insurance) led to more and more demolition contracts being tendered as lump sum contracts. Lump sum contracts were perceived as being more competitive and resulting in lower cost demolitions. After the emergency demolitions were completed following the June 13 earthquake, it is understood all demolitions were carried out under lump sum contracts. This created a waste management problem as contractors tried to minimise costs (maximise their profit on lump sum jobs) through creative waste management. A number of illegal waste sites have been established across the city.

Waste is predominantly being handled at pre-earthquake, privately-owned, waste handling facilities. Several new facilities were established to specifically manage the earthquake waste: Lyttelton Port land reclamation, Burwood Resource Recovery Park (BRRP), Burwood disposal facility (still in the planning process at the time of writing), and several private waste sorting facilities operated by demolition contractors (both legal and illegal). The new facilities were all private ventures. Generally the facilities charged a waste receipt fee on a per tonne basis.

The establishment and operation of BRRP provides some interesting lessons. BRRP was established in the first two weeks after the earthquake. It was established to take mixed materials from demolitions carried out to enable urban search and rescue activities and as a storage facility for waste from buildings where fatalities occurred. The facility was initially operated by a private joint venture. The land was leased from the local authority, Christchurch City Council, for a nominal fee. The site operators had to estimate a price to receive, store, sort, process and remove the waste based on an unknown waste quantity and quality. Within the first two months, the operators noted that they were not receiving the quality or quantity of waste that they anticipated. As described above, the lump sum contracts led to increased recycling and establishment of private (illegal and legal) waste management sites which reduced the quantity and quality of waste going to BRRP. The operators had no control over what waste they would receive and in the dynamic and uncertain post-disaster environment this meant the commercial risks of the operation were extremely high. The disposal price had to be increased to reflect these risks. This, in turn, likely fuelled more contractors to establish their own waste handling sites, further reducing the waste quantity and quality received at BRRP. Eventually, the operators of BRRP determined the risk to be too high to operate alone, and in November 2011, ownership of BRRP was transferred to the public-private partnership which operates the regional landfill in Canterbury. The alternative to this scenario was to close the BRRP operation. In the authors view, BRRP served and will serve an important purpose for the recovery and, therefore, sharing the risk between private and public entities is a good arrangement. Initially a storage facility was needed for demolition material. Transfer stations could not handle the demolition material and the regional landfill was too far away to transport directly (130km round trip and there are logistical constraints around trucks numbers and truck types the landfill can accept). Long term a large scale recycling plant is needed to reduce the volumes of waste going to the regional landfill (to reduce costs and environmental impacts from trucking the waste to the regional landfill).

8.3 Discussion

8.3.1 Typical operational strategies

To better understand and plan for disaster waste management and to enable the following discussion, it is useful to define a generic operational management system. The system definition comprises five different demolition and waste management stages: waste source, waste handling, waste treatment, final disposal / end use, and transportation. The components are described below and the indicative relationships or waste flows between the components are illustrated in Figure 8-2. Figure 3-5, Figure 3-6, Figure 3-7 and Figure 3-8 show specific applications of this diagram for L'Aquila earthquake, Hurricane Katrina and the Christchurch earthquake respectively.

Waste source

As described in Section 4.3.2, the waste source describes where the waste originates from and in some cases what type of waste is being dealt with. There are likely to be different management techniques depending on the source. It may also be useful to delineate waste sources by who is responsible for managing the waste. For example, in Christchurch, private (residential) property detritus includes both (source 1) broken household items and damaged furnishings (dealt with by private property owners and insurance); and (source 2) liquefaction silt (dealt with by private property owners, volunteers and a local authority provided kerbside collection programme).

Typically disaster waste management systems are organised based on the waste source.

Waste handling

Waste handling facilities are those where waste is temporarily stored, for example, a transfer station or a temporary staging area. Some sorting may be carried out but generally there is no processing. These are useful facilities in a disaster waste management system as they act as buffers which allow waste to be moved out of affected areas quickly while long term waste management options (recycling and disposal facilities) are being established. Use of waste handling facilities inevitably increases direct costs because of the double handling required but has the indirect benefits of expediting waste removal and potentially allowing the time for more environmentally beneficial waste uses to be found.

Waste treatment

Waste treatment facilities are where waste is physically or chemically changed in form, for example, incineration, concrete crushing and recycling. Waste handling and treatment sites are commonly combined. For example, the Burwood Resource Recovery Park facility in Christchurch where waste is stored, separated, timber is mulched and concrete is crushed for recycling markets etc.

Final disposal / end use

Final disposal / end use sites are where waste is either resold as a useable product (e.g. crushed concrete) or is buried with no plans for use in the immediate future (i.e. landfill).

Waste transportation

Transportation includes the movement of waste between any of the above waste management activities.

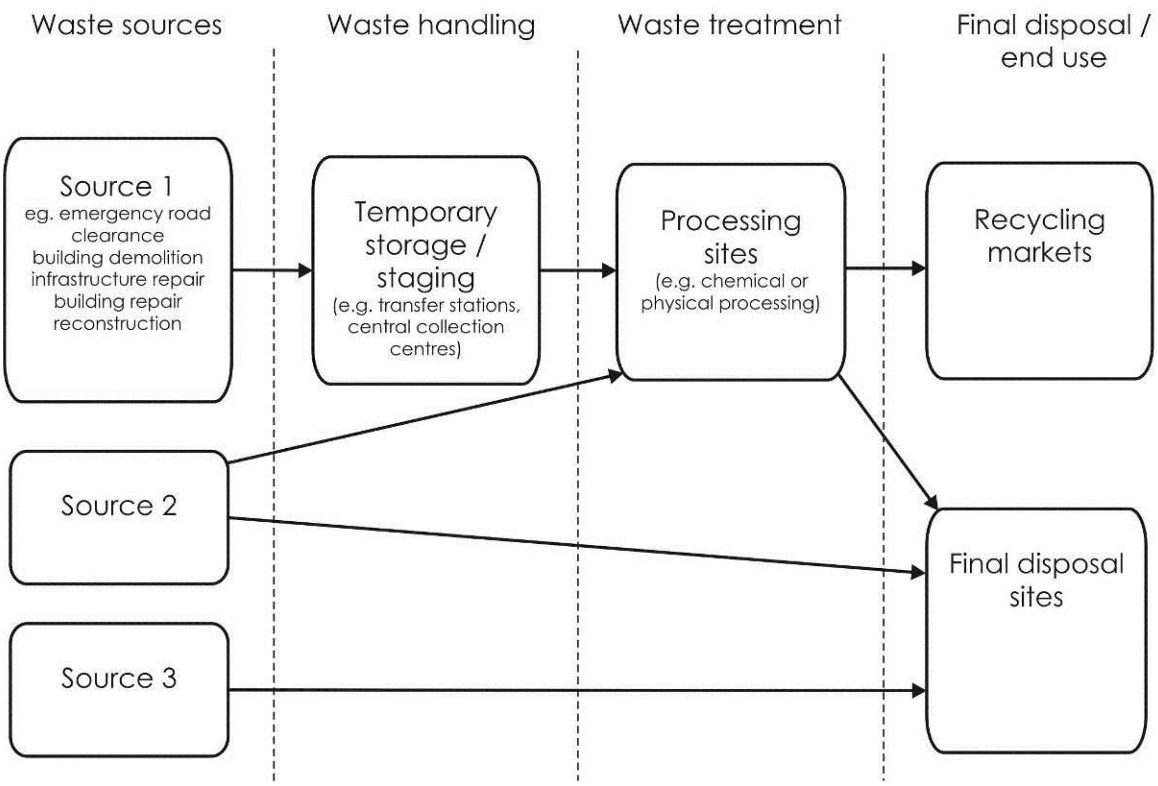


Figure 8-2 **Generic operational disaster waste management system template (waste flows shown are indicative only)**

8.3.2 Operational risk management

When designing an operational management strategy, one of the major determinants in its success is how risks to the project objectives (i.e. those defined in Chapter 5) are considered and managed. Aside from the regulatory and legislative mechanisms for risk mitigation (in particular for environmental and human health risks, as discussed in Chapters 10 and 11) organisational and contractual mechanisms are useful tools in ensuring project objectives are met.

Part of determining how project risks should be managed is first determining what the potential impact of poor risk management will be. For example: What is the economic impact of slow demolition? What is the social impact? What are the remediation costs of illegal waste disposal? Indirect impacts as well as direct impacts must be considered. If a serious death or injury were to occur during the recovery process, health and safety regulations would almost certainly be tightened and controlled, likely introducing cumbersome procedures which may slow down the recovery. If a waste handling facility was closed this may reduce the waste management capacity and slow down the recovery.

Based on the above risks, decision-makers need to determine where the ownership of those risks should best be held. Decision-makers need to ask themselves: does the entity have any incentives to manage the risk appropriately / inappropriately? Conversely, are there incentives for risky behaviour? Is there long term vested interest in good quality work? For example: an individual may make financial savings by illegally dumping hazardous materials.

Last, once risk ownership is assigned, risk mitigation strategies need to be put in place. Strategies include contract incentives (bonds, bonuses) towards appropriate behaviour and establishing monitoring, reporting and enforcement procedures.

These concepts will be used in the following discussion to determine the most appropriate operational management strategies in a post-disaster situation.

Operational strategies need to consider how project risks should best be managed including: consequences of poor risk management; ownership of risk; incentives for risky behaviour; and appropriate mechanisms to mitigate risks.

8.3.3 Operational organisation

Benefits of centralised operational management

Post-disaster, resources will invariably be limited (Chang et al., 2010). Ideally those limited resources should be prioritised on activities that facilitate community recovery. For example, works around lifelines, schools and critical industry should generally be prioritised ahead of other activities. Following the Bushfires, demolition of schools, community buildings and petrol stations were prioritised. The central contractor could manage its work programme against these priorities. With a private approach, all individuals must vie for resources and contractors will determine their own priority (likely based on price), which could potentially lead to 'priority premiums' being paid (contributing to price escalation as discussed in Section 7.3.3).

If well managed, centralised management offers opportunities to ensure recovery objectives are met by prioritising resources and works.

The timeliness of demolition and debris removal works can also be more effectively controlled when centrally managed. As discussed in Section 7.3.1, individually funded and managed works following the September 2010 earthquake, in Christchurch, led to significant disruption for some neighbouring buildings of unsafe structures that were not managed in a timely manner. In places, safety fencing also encroached into roadways. Likely in response to these experiences, to this the recovery law passed following the February earthquake (the CER Act) included powers for the recovery authority CERA to intervene if demolitions were taking too long. Central government clearly did not want the community recovery to be held up by individual's actions or non-actions.

In theory, the CER Act provisions to ensure works were completed in a timely manner, was a good approach to maintain momentum in the recovery process. Generally, it is believed that the demolitions works have proceeded for more expediently than if the CER Act had not been passed. However, where works were progressing too slowly, the ability of CERA to intervene using the specific provisions in the CER Act, was very limited. The costs and time to take over poorly managed private works were often too high to justify any intervention. Commercial demolitions managed by individuals, post-February, were, in the majority, slower than CERA managed jobs.

If well managed, centralised management offers opportunities to monitor and control the timeliness of the works.

A centralised management approach reduces the demands on affected communities. If a centralised clean-up programme is offered, affected persons are not required to secure and manage contractors on top of other post-event demands, such as employment and business disruption, temporary accommodation concerns, post-traumatic stress etc. A central management structure is generally easy for communities to understand as a single point of contact for the demolition is created. In Victoria following the Bushfires the government sponsored clean-up became the 'Grocon' clean-up. Many community members stated they were not even aware that the government funded Grocon. Potential for rogue contractors to take advantage of the affected community is also reduced.

Centralised processes, however, can also takes the initiative and control (over the timing and the nature of works) away from individuals, which can have negative psychosocial effects, as suggested by Denhart (2009). In L'Aquila, frustrated residents protested over the unacceptably slow management of the waste in the city centre eleven months after the earthquake (AreaGenova, 2010). Residents had no control over how quickly the waste was managed and clearly felt frustrated.

Centralised management reduces the demands on the affected community and is easy (for communities) to understand.

Centralised management can disempower the community.

Central management can improve the quality outcomes of the works. As for public funding sources (Section 7.3.1), a centralised approach takes the responsibility (and risk) away from the individual. Concerns about illegal dumping by the Department of Civil Protection in L'Aquila led to the provision of free central waste collection centres where individuals could deposit waste. In Christchurch, CERA and insurance Project Management Offices set standards to which works should be completed to, for example, backfilling basements to a level site. If owners are self-funding the works, they may leave the site in an unsafe or an aesthetically unsatisfactory state, particularly where funding may be limited (Chapter 7). While authorities can set standards, in a post-disaster situation they often lack the human and financial resources to enforce the standards. If authorities establish standards in conjunction with large organisations implementing the works, the organisations can use contractual means to ensure standards are met. Large organisations are likely to uphold standards to protect their long term corporate reputation.

Central management potentially improves the quality control of the works.

Cost quality control

Centralised contracts have the ability to regulate price escalation (Section 7.3.3) on behalf of individuals. Following the Christchurch earthquakes, CERA, and the insurance Project Management Offices all registered contractors for the works. Contractors submitted unit rates and the lowest rate providers were given the most work. Contractors were also more confident of their forward work load and were therefore more willing to reduce unit rates. This created competition in a saturated market. Following the Bushfires the managing contractor was able to control the apparent escalation of landfill prices by frequenting the lowest cost sites. Privately run contracts do not have the same ability to self-regulate. This is discussed further in Section 8.3.4.

Economies of scale can also be achieved in centralised programmes. This can be achieved by combining neighbouring building demolitions, synergy of waste transportation, negotiation or high volume service contracts etc.

Centralised processes, however, can be seen as anti-competitive. For example, there was some concern over the directive approach taken initially by Civil Defence and CERA to use certain waste handling facilities over others. Contrary to the above argument, the concern was that there was a lack of competition and the result would be price escalation. There were environmental and organisational reasons why Civil Defence and CERA identified certain sites for waste handling as well as economy of scale arguments. Mitigation measures, such as reviewing facility pricing structures, were carried out to ensure costs were competitive.

Macro (community level) cost control can be better achieved through centralised recovery works.

Waste system efficiency

Generally, waste management systems are most effective where they are managed as a 'cradle to grave' operation: from waste source to final disposal / end use. For example, a 'cradle to grave' approach is necessary to assess the costs and benefits of using waste handling facilities for sorting, versus sorting on site and slowing site clearance. At a macro (whole of recovery) level, centrally managed systems allow for operational managers to assess the wider effects of different approaches most effectively. Following the Christchurch earthquakes, the centrally managed CERA programme was initially designed around sorting mixed waste offsite to reduce demolition times to aid recovery. The large volumes anticipated reduced the additional expense of sorting offsite. However, the contractors working privately perceived no commercial benefit of sorting offsite and elected to maximise their profit by recycling large amounts of materials on the demolition sites. This slowed down the demolition and, therefore, the recovery works. This is discussed in detail in Chapter 9.

A 'cradle to grave' approach also reduces the uncertainty that the waste handling facilities operate under. As discussed in Section 7.3.2, demolition and debris management systems that include waste handling and disposal facilities can increase quality control of the works, assist in planning and can reduce costs, primarily due to a reduction in operational risks. BRRP in Christchurch was a private operation operating independently from the waste source operations (predominantly demolition). In the author's opinion, BRRP was critical to the success of the originally intended post-disaster waste management system. The operators had to estimate operating costs to manage an unknown quantity and quality of waste in order to charge an appropriate gate rate. This high level of uncertainty presented a large risk to the operation, so the gate rate included a large risk contingency. If the operation fails then this could significantly affect the recovery (by limiting waste management options) as well as potentially create a costly remediation exercise. In the authors' view, a facility of such significance to the recovery of Christchurch should not be operating independently of the front-end waste management process (i.e. collection and demolition) under such high risk and changeable conditions. Centralised management allows for linking front-end operations with waste handling facilities.

Private operational management approaches, on the other hand, tend to be more efficient at managing 'cradle to grave' waste effects on a micro (single site) level. Reuse of waste materials on site for rebuilding purposes, for example, is possible on a site by site basis. On a larger (centralised) scale, the logistics of on-site reuse can become cumbersome and waste ownership issues could become difficult to manage. In Christchurch many contractors crushed concrete at commercial properties to fill excavated basements.

Centralised works allow for waste management systems to be designed on a macro (community) scale.

Risks associated with establishing post-disaster waste handling facilities can be mitigated by linking them with front-end (collection and demolition) centralised waste management processes.

Individual / private operational management approaches allow for 'cradle to grave' waste management at a micro (site level) scale.

Works Insurance

Because of the increase in seismic risk in Christchurch following the earthquakes, and the on-going aftershocks, many contractors were unable to gain insurance for the demolitions. Risks can be more readily shared under centralised management systems.

Strategic management

Centrally managed works (particularly where a 'cradle to grave' approach is taken, as above) enable better information gathering, which in turn enables strategic planning for the demolition and waste management systems. For example, contracts can be used to require reporting. Alternatively, financial information could potentially be interrogated to provide waste information. Centralised management simplifies the job of strategic managers. Data are more readily collectable and this enables potential system bottlenecks (for example, labour and equipment shortages, waste handling facilities) and emergent risks (for example the Black Spur health and safety hazard following the Bushfires (see Section 10.3.1)) to be more easily identified and mitigated than for privately operated works. Many smaller organisations are less likely to identify and respond to potential macro scale problems, creating challenges for strategic managers. Data gathering from private works (demolition contractors and waste handling facilities) may also be difficult as there may be privacy issues (e.g. under private insurance schemes).

For example, the proliferation of waste handling facilities associated with the private demolition following the Christchurch earthquake is creating challenges for dealing with difficult waste streams such as treated timber[11]. First, it is hard to estimate total quantities. Second, it is unknown what "cost" each contractor has allocated for disposal of the

[11] Treated timber was a significant portion of the waste stream and had no existing market.

component. Third, there are commercial sensitivities among contractors as each are trying to find low-cost disposal / recycling options. All of these factors make assessment and comparison of alternative treatment options difficult, particularly where options are dependent on economies of scale. Each contractor owned the risk of their own waste but no one officially owns the risk of the disposal on a city wide scale.

Centralised management of works can be an effective way of gathering the data (particularly where legal mechanisms are not sufficient (see Section 11.3.3). Where an individually facilitated approach is adopted, more rigid regulatory requirements would be useful for data collection and monitoring.

Centralised management methods facilitate information gathering, which enables planning and monitoring.

Operational management strategies must include mechanisms for information gathering (to enable strategic planning).

By centralising management of demolition and waste management works, the number and complexity of the organisational interfaces is reduced. Regulatory and recovery authorities will be able to more easily liaise with a small number of large contractors than numerous individual contractors. Stream-lining of organisational interfaces is particularly important in a resource constrained post-disaster environment (see Chapter 10). For example, in Christchurch, the seven insurance companies each established a Project Management Office in Christchurch to manage their respective insurance demolitions and repairs. Each project management office managed hundreds of contractors and carried out tens of thousands of house repairs and demolitions. This was a far simpler arrangement for regulatory authorities to deal with than each individual property being dealt with independently (e.g. by the property owner). Links between demolition contractors and waste handling facilities were also simplified.

Operational management strategies need to, where possible, reduce the number and complexity of organisational interfaces.

Funding mechanisms

As discussed in the previous chapter, funding mechanisms and operational management strategies are inextricably linked. Private funding approaches inevitably result in private / individually managed implementation strategies; and publicly funded works result in centrally managed operations programmes. There are exceptions to this, for example, the central management of demolitions in Christchurch (paid for by individual property owners' insurance); and the individually facilitated repair works in L'Aquila reimbursed by government funds. In the former case, legislative measures were required to facilitate a central approach to demolition (refer Section 11.3.3) as well as considerable coordination efforts.

Funding mechanisms must be designed with the desired operational strategy (or strategies) in mind.

Applying a centralised approach to a privately funded system can be challenging. In particular, there is a need to accurately record costs for each private interest (building owner / insurer / tenant etc.) rather than accruing costs over the entire project. This leads to high administrative demands. This can also introduce inefficiencies in the waste management works. For example, trucks transporting debris to waste handling facilities in Christchurch could not be used for more than one job at a time as this would make allocation of costs difficult. Publicly funded schemes enable the efficiencies gained in centralised approaches to be maximised.

If a centrally managed operations programme is desired, public funding mechanisms can significantly reduce administrative demands and can improve operational efficiencies.

As discussed in Section 7.3.3, where private funding mechanisms exist, but centrally managed programmes are required (such as the private property demolition and debris removal in Louisiana and the commercial property demolition in Christchurch) cost recovery mechanisms need to be in place.

When central management systems are imposed in a privately funded disaster recovery environment (by an entity other than the funder), consideration into cost recovery mechanisms is important.

Also discussed in Section 7.3.3, one difficulty in managing works centrally, where individual funding mechanisms exist, is determining who should pay for the management costs. In Christchurch, the CERA management costs were charged to the building owners (or their insurers) as a percentage of the total demolition cost. Many owners (and insurers) felt that they should not have to pay this overhead. Given that centralised management is a strategy to benefit the wider recovery (rather than individual benefit), this may be an appropriate fee for public / recovery authorities to cover.

Public funding for central management overhead costs should be considered.

Disaster & disaster waste impacts

There are a number of disaster & disaster waste impacts that may indicate a centralised management approach is operationally beneficial. These are discussed below and summarised in Table 8.1.

The scale of the event and the resultant urgency to clean-up will directly affect the adopted response. All five case studies here adopted a centralised process for some or all of the waste management works. In two of the case studies (Christchurch and Victoria) this involved altering pre-established (and/or default) recovery approaches. The scale of both events led disaster managers to increase the level of control in the recovery and take extraordinary measures to mitigate any further negative impacts.

The difference in scale, in terms of damage, between the September 2010 (smaller) and February 2011 (larger) earthquakes in Christchurch led to a completely different response. As described earlier, the insurance and private property approach moved from an individual level response in September to a centralised management approach in February.

For a large <u>disaster scale</u>, centralised management is likely to be highly beneficial.

Centralised management can help to mitigate environmental and human health risks where they are present. The waste matrix from Hurricane Katrina contained significant hazards (largely due to the petro-chemical hydro-carbons present in the floodwater sediments). If there had not been a centralised clean-up, individuals would either be required to engage a specialist to carry out the work (potentially creating a resourcing bottleneck); or, as Allen (2007) observes, those that could not afford to pay contractors may have put themselves at risk; or, in the most extreme case, no action would have been taken, which would pose a risk to the wider community.

The close quarters of the damaged properties in the Central City Business District in Christchurch, meant that demolition work would present a significant worker health and safety hazard (e.g. demolition fall hazard, increased truck movements). For health and safety purposes, CERA maintained control of the entire Central City Business District to ensure that both the CERA managed and individually managed works were carried out safely in the confined environs of the central city.

One of the questions in the survey outlined in Appendix C specifically addressed this issue. Respondents were asked to determine whether a centralised or decentralised approach was more appropriate based on the amount of asbestos in the demolition waste. Respondents favoured a private approach for small amounts of asbestos in the waste, but a centralised approach for significant volumes of asbestos (50% of houses containing asbestos and above). As discussed above, it is likely that the respondents have assessed that the risk to the wider community is too great to assign responsibility to private contractors and a more controlled approach is desirable.

Where there are significant <u>environmental and human health hazards</u>, a centrally managed clean-up is preferable.

The movement of waste can also influence the waste management strategy. The violent action of the floodwaters during Hurricane Katrina caused waste materials to spread across property boundaries. It was difficult to determine who was responsible for various parts of the waste and who had right to ownership of the recovered materials.

A centralised approach may be necessary where there has been a significant trans-boundary movement of waste during the hazard event.

Person displacement can also influence operational strategies. The high number of people displaced following Hurricane Karina, coupled with the high human health hazard, led to FEMA electing to centrally manage the private property detritus and demolition management to ensure any public health hazard was minimised. Correspondingly, for works on private property, a private approach may be more desirable where there is minor displacement of people. Note that legislative or regulatory provisions may be needed to allow for property access, remediation works and associated waste ownership assignment for works carried out on behalf of property owners and/or on private property. This is discussed in Section 11.3.3.

In Christchurch, for example, there were many habitable houses that needed major repairs or demolition. The timing of the demolition needed to be coordinated with the building owners to minimise the time that they required temporary accommodation. Therefore, a private approach may allow for individuals to better manage the works to meet their individual needs.

A high number of displaced persons may indicate a need for a centrally managed approach.

Where the road network has been heavily affected, centralised management may be necessary in order to effectively control traffic movements. Centralised management offers opportunities to control and potentially minimise vehicle movements (through rationalising vehicle movements) which would help to relieve congestion and damage to a disrupted road network.

Centralised management will be beneficial where there is high disruption to road network (by controlling and rationalising vehicle movements).

Table 8.1 Indicators for selecting an appropriate operational organisational strategy

	Disaster & disaster waste indicators									
	Disaster scale	Number of displaced persons	Geographic extent	Duration of hazard	Disruption to road network	Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Difficulty of handling waste
Centralised	H-M	H-M	-	-	H-M	-	H-M	H-M	H-M	-
Individual	L	L	-	-	L	-	L	L	L	-
L=low, M=medium, H=high, '-' = no influence										

8.3.4 Operational procurement strategies

Procurement strategy

When works are to be centrally managed, the appropriate procurement strategy (that is the contract type) for services needs to be selected. The initial discussion will focus on separated contract types; integrated contracts will be discussed briefly later. The model in Figure 8-3, shows two separated contract types at the extreme ends of the procurement spectrum: cost reimbursement and lump sum. The contract types are plotted against two project considerations: Principal's project control and flexibility (in terms of time and scope) (which is positively correlated with Principal's cost risk) and Contractor's incentive (to work cost effectively). The model will be used to discuss post-disaster contract selection.

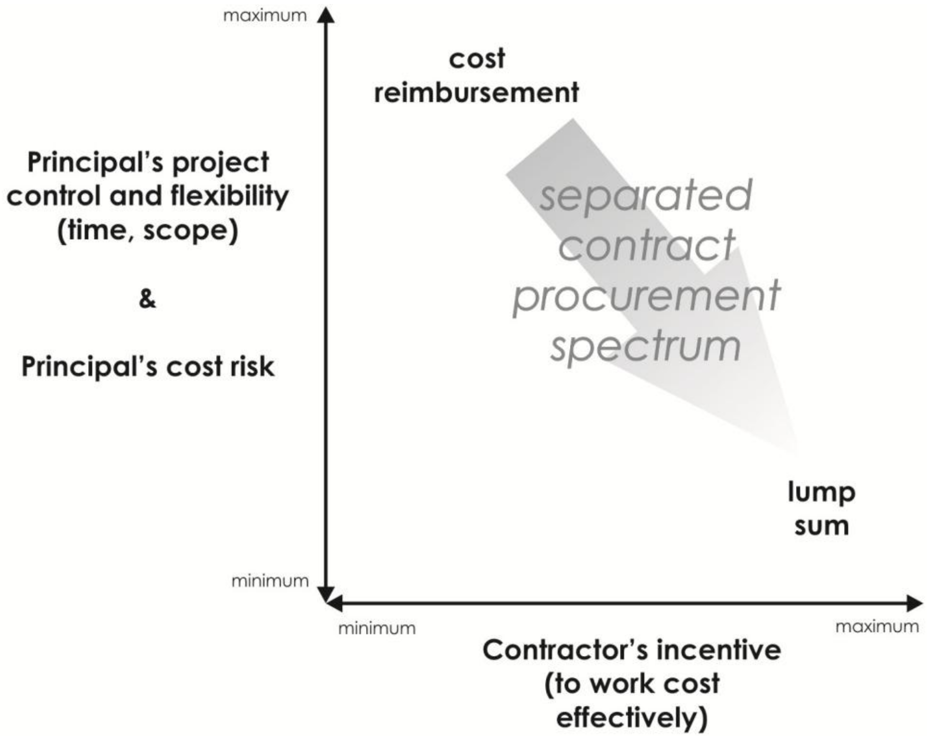


Figure 8-3 Procurement strategy comparison (adapted from unknown source)

Contracts are, in essence, risk management tools which are used to ensure project objectives are met. In traditional separated contracts, the Principal establishes the project objectives (primarily output related) and determines which project risks (financial and operational) will be either transferred to, or shared with, the Contractor[12]. Based on the level of risks involved, and whether risk transfer or sharing is preferred, the contract type is selected. The Contractor in turn has objectives which are primarily profit driven.

In peace-time, the work scope and risk context for demolition projects is usually well defined. Minimum Principal flexibility is required (the Principal wants the building demolished), thus the Principal wants to transfer as much risk to the contractor as possible (minimum Principal cost risk) and to minimise the price by encouraging competition between contractors during bidding (maximise contractor incentive). Referring to Figure 8-3 this equates to a lump sum contract, which is, generally, the default contract type for demolition projects.

[12] Risks can be transferred to third parties. However for this analysis, third party risk transfer is not included.

Post-disaster, the project context and, thus the risk context, changes. First, project scope is less well defined. It is advantageous for the Principal (for a centralised operation with multiple demolition and/or waste management projects) to maintain as much flexibility in the contract terms as possible. Following the Christchurch earthquakes the number of buildings to be demolished increased progressively as buildings were structurally assessed, thus the scope constantly changed. In addition, many buildings had to be demolished without a full understanding of the volume and nature (for example, presence of asbestos) of the waste because initially buildings were too damaged to assess fully prior to demolition. There were also complex stakeholder relationships, as well as a need to coordinate with other demolition works. In terms of Figure 8-3, desired Principal flexibility was high.

Second, the Contractor's incentive also changes. In peace-time contractors want to maximise profit. For a cost reimbursement contract that may mean working inefficiently (and this is undesirable for the Principal). In other words, there is minimum (financial) incentive for contractors to work efficiently. If a lump sum approach is taken, contractors have incentives to reduce the bid price to secure the contract and to perhaps generally accept higher risks as a result. However, in a post-disaster environment, where resources are maximised[13] and availability of work is all but 'guaranteed', there is less incentive for contractors to take financial risks on projects (when other less low risk projects could be accepted). Consequently lump sum prices can increase to account for the risks and demand for resources. A cost reimbursement contract in this case, mitigates the potential for risk loading on prices. Contractors are also encouraged to work efficiently to gain a higher volume of work. There is no such incentive for efficiency in lump sum contracts as the costs will dictate the work speed (unless there are penalties or incentives for timely completion). In terms of Figure 8-3, the need to create Contractor incentive is minimised.

The above incentive shift has been illustrated in Christchurch. When demolition contracts were slowly released[14] to the market there was stiff competition between contactors trying to secure jobs. Lump sum contract prices were driven so low that authorities believed the work would not be possible in the time desired and within expected environmental and human

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[13] Note that resources may not be maximised if there is no urgency to clean-up.

[14] Slow release of works can result from a number of factors, such as delays in insurance payments, engineering assessments, building owner inaction etc.

health standards. When there was an oversupply of work, contractors were seen to inflate lump sum prices. Generally this latter scenario led to a timely clearance of the city but at a higher price. Contractors wanted to finish the job quickly in order to move on to the next project before the contracts dried up again.

Post-disaster cost reimbursement contracts allow the Principal to retain control of the works (and arguably costs) while providing low risk, high volume work for Contractors.

Third, project objectives and risks change. As discussed earlier, because of the community-wide work scope, the risks no longer only focus at the individual project (micro) level, but there are significant community wide (macro) risks to be considered. That is, if the projects are not well managed and controlled then there could be wider community effects including business loss, social disruption, public health impacts etc. In terms of Figure 8-3, because of the consequences of project failure, it is more desirable for the risks to be held by the client / Principal rather than the contractor. Therefore, the Principal should hold the maximum project control and, subsequently, risk.

Based on all of the above, this indicates that cost reimbursement contracts are the most appropriate contracts for post-disaster demolition works because of the change in risk context. In particular, there is a need for project risks and control to be held by an entity with responsibility for meeting recovery objectives rather than solely profit. Interestingly, FEMA prohibits cost plus percentage contracts and does not allow time and material contracts past the emergency phase. As discussed in Section 7.3.3 and the previous section, operational and funding systems must be designed together.

In Christchurch, demolition contractors reported that they were generally happy with a cost reimbursement approach. However, there were some who insisted on marketing their services, on a lump sum tender basis, outside the CERA process to building owners. The lump sum option offers Contractors potentially greater return but at a higher risk. Also, in turn, it creates greater risk to the overall recovery programme, in particular by contractors trying to reduce costs; in the Christchurch case this was achieved by salvaging more recyclables on-site and slowing the demolitions (see Chapter 9).

Cost reimbursement contracts can also reduce incentives for risky behaviour in terms of environmental and human health. This is essentially because under cost reimbursement contracts contractors are instructed to carry out specific works and are paid for what they do; whereas, under a lump sum contract, there is an incentive for contractors to cut corners for economic gain. The gradual shift to lump sum contracts in Christchurch created an incentive for contractors to establish their own debris management sites to try to reduce costs (and therefore increase profits). Subsequently a number of debris management sites emerged across the city. Many of these facilities were not legal and posed potential environmental and public health hazards. There is concern that some contractors have underestimated the costs involved in handling the waste and will not be able to pay for the residual waste to be disposed and the site to be remediated. There were also some cases where contractors, engaged on a lump sum basis, were working inside a building, stripping out the interior (to reduce disposal fees), when significant aftershocks occurred. The contractors had been instructed not to strip-out the building. Contractors were, evidently, willing to accept higher levels of human health and safety risk to gain financially. There was also concern from the public and CERA that some contractors would not handle hazardous materials properly. In particular release of asbestos particles presented a major concern and, indeed, illegal dumpsites containing asbestos were found (Greenhill, 2011; Wright, 2011).

As discussed in Section 8.3.5, regardless of the contract type, contracts can be written to mitigate potential negative effects and associated monitoring systems designed but the increased volume of work may make monitoring difficult. Therefore, low risk contract types should be utilised.

Cost reimbursement contracts reduce incentives for contractors to adopt risky behaviour (environmental or human health), particularly in cases where there is a high <u>human and environmental health hazard</u> in the waste.

Cost reimbursement contracts can, however, reduce ingenuity, creativity and diversity when managing waste. Lump sum contracts give contractors some latitude to manage waste as they see fit. In Christchurch this freedom led to a number of markets being developed by contractors which may not have been found if contractors had been instructed how to manage the waste under a time and cost contract. For example, crushed concrete changed from a cost negative recycled commodity (a $20/T fee to dispose of waste for crushing), to a cash positive endeavour ($2/T payment for concrete debris). Markets for hogged timber also emerged.

Cost reimbursement contracts may reduce contractor incentives to independently develop new waste management options, including recycling markets.

Management

There is a perception that, from an administration and management perspective, cost-reimbursement contracts create more work than lump sum contracts, particularly in terms of on-site supervision and contractor payments. According to Turner and Simister (2001), cost savings for administering a lump contract (over cost reimbursement contracts) are only really made when the uncertainty of the works is low (see Figure 8-4). Post-disaster situations, as described earlier, hold large uncertainties, such as, waste volume and nature, and complex stakeholder issues, etc. Therefore, it could be inferred that administrative savings made from not having to assess payment claims and monitor works, would not be significantly more or less than the costs incurred for auditing and quality control on lump sum contracts in this high risk environment. Further research into this would be beneficial.

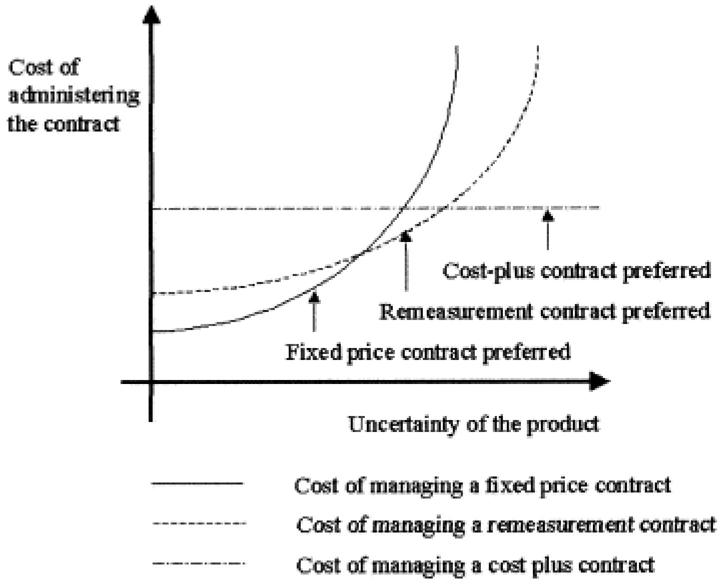

Figure 8-4 Administration costs of different contract types relative to the uncertainty of the product (or project) (Turner and Simister, 2001)

Integrated procurement

Integrated approaches to procurement (including management oriented contracts, collaborative contracts, turnkey, alliances etc.) has been proposed by some authors as a potentially suitable approach for post-disaster reconstruction (Le Masurier et al., 2006; Zuo, 2010). In line with the arguments presented above, Le Masurier et al. propose that if a recovery was attempted as a coordinated programme of work, alliancing would be a possible way of managing the degree of uncertainty and complexity. Le Masurier et al. also stated that alliances offer clearer communication systems which are imperative following a disaster. Project alliancing is essentially a form of risk sharing between project Principal, Contractor and other key stakeholders. The key aspect of an alliance is that rather than transferring the risk to the contractor (which has been established above as undesirable) or taking the entire risk under a cost reimbursement contract, alliancing offers a risk share arrangement. Zuo suggests that the appropriate procurement mode will depend on the scale and type of the disaster and the control mode (organisational structure) governing the reconstruction.

Following the Christchurch earthquake an alliance was established to manage the repair of the damaged local authority owned water and wastewater infrastructure. It is too early to determine how effective the approach was, however, early indications are that the approach is fairly effective.

According to Ross (2003) there are eight project characteristics that indicate when risk sharing should be practiced and, therefore, alliancing (or other risk sharing procurement arrangements) may be appropriate. These are shown in Table 8.2. Each project characteristic was assessed as unlikely, possible or likely to occur in a post-disaster demolition and debris management situation at both a micro (site) and macro (community wide) level. It was clear that 1) the project characteristics are very different when assessed at a micro and macro level and 2) risk sharing is beneficial at a community level.

Table 8.2 Applicability of risk sharing project characteristics in a post-disaster demolition project using characteristics from Ross (2003)

Project characteristic	Micro (individual property demolition)	Macro (community wide)
Numerous complex and/or unpredictable risks	Unlikely	Likely
Complex interfaces	Possible	Likely
Difficult stakeholder issues	Likely	Likely
Complex external threats	Unlikely	Likely
Very tight timeframes	Likely	Likely
High likelihood of scope changes (eg due to technological change, political influence etc)	Possible	Likely
A need for owner interference or significant value-adding by the owner during delivery	Unlikely	Likely
Threats and/or opportunities that can only be managed collectively	Unlikely	Likely

Contract conditions

If a centralised management process is implemented, contract conditions need to be written to limit inappropriate behaviour. The risks associated with cost reimbursement contracts discussed above can potentially be mitigated by appropriate contractual measures. For example, contractors could be contractually required to install self-reporting GPS systems in their trucks so that anomalies in truck behaviour (for example diverting loads or performing work outside of a given task) can be more easily monitored. This was investigated in Christchurch, however various factors hampered these attempts (in particular the fluidity of the truck fleet between CERA and privately managed jobs and the concern that requiring specific GPS systems might limit the available truck fleet and create a bottleneck).

Contracts conditions can be written to mitigate risks associated with cost reimbursement contracts.

Contracts must include waste ownerships issues. Approaches to waste ownership are likely to change between contract types. As the demolition process matured following the Christchurch earthquakes, in May 2011, waste ownership issues were written into the demolition contracts. The different contract types (cost reimbursement and lump sum) required different approaches to waste ownership. For cost reimbursement contracts, the waste was essentially owned by CERA. CERA assumed the risk and the responsibility for ensuring appropriate management of all the waste components. Under the lump sum contracts however, the ownership of the waste, and therefore any profits gained from the waste, belonged to the contractor (unless some or part of the waste was excluded in the contract documents). Thus, there was much less control on management of any personal items that were found during the demolition process for lump sum projects. For example there were several media reports of the improper salvage of personal belongings from Community House in Christchurch (NZPA, 2011a; Van Beyen, 2011a; Van Beyen, 2011b). It is likely, though unconfirmed, that this was as a result of a lump sum contract.

With the high tangible and intangible value associated with contents of disaster damaged goods (personal value, value to business continuity, confidentiality issues), waste ownership is an important consideration. Cost reimbursement contracts have a significant advantage in that there is greater clarity around ownership of any valuable personal items recovered.

Legal issues regarding waste ownership are discussed in detail in Section 11.3.3.

Waste ownership needs to be appropriately incorporated into contracts. Waste ownership will be different depending on contract type.

8.3.5 Operational management principles

Contractor selection

In a post-disaster situation, peace-time procurement policies can be expedited to facilitate aspects of the recovery. In Christchurch, post-earthquake, a number of contracts and appointments were awarded without following standard peace-time procurement procedures. Included in the appointments of concern was the selection of contractors to operate the Burwood Resource Recovery Park (BRRP) facility without a tendering process (Gorman, 2011). There was no contract for the operations (that is, it was run as an independent operation and no guarantee of business was given), however the contractor were given a low cost lease of the recovery park land on the provision that a resource recovery park would be established. Regardless of the legal particulars, there was discontentment by some contractors, the public and Christchurch City Councillors, that, certain companies had been given the opportunity to make a profit from the venture.

In the author's opinion, there are several reasons that ameliorate the decision not to tender this particular contract. First, a facility was urgently needed post-earthquake to take waste from the city centre during search and rescue operations. In addition, a secure area was necessary to take building materials that may have been required for coronial or other investigations. The urgency did not allow for a tender process to be carried out. Second, the waste industry is small in New Zealand and the main contractor selected was arguably the only company with sufficient expertise and financial means to establish and operate a facility of this scale and risk. The level of risks involved are illustrated by the fact that two of the original joint venture partners withdrew from the project because the financial risks were too great (Williams, 2011c). In addition, local and regional authorities eventually agreed to manage the facility under a public private partnership (the same partnership that operates the regional landfill) (Heather, 2011) so that the risks of the project would be shared.

Given waste was largely being stockpiled at BRRP for the first 12 months, in hindsight it may have been possible to engage the contractors on a temporary basis before a formal tender process could be carried out for the long term operation.

When appointing contractors quickly in uncertain environments (such as in a post-disaster scenario), risk management is very important. With limited time to act, there is little time to gather information on potential unknown contractors. Engaging contractors with proven work records and commercial reputation to uphold is a method of managing the potential risks. Engaging contractors where there is already a working relationship, again reduces the project risk. If unknown operators were appointed, even at a 'lower cost', the potential negative (economic as well as environmental and social) effects of an unknown entity may outweigh the projected savings. Zuo (2010) also identifies the importance of utilising existing relationships in his study of post-disaster procurement processes.

Because debris management activities transition from the response to the recovery phase of disaster management (see Section 6.3.3), different procurement approaches are likely needed for each phase. For example, those contracts that commence during the emergency phase may need to be time limited such that longer term contracts can be appropriately and transparently let.

Generally procurement procedures will be legislated and/or regulated. Therefore appropriate provisions to enable expedient procurement processes must be in place (see Section 11.3.3). Note, that if diversions from peace-time procurement procedures are to be considered, the potential for corruption must be managed[15]. For example, if contracts are awarded without standard procurement procedures, it is important to document the reasons for the decisions for future auditing.

Transparent post-disaster procurement policies need to be established.

Where possible, contracts let during the emergency phase should be time limited to allow for full procurement procedures to be followed for long term operations.

Cash-flow

Cash-flow was identified, in both the Christchurch earthquake and Victorian Bushfire case studies, as an issue for many contractors participating in recovery works. Under the CERA-managed commercial demolition programme, a process was established several months into the recovery effort whereby contractors were paid directly from a revolving credit provided by the government. The contractor would charge CERA, the Government would pay and the costs would then be recovered from the property owner (who would generally be claiming the money from their insurer). This ensured that contractors could continue operating without waiting for lengthy insurance claim settlement delays.

One of the benefits of the cost reimbursement contracts in Christchurch was that the contractor did not receive the invoice for the disposal fees. The dedicated disposal facilities would charge CERA directly. This reduced one link in the payment chain, meaning payments could be made within a month of invoice. For lump sum contracts the contractors would theoretically have to pay for the waste disposal costs until invoices were paid by CERA. However, in some cases the disposal fees were too high for contractors to do this. In this case, payments to disposal facilities would have been delayed by a further one to two months.

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[15] In L'Aquila, there were allegations that contracts for construction of temporary housing units were awarded to contractors for reasons other than capability and price.

Similar concerns, regarding cash-flow, were expressed by the public in Christchurch. There were some complaints that, despite being able to claim reimbursement from their insurers, that disposal costs for debris were too high. Immediately post-earthquake, particularly where livelihoods had been affected, immediate cash-flow was a concern for residents and they sometimes could not afford to pay waste management fees, even in the short term. Where possible, it would be beneficial to investigate the possibility of directly charging the funding 'source' (as for the contractors above). This would relieve pressure on affected persons and, in turn, reduce the potential for improper waste disposal.

Regardless of the procurement strategy (and funding mechanism) contractor cash-flow must be facilitated to ensure recovery works can continue.

Cost reimbursement contracts can simplify payment chains as service providers can directly charge the Principal (rather than the subcontractor).

Human resourcing

The success of a disaster waste system is highly dependent on the skills and effectiveness of the people involved in the strategic management (see Chapter 6) and the operations. Thus, the operational systems discussed in this chapter must be considered in light of the human resources available (quality and quantity).

The first and most important realisation is that demand is likely to outstrip supply of qualified resources[16]. Consequently, personnel and organisations who do not have demolition and waste management skills will almost certainly emerge. For example, the contractor managing the Bushfire response in Victoria was a construction contractor with no demolition experience; in L'Aquila the majority of the demolition was carried out by Army and Fire personnel; and several waste handling facilities were established after the Christchurch earthquake by organisations who have never operated waste management facilities before. The US is perhaps an exception to this rule, where there is a growing

[16] Human resource constraints are likely but not inevitable. For example, resource limitations may not eventuate if there are delays in demolition or recovery decision-making, such as, slow insurance settlements, heritage building approvals, and building owner issues.

industry of disaster debris management specialist contractors around the country which can be mobilised quickly (Fickes, 2010). It should be noted that, despite this, the scale of Hurricane Katrina generated resource shortages.

A lesser skilled workforce is likely to be less effective at management of human health and environmental risks, as well as maintaining work programmes (Lawther, 2009). The increased operational control offered by both the centralised control and cost reimbursement type contracts would help to manage the increased risks associated with a less skilled workforce. Following the Christchurch earthquake a tiered contractor accreditation process was implemented. Contractors were accredited to carry out certain activities to ensure unqualified contractors were not allocated works outside their abilities. This seemed to be an effective way of managing the risk for the expanded workforce.

Legislative and regulatory provisions that can limit (or increase) human resource availability are the waste classification processes (if any) and the operational personal certification requirements. These are discussed in Sections 10.3.1 and 11.3.3.

The work force is likely to be less skilled and operational strategies which increase control of operations (such as centralised management and cost reimbursement contracts) are beneficial.

There were two notable comments from communities and experts from three of the five case studies about the demolition and debris management programmes: 1) there was a resentment of the use of non-local labour; and 2) communities and individuals wanted the opportunity to physically participate in the recovery. Some communities and experts have expressed concerns over the quality (in particular with respect to environmental and public health outcomes) of the waste management works by outside contractors. Allen (2007) cites the lack of local knowledge and lack of care for long term impacts of debris management activities by non-local contractors as a concern. In addition, where non-local contractors are brought in, jobs and the associated economic benefits are perceived as being taken away from the affected area (as observed following the Victorian Bushfires, the Christchurch earthquake (with respect to hiring of insurance loss adjustors), and as observed by Haas et al. (1977)). However, it must also be noted that using non-local contractors stimulates other areas of the economy, particularly hospitality (accommodation and food). Some authors and community members interviewed identified adverse psychological effects from not directly participating in their own recovery (as observed following the Victorian Bushfires and Hurricane Katrina (Denhart, 2009)).

When considering use of local unskilled labour and volunteers, authorities must consider the desired quality of outcome and how risks will be managed. Poorly supervised or informed volunteers can inadvertently cause additional distress to community members. Overzealous volunteers following the 1995 Kobe earthquake, for example, reportedly led to a significant loss of personal property during debris removal (Atsumi and Yamori, 2008). Figure 8-5 shows community members participating in some mangrove clean-up activities in Samoa.

Use of unskilled local labour is constrained by some of the disaster and disaster waste impacts (as discussed below and summarised in Table 8.3). First, public participation is constrained by the level of human health risks workers may be exposed to. For example, many people volunteering their services following the 2001 World Trade Centre collapse were turned away due to the potential risks and specialist skills required to work on a crime scene holding human remains. Even those skilled in emergency and demolition works have since reported significant health impacts (Landrigan et al., 2004). Many volunteers reported they were left feeling frustrated that they were not allowed to help (Phillips, 2009).

Where volunteers or local labourer are used, legislative provisions around liability (for effects caused by and effects on the volunteer or labourer) need to be considered (see Section 11.3.3).

Where there are significant <u>human health hazards</u>, public participation should not be called on.

Second, public participation is also limited by how difficult the waste is to handle. As was observed following the 2010 Haiti earthquake, communities were generally unable to contribute to the clean-up effort due to the weight of the collapsed masonry structures which required heavy machinery to move (Booth, 2010). A review of the response in Kobe, Beirut, Lebanon and Mostar also identified the need for heavy machinery as a constraint in the selection of waste management options (Lauritzen, 1998).

When waste is difficult to handle and when specialist waste handling equipment is required public participation cannot be relied upon.

Third, and conversely, there is not always a desire by the public to participate. As Cook (2009) observed following Hurricane Katrina, the large displacement of people meant that the usual expectation for residents to participate in the clean-up was not feasible. Lawther (2009) observed indifference in the wake of the Indian Ocean tsunami in the Maldives where locals were unwilling to participate either due to private recovery / livelihood efforts or dissatisfaction with proposed pay-rates. Following Hurricane Katrina and the Samoan tsunami, some community members did not want to participate in the clean-up because they were afraid of finding human remains in the debris.

Reliance on private property owners to manage waste should be avoided when there are a high number of displaced persons or where it is anticipated that there is not a strong desire to participate.

Despite these constraints, operational strategies need to be sensitive to a community's needs. In particular, residents have a desire to salvage personal property and access their properties in general. As Esworthy et al. (2006) note, public health protection must be balanced with allowing the public to access homes and businesses.

Table 8.3 Indicators for determining the feasibility of public participation in clean-up works

	Disaster & disaster waste indicators									
	Disaster scale	Number of displaced persons	Geographic extent	Duration of hazard	Disruption to road network	Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Difficulty of handling waste
Public participation desirable	-	L	-	-	-	-	L	-	-	L
Public participation likely not feasible*	-	H-M	-	-	-	-	H-M	-	-	H-M
* For private property clean-up public participation may be even more difficult to achieve where a low level of insurance is combined with these indicators.										

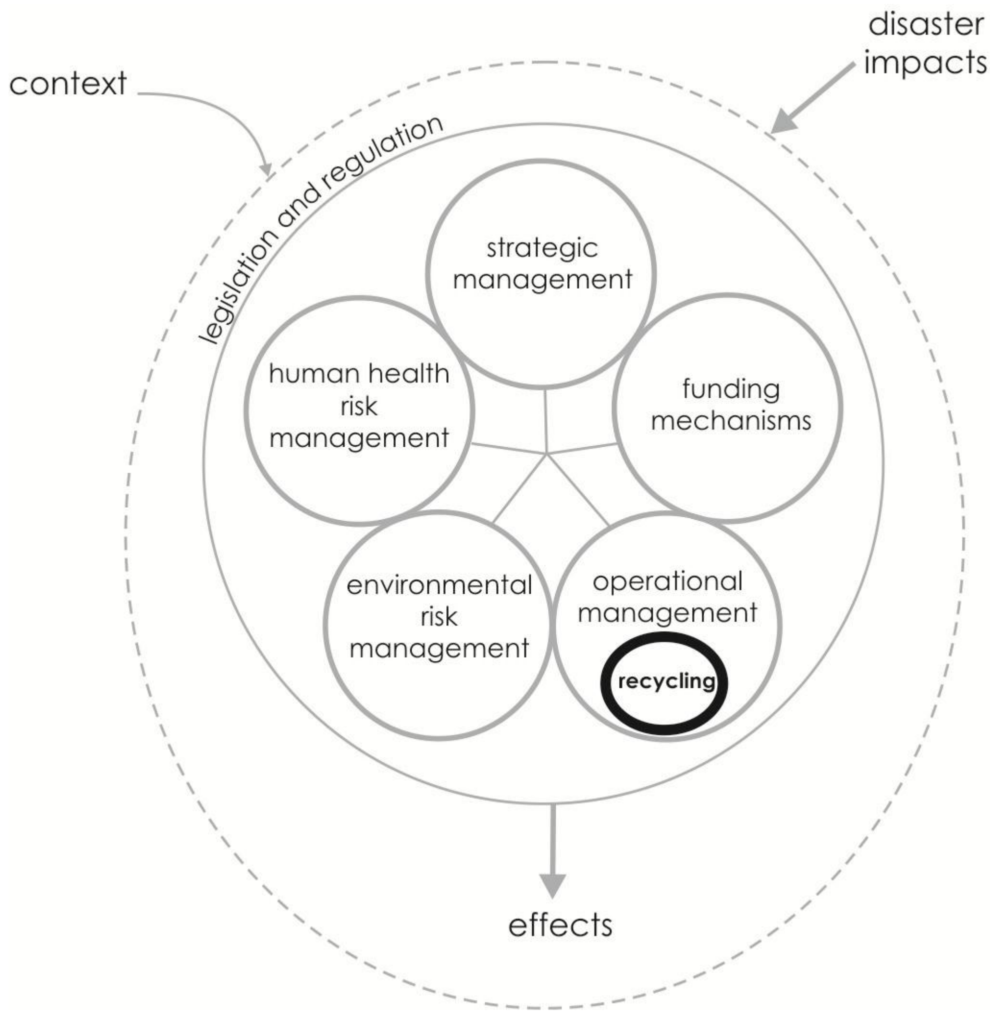
Figure 8-5 Community members participate in a Conservation International sponsored mangrove clean-up following the 2009 Samoan Tsunami. (Photo date: April 2010.)

8.4 Summary

As the case studies have shown, the suitability of operational management strategies is highly dependent on many contextual (in particular funding and legal) constraints and the disaster impacts. Many of the case studies discussed here significantly altered established approaches to disaster response because existing systems were not seen as appropriate for the scale and impact of the event. Disaster waste managers need to have flexible plans in order to determine the most suitable implementation strategies specific to that event. Generally operational management structures can be divided into individual or centrally managed systems.

As the impacts of a disaster increases, greater control of operations is needed. In particular, where the following impacts are present, centralised operational management systems should be considered: high disaster scale, high number of displaced persons, high disruption to the road network, medium to high environmental and human health hazards, medium to high movement of the waste (across property boundaries) and high difficulty in handling the waste. When these impacts are present, centralised, controlled approaches will help to offset the potential negative effects on the recovery through slow or inappropriate demolition and waste management. Centralised management processes should also include waste handling facilities. This enables forward planning, better quality assurance, and is arguably more cost and time effective. Use of local labour, has many positive environmental, economic and social effects on the affected community.

In terms of procurement, in the author's opinion, operational risks during a recovery process should be held by persons or authority with the overall recovery in mind, such as the designated recovery authority. The collective (community-wide) risk of failure of the demolition programme, community-wide, is far greater than the risks considered by a series of independent contractors planning their own operations. In the absence of an integrated management procurement structure, time and cost contracts remove the majority of risk from the contractors and places it with the authority / organisation managing the demolition.



9. Post-disaster reuse and recycling

9.1 Introduction

As discussed in Section 1.5.2, recycling post-disaster has not been systematically researched. Many authors describe recycling as a necessary part of disaster waste management; however, few have critically analysed the opportunities and constraints of recycling in a post-disaster situation, and how recycling can best be achieved. For example, why and how did waste managers achieve a 95% reuse and recycling rate following the 2000 Cerro Grande Wildfire in New Mexico (USEPA, 2008), whereas, in Louisiana, following Hurricane Katrina, the primary management option was landfilling?

Despite environmental benefits, in peace-time recycling is generally only carried out if it is the most economically favourable option. Figure 9-1 is a diagrammatic representation of the economics of recycling. From an economic point of view the feasibility is dependent on: the cost of waste disposal (including transportation), and the value of the recycle materials (including transportation) (which in turn is dependent on the usability of the product and the cost of raw materials). Incentives are sometimes provided to ensure the economics of recycling are favourable (such that the environmental benefits are realised).

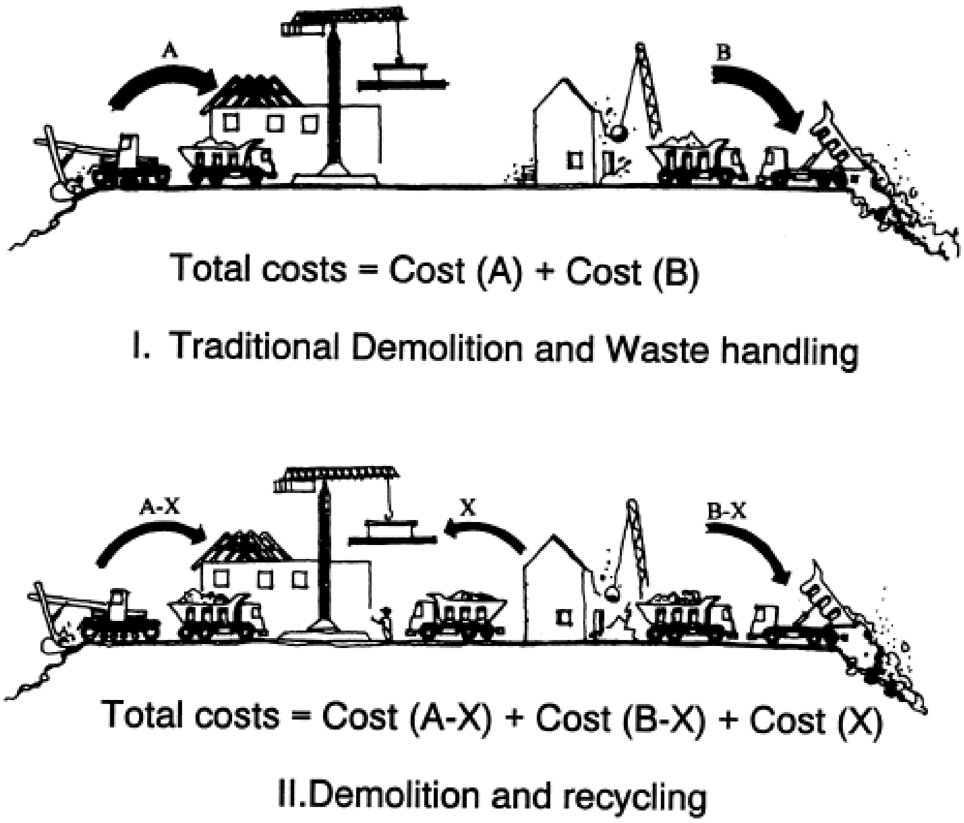


Figure 9-1 **Costs of demolition without recycling (I) and with recycling (II) where A: amount of natural materials and transportation; B: amount of transportation and disposal of waste materials; X: amount of recycled materials. (Lauritzen, 1998)**

Post-disaster, the equation is largely the same. However, how does an increased volume of waste and a post-disaster environment alter the feasibility and desirability of recycling?

The mechanism for post-disaster recycling also needs to be considered. Recycling can either be carried out at the waste source site (for example, the demolition site) or it can be transported mixed to a waste handling facility. In peace-time the relative advantages and disadvantages of each method are reasonably well known, see Table 9.1. The relative merits of each method have not, however, been assessed post-disaster.

Table 9.1 Advantages and disadvantages of source and co-mingled separation (Department of Labour, 2011)(reformatted)

Recycling Method	Advantages	Disadvantages
Source Separation	• Higher recycling rates • Lower recycling costs; revenues paid for some materials • Often a cleaner, safer worksite	• Multiple containers on site • Workers must separate materials for recycling • More complex logistics • Multiple markets; more information to manage
Co-mingled Recycling	• Only one or two containers onsite • No need for workers to separate materials for recycling • Easier logistics • One market; less information to manage	• Lower recycling rates • Higher recycling costs

The aim in this chapter is to answer, in qualitative terms, the following:

- What are the drivers and barriers to recycling post-disaster?
- How should recycling be integrated into the recovery works?

9.2 Case studies

9.2.1 2009 Victorian Bushfires

Initially no provision or requirement for recycling was made by either the managing contractor or environmental authorities. However, as part of business best practice and in order to reduce costs of demolition, the contractor instigated a recycling programme. The proceeds from the recycling were donated to the community and bushfire recovery funds. Recycling did not appear to significantly affect the demolition activities. Figure 9-2 shows metal being removed from a bushfire affected property.

Figure 9-2 **Contractors remove metal separated from bushfire waste following the 2009 Victorian Bushfires. (Photo date: March 2010.)**

9.2.2 2009 Samoan Tsunami

Efforts to recycle in Samoa, following the tsunami, were mixed between agencies and clean-up projects. Some recycling was carried out at source and some recycling was carried out at the disposal site by informal scavenging. In peace-time, Samoans actively recycle, therefore it was natural aspect of the recovery.

9.2.3 2009 L'Aquila earthquake

Early in the recovery process, the Department of Civil Protection decided that the debris would be recycled. It is unknown why this decision was made. There is a law regarding local authorities responsibilities to increase recycling rates (Ministerial Decree 11.4.2007), however there is currently no legislated target for recycling.

The desire to recycle, however, was not well supported by the operational plan and legal framework. Initially waste was taken mixed to a waste handling facility (temporary staging areas) to be sorted. The limited available staging areas were soon full as authorities struggled to find temporary staging areas and end-use markets for the predominantly aggregate material. Markets considered by authorities included aggregates for quarry remediation, and recycled aggregate for engineering applications. Perhaps as a result, a decision was made to separate waste at source. This contributed to a reduction in the speed of demolition and debris removal from an estimated 600 tonnes/day to 100-200 tonnes/day.

9.2.4 2005 Hurricane Katrina

Initially, recycling was not included as a priority for emergency and early recovery phase works in Louisiana. Two months after the hurricane, recycling was identified as a priority to minimise waste going to landfill. Despite this intent, the majority of waste was taken mixed to low cost Construction and Demolition landfills (with expanded post-disaster waste acceptance criteria). There were several reasons cited for this:

- Time constraints on contractors (Roper, 2008; Ardani et al., 2009) / recycling was believed to be unreasonably slow (GAO, 2008)
- Mixed nature of the waste (Esworthy et al., 2006; Roper, 2008).
- Presence of formosan termites (Roper, 2008).
- Presence of asbestos.
- Flood damage to gypsum (Roper, 2008).
- Limited number of temporary staging sites (LDEQ, 2006b).
- Cheap disposal fees (Roper, 2008) due to high competition between private landfills.
- Higher (than landfilling options) transportation time and fossil fuel use (GAO, 2008)
- Large geographical collection area (loss of economies of scale) (Roper, 2008).
- Possible disruption and/or capacity of local or regional recycling industry and/or funds to purchase capital equipment (Ardani et al., 2009).
- Lack of capital equipment or operating space to recycle (Ardani et al., 2009).
- Lack of assured income from tipping fees or from electricity sales (waste to energy technology) (Ardani et al., 2009).
- Lack of contract specific requirements for recycling (Roper, 2008).
- Contract payment methods (e.g. payment per load to staging area or landfill) (Ardani et al., 2009).
- Lack of education / awareness of recycling options (Roper, 2008; Yepsen, 2008).
- Extended ‘crisis’ mentality leading to inertia in establishment of recycling facilities (Ardani et al., 2009).

- Directives mandating either transport of vegetative debris from processing sites to landfills or air curtain incinerators (Ardani et al., 2009).
- Lack of a plan and/or means to implement recycling opportunities identified in the plan (Ardani et al., 2009).
- Absence of residents to carry out initial waste separation (Cook, 2009).

There seemed to be a disconnect between the stated intent to recycle and the practicalities of achieving this goal. The systems and facilities were not put in place to ensure the recycling objectives were met (see Section 6.2.4). Conversely, the objectives did not consider the realities of the situation.

9.2.5 2011 Christchurch Earthquake

Recycling was included in the debris management plan for many reasons:

- To reduce waste going to landfill and therefore disposal costs[17]
- To avoid bottlenecks in the transportation of waste to Christchurch's regional landfill.
- To optimise cost recovery and the environmental benefit of beneficial reuse and recycling.
- To maintain Christchurch's 'green image'.

Recycling, in peace-time, is generally feasible due to the high disposal costs in Christchurch and several regulatory provisions (the Christchurch City Cleanfill Bylaw and the Waste Minimisation Act). The economic feasibility of recycling concrete for reuse (e.g. in roads and construction) is marginal however, due to the ample and low cost supply of raw aggregate in Christchurch.

Post-earthquake, the free disposal of aggregate at Lyttelton Port, initially further reduced the economic feasibility of traditional aggregate / concrete recycling. However, it is interesting to note that within a year of the earthquake, the crushed concrete re-sale market had changed

[17] Waste disposal at Christchurch's regional landfill is, generally, the most expensive waste management option. This is partly due to the distance of the landfill from Christchurch (130km return) and the requirement to use specialist trucks (requiring double handling between demolition trucks and closed landfill trucks).

from a cost negative ($20/T disposal fee for waste concrete) to a cost positive ($2/T payment for receipt of waste concrete). It is unknown whether other recycling markets improved or reduced during the clean-up.

Initially, no on-site separation was carried out post-earthquake. All mixed waste was taken to Burwood Resource Recovery Park (BRRP) or other mixed waste facility for separation. Following completion of search and rescue type activities, a 'quick pick and go' demolition model was established. This enabled 'clean' debris that could be easily and quickly removed from the buildings to be directed straight to end-use market while the remaining mixed waste could be sent to BRRP or other for separation, processing, recycling and onward disposal. The aim of this approach was to maximise speed of demolition but also to balance costs and environmental impacts. Full building internal strip-outs (as is practiced in peace-time) were often not possible due to the continuing aftershocks and subsequent danger to workers, therefore waste often included building contents and fittings. It was acknowledged that the 'quick pick and go' approach would likely be marginally more expensive on a site by site basis but the economic benefits of the faster recovery for the community would outweigh the additional costs. As the recovery progressed, the buildings being demolished became more stable, lump sum contracts (see Section 8.2.5) were issued, and more and more recycling (including full internal strip-outs) was carried out on site.

Waste from major building repairs, infrastructure, detritus and reconstruction were / are being largely handled in line with peace-time regulations and approaches. That is, recycling is being carried out where economically feasible.

9.3 Discussion

9.3.1 Feasibility of post-disaster recycling

The drivers for, and barriers against, recycling in peace-time are well acknowledged. Generally the drivers stem from a desire to reduce costs, reduce the demand for raw resources, reduce a community's environmental footprints, to meet government policies and take advantage of recycling incentives. The barriers generally arise from: high collection, separation, disposal, and transportation costs; the absence of viable recycling markets; the availability of low-cost raw materials; and high carbon emissions from recycling processes.

This discussion is going to focus on the drivers and barriers which are specific to the post-disaster situation.

Using the disaster & disaster waste impacts developed in Chapter 4 the major 'driver' for recycling identified by the author is the volume of waste. Other disaster & disaster waste impacts which indicate where recycling may not be feasible include: the geographical extent; the human health hazard; and the difficulty handling the waste. These are discussed below and summarised in Table 9.2.

The desire to recycle disaster waste is likely to increase as the volume of waste increases. This is particularly true if the capacity of alternative waste management options such as landfilling and incineration are insufficient to handle the waste. In Japan, following the 2011 tsunami, the limited land area and peace-time reliance on incinerators (with limited capacity) have made recycling an imperative part of the recovery effort.

As the volume of waste increases, the need to recycle will generally increase.

As the volume of waste increases, however, the economic feasibility of recycling is likely to decrease. Peace-time reuse and recycle markets will quickly become flooded with the huge amounts of recyclables potentially generated, which will decrease the value of the items / materials. For example: what is Christchurch or New Zealand going to do with 10,000 second hand toilets? New markets may emerge because of improved economies of scale; however, the author believes that new markets are unlikely as the short duration of the waste supply will counter the economies of scale benefits, especially for operations with high capital investment. One option would be to store the large waste volumes for later recycling (at a more sustainable rate). However, this requires significant storage areas. A medium term storage option is currently being investigated in Christchurch for treated timber. The treated timber is being disposed of in a separate site for later mining if a suitable and economically beneficial use for the timber is developed (for example, waste to energy).

As the volume of waste increases, the economic viability of recycling will likely decrease.

Recycling is generally more labour intensive than other waste management options. Consequently, as the volume of waste increases, the demand on labour resources will increase. In a resource constrained post-disaster environment, this could create delays and therefore may limit the feasibility of recycling. Availability of sufficient plant, equipment and space, similarly, will also constrain a community's ability to recycle post-disaster.

As the volume of waste increases, resource shortages (plant, personnel and processing facilities) are likely to limit recycling capacities.

As the geographical extent of the damage increases, the economies of scale are likely to decrease (for a constant volume). Transportation distances to recycling processing facilities and the recycling markets themselves will increase and will reduce the feasibility.

As the geographical extent of damage increases, the feasibility of recycling likely decreases.

The economics of recycling will also depend on the geographical isolation of the affected community. In a small and isolated community like Samoa or New Zealand, there are unlikely to be large recycling markets (compared to, say, Europe). Constraints arising from geographic isolation are likely to be reflected in peace-time recycling practices, so for the purposes of this thesis they are not considered a disaster specific consideration.

Geographical isolation will decrease likelihood of post-disaster recycling being feasible.

If the waste presents a human health hazard the feasibility of waste separation / recycling decreases. In particular, if there is a chemical hazard it may become too difficult, too expensive or even impossible to separate the recyclables and non-recyclables.

As the human health hazard increases, the feasibility of recycling decreases.

Highly mixed wastes can be costly to separate. Poorly separated wastes in turn can reduce the value of the recycled product. Given the volume and speed at which the waste is being dealt with post-disaster, impurities are highly likely. The hurricane and flooding damage caused by Hurricane Katrina meant that wastes were often mixed beyond the point where separation was practical (Esworthy et al., 2006). Much of the material was also damaged beyond the point of being able to recycle it (e.g. flood damaged gypsum) (Roper, 2008). The collapsed buildings in Christchurch meant that building contents (personal property, putrescible wastes, electronic goods, furnishings etc.) were mixed with the construction and demolition wastes and this made separation difficult, time consuming and potentially hazardous. All these factors tend to have a negative effect on recycling.

The more mixed the waste is (the more difficult it is to handle), the less feasible recycling is.

Table 9.2 Indicators for recycling feasibility

	Disaster & disaster waste indicators									
	Disaster scale	Number of displaced persons	Geographic extent	Duration of hazard	Disruption to road network	Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Difficulty of handling waste
Recycling feasible	-	-	L-M	-	-	L-M	L	-	-	L-M
Recycling feasibility unlikely	-	-	H	-	-	H	M-H	-	-	H
L=low, M=medium, H=high, - = no influence										

Post-disaster market challenges

As discussed in Section 7.3.3 price escalation is a common phenomenon in disaster responses. The subsequent and inevitable increases in labour and service costs post-disaster coupled with the likely drop in recycled product market demand and value (as described above), severely affects the economic feasibility of recycling. Compounding that, there are some cases where the disposal costs also dropped, such as in the highly competitive C&D landfill market in Louisiana. The low disposal costs in Louisiana made recycling less tenable. In contrast, the regulated landfill in Christchurch ensured disposal costs remained constant and recycling largely remained viable.

If recycling is a desired part of the waste management strategy, but is less feasible than other options, authorities could use legislative or regulatory provisions to ensure recycling is a viable option (see Section 11.3.3).

Recycling, as in peace-time, is dependent on the availability and relative costs of alternative waste management options.

Further research into the challenges of post-disaster recycling market fluctuations would be beneficial.

Funding

The policies around debris and demolition management funding often dictate which waste management options have to be taken, including the level of recycling. In general, as stated in Section 7.3.3, policies stipulate the lowest (direct) cost option should be taken. Additional direct costs for a more environmentally sustainable option (such as recycling) are harder to justify when private funding systems are in place (such that individuals essentially take the additional costs for wider community benefits). If there is a private funding, one option could be for the local, regional or national authorities to accept the responsibility of paying a 'disaster premium' – the value between the lowest cost to the individual and the cost of the option most beneficial to the wider community.

Stringent reporting and monitoring requirements, required by funding providers, have also reduced the viability of recycling options in the past. Following the 2003 Cedar and Paradise Firestorm, San Diego County elected to used recycling to conserve landfill space. However, the waste monitoring systems at the recycling facilities did not meet FEMA's funding eligibility requirements. Therefore, the County did not receive reimbursement (County of San Diego, 2005).

Generally, it would be beneficial to have funding mechanisms that consider indirect as well as direct costs, such that options like recycling are not inadvertently ruled out.

Funding mechanism policies need to consider indirect costs (as environmentally beneficial options such as recycling are not always the least expensive option).

Public perception

Last, an important consideration is the public acceptance of and desire for recycling. According to Ardani et al. (2009) communities in Louisiana were in favour of recycling.

Following the Christchurch earthquake, residents were reportedly disappointed that there was limited recycling: particularly in response to the disposal of native timbers and the consenting of the land reclamation at Lyttelton Port (in place of concrete recycling). Some residents in the residential red-zone were disappointed that they were unable to relocate their houses due to restrictive building covenants on new subdivisions. In contrast, one community member in L'Aquila felt it was wrong to recycle and reuse rubble that 'had killed people' to rebuild the city.

Public perception towards recycling should be assessed and considered during the decision-making process.

9.3.2 Post-disaster recycling strategies

After determining whether recycling is feasible / desirable, it is necessary to assess how recycling strategies should be implemented. As discussed in Section 9.1, primarily this is the decision to either recycle onsite or offsite. The following factors should be considered:

Time constraints

As discussed in Section 5.2.4 the speed of recovery is often a key recovery objective. The urgency to clean-up is not a total barrier to recycling but it does affect how recycling can be implemented. In terms of demolition and debris management, 'the speed of recovery' essentially translates to 'the time taken to clear the site' (as opposed to completely managing the waste). Site separation can typically take upwards of two times longer than straight demolition, depending on the level of recycling achieved. Therefore, if there are time constraints, an offsite recycling model may be the most effective approach. After the 2010 September earthquake in Christchurch, Manchester Courts was an example of where site separation was practiced and the community became disgruntled over the extended demolition time and resultant economic impacts on neighbouring businesses (Sachdeva, 2010). In L'Aquila the decision to move from offsite to onsite waste separation slowed the debris removal rate from 600 tonnes/day to 100-200 tonnes/day.

Offsite separation reduces the time required onsite to demolish structures.

Costs

Offsite separation, as noted in Table 9.1, can increase the waste management costs. It is acknowledged that collection of mixed wastes and the use of waste handling facilities (such as temporary staging areas) increases the cost of waste management systems (FEMA, 2007). In addition, with less material likely being recycled, there will be reduced recycling revenues and potentially (depending on the context) higher disposal costs. In Christchurch, where disposal costs are particularly high, it was initially estimated that offsite recycling would increase the demolition and debris management costs by approximately 15%.

Therefore, in general, direct costs are likely to increase as site separation reduces, however the time to demolish will decrease and therefore indirect costs (such as business losses) will reduce (as discussed in Section 5.2.4). Direct costs of offsite separation may reduce if labour costs increase significantly and/or offsite separation costs reduce (say, for example, through advanced labour-free technology).

Offsite separation increases the direct costs but likely reduces the indirect costs.

In order for separation offsite to be more feasible (than onsite separation) the net cost of transport to the resource recovery park, sale of processed materials, and disposal of residuals, needs to be comparable to onsite net costs. If the resource facility is close to the affected area and the facility is large (that is, there will be economies of scale) this is possible. Burwood Resource Recovery Park in Christchurch met these criteria, however the large number of demolition contractors working independently affected the feasibility of this model. The demolition contractors were only interested in maximising profits for the demolition works: generally, maximising revenue from recyclables and minimising residual disposal costs. Many contractors established independent waste management sites to achieve their own financial objectives (legal and illegal) so the possible economies of scale at the Burwood Resource Recovery Park were not fully realised. As a result, the offsite sorting costs were higher than necessary, more onsite recycling was carried out and the demolition times increased.

Offsite separation costs can be comparable to onsite separation costs where the recovery facility (facilities) is close to the affected area and economies of scale can be realised.

Resource availability

The feasibility of offsite separation is of course dependent on an available waste handling facility or facilities close to the affected area.

Offsite separation is dependent on access to a suitable waste handling facility, relatively close to the affected area.

The feasibility of site separation is dependent on the availability of demolition resources (e.g. equipment and trained personnel). As discussed in Section 8.3.4, if buildings are continually identified and released for demolition (by authorities or insurance companies) then resources should theoretically be maximised. Therefore, contractors are able to work quickly on site and move to the next site to reduce the overall recovery time. However, if works are not released quickly and there are ample contractors, there is more time to carry out onsite recycling.

Site separation is more feasible when there are more demolition resources available.

A fast demolition or debris management programme due to offsite separation, may introduce resource bottlenecks. For example, there may be insufficient trucks to transport the waste to the offsite facility, as feared (but not realised) in Christchurch. There could also be bottlenecks on roads or at waste handling facilities.

Offsite separation may create resource bottlenecks due to the fast demolition, such as: contractor availability, truck availability and waste handling facility capacity.

Disaster and disaster waste impacts

A number of disaster and disaster waste impacts will influence whether recycling is feasible or not. These are discussed below and summarised in Table 9.3.

Generally if the waste is very mixed (but separation is generally feasible, see Section 9.3.1), site separation may be more costly and time consuming than offsite separation. Offsite separation may be more feasible, particularly where mechanical equipment is necessary to separate the wastes efficiently.

Generally, the more mixed the waste (difficulty in handling), the less likely site separation is feasible.

While chemical hazards make it almost impossible to recycle, physical hazards (e.g risk of fall or collapse) generally indicate that offsite separation should be used. For example, demolition of buildings in Christchurch initially had to be carried out without internal strip-outs due to their risk of collapse. This made the wastes very mixed and onsite material separation, less feasible.

In addition, as described in Section 5.3, environmental and human health hazards are also likely to need to be cleared quickly to manage the risks. This, in turn, makes site separation less desirable. Hazards with a high potential for human health hazards such as tsunami and flood events (see Table 4.7), therefore, are less likely to be able to be site separated.

Offsite separation is appropriate where (physical) human health hazards exist.

Separation off-site at temporary staging areas, potentially exposes workers at the temporary separation sites to greater levels of hazards (both physical and chemical) as they have less control over what materials they receive. The risk to the environment is also higher. Mitigation measures, however, can be put in place to minimise exposure to potential risks more easily at a limited number of disposal sites as opposed to hundreds or thousands of individual demolition and debris management sites. On-site separation exposes the community around the demolition and debris management sites to greater risks and potentially exposes a greater number of workers to hazards within the waste.

Human and environmental health hazards can be better managed by off-site waste separation.

In the US, public participation is relied upon to carry out source separation of wastes (for private property detritus removal). The absence of residents to carry out initial waste separation following Hurricane Katrina, significantly affected the ability and feasibility of waste contractors to source separate (separate on-site) materials for kerbside collection (Cook, 2009).

The ability to rely on public participation for site separation (on residential properties), decreases as the <u>number of displaced persons</u> increases.

Conversely, onsite separation becomes more feasible when there is a large displacement of people because there are fewer space and vehicle movement constraints. Note that this only applies if contractors (not residents) are doing the separation. It should also be noted that contractor separation on-site will take more time which will prevent people returning for longer (see Section 5.3).

The ability for contractors to site separate waste (on residential properties) increases as the <u>number of displaced persons</u> increases.

If the road network has been heavily affected, authorities will likely want to rationalise truck movements – in both quantity and routes taken. Separation offsite would limit the destinations for waste coming from the site to designated waste separation areas. Separation onsite, on the other-hand, would mean trucks would be travelling to multiple destinations (to recyclable end-markets). The number of trucks may be slightly higher for sites relying on offsite separation due to the bulkiness of the waste leaving the site.

Separation offsite will allow for greater consolidation of truck movements if there is significant <u>disruption to the road network</u>.

Table 9.3 Indicators for recycling strategy

	Disaster & disaster waste indicators									
	Disaster scale	Number of displaced persons	Geographic extent	Duration of hazard	Disruption to road network	Volume of waste	Human health hazard	Environmental health hazard	Movement of waste	Difficulty of handling waste
On-site separation	-	H (by contractors) L (by public)	-	-	M-L	-	L	L	-	L
Off-site separation	-		-	-	H	-	M-H	M-H	-	M-H
L=low, M=medium, H=high, - = no influence										

Environmental effects

From an environmental point of view, increased site separation increases the amount of material salvaged. But environmental benefits of recycling are also dependent on transportation distances and energy input for recycling. Some recycling operations, also, can have environmental risks. For example, the large stockpile of unprocessed waste at the Burwood Resource Recovery Park in Christchurch has the potential to contain materials that may have adverse environmental effect, such as electronic equipment, whiteware, putrescibles etc. This is especially possible due to the uncertainty in the nature and quality of wastes received during the initial stages of the operation (see Section 10.3.1). While the intent of the recycling operation is an environmentally beneficial waste management solution (by reducing waste to landfill and maximising raw material reuse), there are some immediate environmental concerns with the operation and potential for contamination.

Environmental risks around both onsite and offsite separation need to be considered.

9.3.3 Recycling Principles

Generally it is the responsibility of strategic managers to determine the extent and mode of recycling. Strategic managers must weigh up the factors discussed in this Chapter to determine the most appropriate approach for the recovery effort. The case studies show, however, that in the past strategic managers have not proactively set recycling policies and/or they have not established the systems to support the recycling policies. This was particularly evident following Hurricane Katrina.

Following the Bushfires, all recycling decisions were the responsibility of the main contractor. Following L'Aquila, the decision to recycle everything was made without a robust operational plan and legislation to enact the intent. This caused a stale mate in the debris management activities. Following Hurricane Katrina, as discussed in Section 9.2.4, recycling decisions were largely left to contractors. Authorities failed to educate on, implement and coordinate substantial recycling facilities. In Christchurch, while initially there were limits over the degree of recycling onsite, the lack of control of individual contractors and business owners (as discussed in Section 9.2.5), led to individual decision-making regarding recycling. This arguably slowed the demolition activities as there was increased on-site sorting.

Strategic management strategies need to include recycling policies and corresponding institutional support systems.

From an operational point of view, control of recycling initiatives can be better affected if a centrally managed approach is used. In Christchurch, for example, during the early demolition in the CBD, there was a time imperative. Contractors working independently consistently recycled more on site and in turn took longer to clear the store than contractors engaged by CERA. As discussed in Section 8.3.2, private approaches more effectively allow for reuse opportunities (e.g. to crush concrete on site) on a site by site basis.

Recycling operations (particularly in terms of timeliness) are better effected under a centrally managed approach.

From a procurement perspective, lump sum contracts tend to give the recycling decisions to the contractor. Lump sum contracts, in the high disposal cost environment of Christchurch, provided incentives for recycling: whereas in low value recycling environments, such as Louisiana, disposal became the favoured option. As discussed in Section 8.3.4, lump sum contracts will generally favour highest profit options and will not consider effects on overall recovery. Some recycling and debris reuse advocates have cited the default option under FEMA regulations of contracting disaster waste activities (lump sum contracts) as a limiting factor in achieving desired recycling levels. Contractors in the past have brought in the wrong equipment and have not processed materials to match the markets that are available (Yepsen, 2008). By contrast, in Christchurch, contractors have shown initiative in developing new recycling markets and making existing markets more economically viable. Regardless of contract type, contract conditions could be written to include desired levels and mode of recycling, as suggested by Roper (2008).

Payment mechanisms within contracts, for example, can be written to encourage recycling. After both Hurricane Katrina and the Samoan tsunami, contractors were paid on a per truck trip basis to the point of disposal. There was no incentive to source separate. In Samoa, in fact, waste was sometimes segregated at source and then carried mixed to the disposal site. More monitoring or incentives for separated loads may have increased the recycling rate.

Incentives were suggested as an improvement after the Cedar and Paradise Firestorm (County of San Diego, 2005) and following Hurricane Katrina (Ardani et al., 2009).

Contract types and terms need to include for recycling.

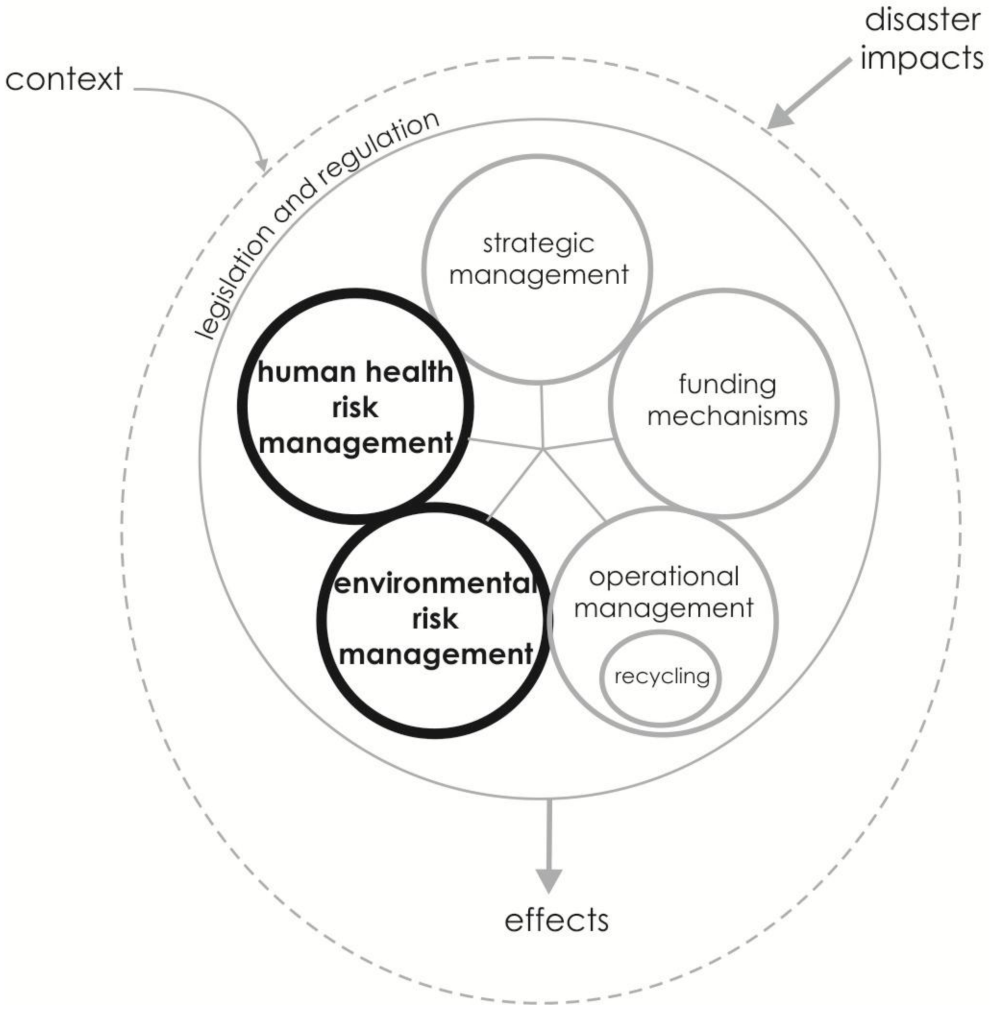
Legislative and regulatory provisions can be used to achieve the desired recycling goals. The discussion in this chapter can be used to determine where legislative and regulatory controls may be most effective to facilitate or manage post-disaster recycling. This is discussed further in Section 11.3.3.

9.4 Summary

The case study analyses have identified a number of factors that influence the viability of recycling post-disaster. While it is possible to list the factors in isolation, a much deeper understanding can be gained by looking at how the individual factors influence each other, and the overall recovery goals. Based on the discussion in this chapter, over and above the peace-time challenges to recycling (largely economic feasibility), the following barriers to post-disaster recycling have been identified:

- Time constraints
- Resource availability (plant, personnel and processing facilities)
- Mixed nature of waste
- Hazards in the waste matrix
- Displaced population
- Post-disaster market challenges (capacity, availability, value, disruption, space limitations, location relative to affected area)
- Contractual arrangements
- Availability and feasibility of alternative waste management options

Generally, the method of integrating recycling into the demolition will depend on the urgency to demolish the structures. If there is an urgency to clean-up, and there are facilities / spaces available to operate a resource recovery facility close to the affected area, recycling should be carried out offsite. However, if a processing facility cannot be established within a reasonable distance to the affected areas and/or the market, source separation may be preferable.



10. Environmental and human health risk management

10.1 Introduction

Most communities have established environmental standards that guide the process of managing waste in peace-time. Environmental standards generally include the protection of land, air and water and will often provide special protection for sensitive ecosystems such as marine and wetland areas. Similarly, communities will generally have human health standards in place to protect both workers and the general public from risks associated with waste management.

These standards or risk management mechanisms are generally developed in, and for, a peace-time context. In a post-disaster situation, this context changes considerably: the affected community's priorities have generally been altered; there can be pressure to manage the waste as quickly as possible (see Chapter 5); and waste management personnel and facilities are often overwhelmed. In past disaster events some peace-time risk management approaches have been considered too time or resource intensive or too costly. Consequently, as described in Section 1.11, disaster waste managers have been forced to either alter peace-time standards and/or implement alternative risk management strategies.

This chapter includes an analysis of how environmental and human health risks were managed in the five case studies discussed in this thesis. The aims of this chapter are:

1. To identify the key environmental and human health risks associated with post-disaster waste management;
2. To understand the different methods of altering risk management strategies; and
3. To determine the key principles for managing environmental and human health risks post-disaster.

10.2 Case studies

In all of the case studies presented in this thesis, except for the Samoan Tsunami, peace-time environmental and/or human health standards were altered to facilitate recovery through legislative, regulatory or organisational changes. Key deviations from environmental risk management standards (related to waste management) are presented in Table 10.1. Deviations from human health standards (related to waste management) are presented in Table 10.2. The tables outline the nature of the standard alteration, the reason for altering the standard (if known) and the management strategy. For the purposes of this analysis the nature of the standard change is divided into four categories: higher risk accepted (standard altered); higher risk ignored; exempted permitting (i.e. no specific consent is required to carry out the activity); expedited processes (i.e. approval is required to carry out the activity but the peace-time process is stream-lined to allow more expedient approval).

It should be noted that Table 10.1 and Table 10.2 shows the strategy taken not the outcomes achieved. That is, acceptance of high environmental risk does not mean that the environment was adversely affected. In addition, expediting processes to achieve peace-time outcome does not mean that peace-time outcomes would always be achieved. As outlined in the Methodology Chapter (Chapter 2), the intent of this research is not to make absolute assessments of the suitability of peace-time standards, rather it is to determine whether the desired outcomes where achieved, relative to the context. Thus, only examples where existing standards have been altered have been included in the analysis.

Table 10.1 Case study deviations from environmental risk management standards (associated with waste management)

Disaster Environmental standard	Management strategy	Nature of standards alteration*				Justification
		Higher risk accepted (standard lowered)	Higher risk 'ignored'	Exempted permitting (no approval needed)	Expedited processes (stream-lined approval process)	
2009 Victorian Bushfires						
1. Bushfire waste classification	All waste was classified as "C&D waste with contamination" and authorised for disposal at municipal landfills despite potentially containing elements which ordinarily would need to be disposed at a prescribed industrial waste landfill. No testing was carried out.	✓		✓		• To remove hazardous materials, minimise public health hazard and to help communities recover as quickly as possible. • To simplify regulatory and procedural requirements to handle the waste.
2. New landfill cell constructed	An existing landfill site, with known hydrogeology and existing monitoring equipment, was utilised for bushfire waste disposal. The waste was qualitatively assessed to be primarily inert and posing low environmental risk in an unlined landfill cell. It is unlikely this would have been approved in peace-time.	✓			✓	• To eliminate the need for waste trucks to drive over a dangerous stretch of road.
2009 L'Aquila earthquake						
1. Temporary staging, recycling and disposal siting.	Existing standards for identification of waste handling facilities were maintained, while regulatory processes for approval of the sites were expedited and delegated to the earthquake recovery commissioner (as opposed to the local and regional environmental authorities).		✓		✓	• To expedite debris management works.

* Note that this indicates the risk management strategy taken, not the outcome achieved. That is, acceptance of high environmental risk does not mean that the environment was adversely affected. In addition, expediting processes to achieve peace-time outcomes does not mean that peace-time outcomes were always achieved.

Disaster	Management strategy	Nature of standards alteration*				Justification
Environmental standard		Higher risk accepted (standard lowered)	Higher risk 'ignored'	Exempted permitting (no approval needed)	Expedited processes (stream-lined approval process)	
2005 Hurricane Katrina						
1. Open burning	Open burning permits were no longer required.		✓	✓		• To maximise treatment options. • To reduce delays due to permitting.
2. Landfill waste acceptance criteria	The waste acceptance criteria at Type III (C&D) landfills were expanded. Furniture, carpet, painted or stained lumber contaminated waste (LDEQ, 2005b) were also included where it could not be separated.	✓			✓	"the most expeditious and environmentally sound manner as possible under the circumstances" • To provide adequate disposal space. • To reduce the cost of disposal. • To reduce the time-lag that would be incurred in lining new landfill cells. • To preserve space in Type I and II landfills (LDEQ, 2006b)
3. Landfill permitting	Gentilly and Chef Menteur landfills were reopened and opened, respectively, using emergency powers.	✓			✓	• To reduce waste haul times. • To reduce cost. • To minimise waste disposal facility bottlenecks.
2011 Christchurch earthquake						
1. Temporary staging area permitting	An Order in Council was passed to permit all facilities, meeting specific criteria, to operate as waste storage facilities for up to five years. Minimal environmental impact assessment and public consultation was carried out.		✓	✓		• To prevent delays in approval of temporary staging areas.
* Note that this indicates the risk management strategy taken, not the outcome achieved. That is, acceptance of high environmental risk does not mean that the environment was adversely affected. In addition, expediting processes to achieve peace-time outcomes does not mean that peace-time outcomes were always achieved.						

Disaster Environmental standard	Management strategy	Nature of standards alteration*				Justification
		Higher risk accepted (standard lowered)	Higher risk 'ignored'	Exempted permitting (no approval needed)	Expedited processes (stream-lined approval process)	
2. Lyttelton Port land reclamation permitting	An Order in Council was passed to allow for land reclamation at Lyttelton Port. Expedited environmental impact assessment and public consultation was carried out.	✓			✓	• To ensure continuing economic activity of the Port (by allowing repairs and providing more space). • To enable the Port to manage building supplies for the rebuild. • To reduce waste disposal costs.
3. Burwood Resource Recovery Park permitting.	An Order in Council was passed to allow for operation of Burwood Resource Recovery Park. Minimal environmental impact assessment and public consultation was carried out.	✓			✓	• To reduce waste going to landfill. • To reduce waste management costs.
4. New disposal site permitted	An Order in Council was passed to allow the permanent disposal of residual (post-recycling) earthquake waste at Burwood Resource Recovery Park. Minimal environmental impact assessment and public consultation was carried out.	✓			✓	• To reduce waste going to municipal landfill. • To reduce waste management costs.

* Note that this indicates the risk management strategy taken, not the outcome achieved. That is, acceptance of high environmental risk does not mean that the environment was adversely affected. In addition, expediting processes to achieve peace-time outcomes does not mean that peace-time outcomes were always achieved.

Table 10.2 Case study deviations from human health risk management standards (associated with waste management)

Disaster	Management strategy	Nature of standards alteration*				Justification
Human Health standard		Higher risk accepted (standard lowered)	Higher risk 'ignored'	Exempted permitting (no approval needed)	Expedited processes (stream-lined approval process)	
2009 Victorian Bushfires						
1. All waste classified as "C&D waste with contamination"	Workers were required to protect themselves against potential asbestos and other contaminants. However, standard mitigation measures protecting public health and safety were reduced such as removing the requirements to double bag asbestos and to seal demolition sites. No material testing was carried out.	✓		✓		• To remove hazardous materials, minimise public health hazard and to help communities recover as quickly as possible. • To simplify regulatory and procedural requirements to handle the waste.
2009 L'Aquila earthquake						
Insufficient data for analysis						
2005 Hurricane Katrina						
1. Landfill waste acceptance criteria.	Some construction and demolition landfills were designated as "enhanced landfills" and were authorised to accept asbestos.	✓			✓	• To provide adequate disposal space.
2. Demolition asbestos management.	Demolition procedures for buildings with asbestos were streamlined by reducing notification, inspection and reporting requirements, expediting contractor certification, reducing demolition risk mitigation requirements (for example, pre-demolition asbestos removal).	✓			✓	• Minimise exposure while expediting clean-up (Luther, 2008).

* Note that this indicates the risk management strategy taken, not the outcome achieved. That is, acceptance of high human health risk does not mean that human health was adversely affected. In addition, expediting processes to achieve peace-time outcomes does not mean that peace-time outcomes were always achieved.

Disaster	Management strategy	Nature of standards alteration*				Justification
Human Health standard		Higher risk accepted (standard lowered)	Higher risk 'ignored'	Exempted permitting (no approval needed)	Expedited processes (stream-lined approval process)	
2011 Christchurch earthquake						
1. Demolition asbestos management.	Authorities advised that asbestos handling standard best practice could be modified to allow for work on dangerous buildings.	✓			✓	• To minimise risk to demolition workers.
2. Building material salvage	The recovery authority, CERA, advised building owners and demolition crews whether or not it was safe to enter damaged buildings to carry out strip-outs. There were no existing standards.	no existing standards	no existing standards	no existing standards	no existing standards	• To minimise risk to demolition workers.
* Note that this indicates the risk management strategy taken, not the outcome achieved. That is, acceptance of high human health risk does not mean that human health was adversely affected. In addition, expediting processes to achieve peace-time outcomes does not mean that peace-time outcomes were always achieved.						

10.3 Discussion

10.3.1 Risk management principles

Balance environmental, economic, social and recovery objectives

As discussed in Chapter 5, it is important to recognise the contextual shift when assessing and managing risks post-disaster. Peace-time environmental, economic, and social norms may have changed and the recovery objectives provide the added dimensions of timeliness and community focus.

The risk management decisions following the Victorian Bushfires were largely successful. Both the decision to classify the waste as a single waste stream and the construction of the new landfill were examples of where environmental and human health risks were balanced to achieve recovery outcomes. The decision to construct a new landfill cell was largely driven by health and safety concerns for workers and the public resulting from truck travel on a dangerous stretch of road. The landfill cell design did not undergo the same rigorous design and assessment of effects that would have occurred during peace-time to ensure the recovery was not delayed. Decision-makers here made a conscious decision to prioritise human health and safety ahead of environmental protection during recovery. The decision also had secondary benefits of reduced disposal and transportation costs and reducing truck travel time.

Several other cases included examples where environmental standard reduction decisions were made to meet recovery objectives. In Louisiana, after Hurricane Katrina, Gentilly Landfill (a site previously closed on environmental grounds) was reopened on the belief that it would halve the waste disposal time (LDEQ, 2006b). The land reclamation at Lyttelton Port in Christchurch (which pre-earthquake was going through a length Environment Court approval process) was permitted on the understanding that it would aid the economic recovery of Christchurch and assist in the rebuild (through ensuring continuity of Port operations) (Brownlee and Smith, 2011).

The response to the L'Aquila earthquake clean-up, however, was the antithesis to the above examples. The adherence to peace-time environmental standards all but halted the recovery process. It took four months to locate and approve the first temporary storage facility (Bonanni and Stagnini, accessed 2010). Eleven months after the earthquake, expedited processes for identification of the sites were only just established; however, no dispensation on environmental outcomes had been made and authorities were expected to achieve the same environmental outcome in a shorter time. Consequently authorities did not utilise the expedited processes established and the waste removal process was stalled by a lack of waste handling facilities; the environmental outcome at the disposal sites was preserved but the overall recovery objectives (including economic and social objectives) were not being met. The slow waste removal also had public health risks, including: asbestos exposure from an estimated 40-50% of houses containing asbestos; vector breeding from unmanaged putrescible wastes; and risks associated with other unmanaged household hazards.

While balancing environmental, economic and social objectives as part of recovery, it is important to distinguish local effects versus community effects. Following Hurricane Katrina, an activist group protested against the opening of landfills believed to be too close to the affected, and already marginalised, communities (Allen, 2007). Recovery authorities countered that the closer the facility was, the quicker the recovery would be (which would be beneficial to the wider community). If the facility had not been allowed to open, the recovery process would have been slowed significantly and additional disposal facilities would have had to be sought. In Christchurch, at least one potential waste handling facility was prevented from opening because of protests from the neighbouring community (Mathewson, 2011; Sachdeva and Mathewson, 2011). Fortunately this facility was not essential to the recovery and had no noticeable effect on the overall recovery. Somehow, risk assessments must be able to balance these local and wider effects transparently, and communicate these trade-offs to affected communities.

The long term effects of risk management decisions also need to be considered. During the clean-up of the World Trade Centre (WTC) collapse in 2001, regulatory authorities ignored their own health and safety regulations (in particular with respect to asbestos) to facilitate the recovery (Lange, 2004). Air monitoring during the clean-up suggested that the particulate matter (resulting from the collapse and burning of the WTC) was not particularly hazardous due to low asbestos levels, short dust particles and low concentrations of volatile organic compounds. However, construction and demolition workers clearing debris have since shown increased prevalence of respiratory symptoms, particularly those that were exposed to the contaminants for an extended period of time (Landrigan et al., 2004). Short term benefits to the recovery need to be balanced with long term effects on individuals and the wider community.

When establishing post-disaster environmental and human health standards, disaster waste managers need to understand the effects of various approaches on the overall recovery. Most of the decisions in the case studies were qualitatively assessed independently and consequently were, at times, not well received by the affected communities. It would be beneficial to have a more robust and transparent approach to empower the decision-maker (see Section 11.3.5) and to increase public support for decisions that significantly affect the recovery. A possible approach would be to apply the semi-quantitative system effects measurement approach developed in Chapter 5 to risk management decisions. Generally it should be the responsibility of strategic managers to lead this process (see Section 6.3.3).

Environmental and human health risk decisions need to be made (1) in the context of the wider community recovery and (2) as transparently as possible.

Strategic management

As discussed in Section 6.3.2, good cross-organisational coordination is essential for post-disaster risk management. This is especially important when peace-time standards managed by one authority are altered to reduce risks faced by another authority: for example, the Victorian Bushfire landfill cell construction where environmental authorities essentially reduced standards to reduce a health and safety risk. The role of a strategic management authority is vital in risk prioritisation such as this.

Coordination is also essential between risk managers and operational personnel to ensure that risk management strategies proposed are practical and effective. In many of the case studies investigated, there appeared to be minimal coordination between risk decision-making and operational implementation. In terms of risk management, this means that the risks being regulated may not be being managed as effectively as possible. For example, in Christchurch a health and safety issue emerged when independent contractors elected to enter buildings deemed unsafe to perform internal material strip-outs. A central management system (Section 8.3.4) for operational activities is one way that these emergent risks could be better managed.

Risk managers must maintain oversight of operations to ensure emergent risks are identified and managed effectively. Centralisation of operational activities may reduce likelihood of emergent risks.

Accept the uncertainty

Uncertainty is always a factor in risk management. However, the level of uncertainty post-disaster is undoubtedly increased due to: difficulties in gathering and assessing information (see Section 4.2); the volume of waste and the speed at which the work is being carried out; and probably, an augmented waste management work force (experienced and inexperienced) often working under time and financial pressures (see Section 8.3.5). In Louisiana there was significant public concern over the potential for hazardous material inclusion in the debris due to the speed of the clean-up process and the number of out-of-town contractors. These concerns were particularly strong in respect to landfills which had not been operating prior to Hurricane Katrina (Luther, 2008) as operators were inexperienced and were perceived as disaster 'opportunists'.

In the decisions analysed in Section 10.2, disaster waste managers either accepted higher levels of uncertainty and mitigated against all potential effects; or they failed to recognise (or ignored) the increased uncertainty. Examples of where greater uncertainty was acknowledged, included: the management of asbestos following the Bushfires (single waste classification); and the management of asbestos following Hurricane Katrina. When higher risks are assumed and accepted, appropriate mitigation strategies can be put in place to reduce potential short term and long term effects. In the Bushfire case, the mitigation measures put in place provided a high protection level for workers as all waste was assumed to contain asbestos and personal protection equipment was mandatory. Mitigation management techniques can be more-time consuming when a risk-averse approach is taken but considerable time can also be saved by not requiring individual site testing. Increased protection levels also invariably induce higher costs. These costs are often outweighed by the positive effects on the recovery quality and expedience.

Examples of where the uncertainty had been ignored or not fully recognised include: the permitting of open burning following Hurricane Katrina; and the permitting of temporary storage areas following the Christchurch earthquake. In these two examples, authorities allowed for these activities to occur within a set of standards without fully recognising the increased risk and uncertainty posed by a post-disaster situation. Following Hurricane Katrina, the permitting of open burning did not recognise the high volumes and risk of contaminated waste being burnt. In Christchurch, the permitting of temporary storage facilities failed to fully assess and mitigate against the potential environmental and social risks associated with the operation of multiple facilities across the city, by contractors inexperienced in dealing with waste.

As shown by these examples, accepting the uncertainty and mitigating against the potential effects is a prudent approach.

In the absence of data and a full understanding of the risk, accept a higher level of uncertainty and mitigate against the potential effects as far as possible.

Accept resource limitations

By definition, resources (human and equipment) following a disaster are overwhelmed. As discussed in Section 1.1, disasters generate many times the annual waste volume a community ordinarily deals with. Both regulatory and operational resources will be stretched. Risk management strategies need to acknowledge and account for this. Risk management strategies that are too cumbersome are likely to either 1) slow down the recovery by creating a bottleneck or diverting resources away from other recovery activities; or 2) be ineffectual at managing the risks because they are impractical to implement.

Regulatory resource limitations can be mitigated by either:

1. Exempting permitting requirements for specific activities; or
2. Expediting the peace-time risk assessment process.

The first strategy, exempting permitting requirements, can have very mixed results. For example, the approval for demolition of certain buildings without the removal of asbestos pre-demolition following Hurricane Katrina was successful. The risks were well considered and mitigation strategies were established. Louisiana Department of Environmental Quality staff were able to divert their limited resources to other recovery tasks. The exemption from permitting requirements for temporary storage sites for waste after the Christchurch earthquake, however, was not well considered. Basic standards for operation of temporary storage facilities were established which site operators theoretically have to meet. However, some sites were set up without the knowledge of authorities and thus authorities lost visibility of the activities that were taking place. Several sites were not meeting the requirements set out by the authorities. Managing these 'illegal' sites subsequently consumed valuable regulatory resources which negated one of the purposes of the permitting exemption: to reduce demands on regulatory authorities. Meadows (2009) described this system trap as 'rule beating'.

One challenge and potential drawback of establishing permit exemptions is whether to take a risk-averse or risk-taking approach. If a risk-averse approach is adopted, operational costs may be higher than necessary. However, cost and time savings will be made by reducing the level and degree of management and monitoring required. If a risk taking approach is adopted there may be adverse effects in the future which require costly remediation / treatment. The net effect of this will vary depending on the context.

When considering permitting exemptions in a post-disaster situation, cost implications and opportunities for misuse need to be considered.

A major negative related to a permitting exemption is the loss of oversight and control over the process. Once an activity has been approved, if no reporting or notification process is in place, authorities will be 'blind' to that activity and any potentially adverse effects. For example, in Christchurch, due to a law change in late 2010, there is no legal requirement to notify authorities if demolition is taking place and how waste will be managed. As a result, it has been difficult for authorities to identify, monitor and mitigate potential effects resulting from demolition works. Therefore, if permit exemption is adopted, including a requirement for basic reporting or notification is useful for planning and monitoring purposes. In some cases (specifically for environmental risks) this would enable retrospective analysis of an action to be carried out and future remediation completed if necessary. Note that this is only feasible if the risks being accepted are reversible.

Basic notification or reporting should be required for any risky activity to assist authorities in planning and monitoring.

The second strategy, expediting peace-time risk assessment processes, has some benefits compared to permit exemptions. It allows for a site by site assessment to be carried out which is highly beneficial where risks vary significantly between sites. For example, following the Christchurch earthquake, each building had to be individually assessed for safety to determine whether or not an internal building strip-out was possible. A risk-averse, permit exemption approach might have dictated that no buildings could be stripped. This would have had significant cost implications and would likely have been rejected by contractors and building owners. Instead, a site by site assessment and approval process was carried out.

If an expedited assessment approach is adopted, authorities must, however, recognise that the level of uncertainty has increased (due to the reduced time for assessment) and, therefore, mitigation measures must be increased accordingly (as discussed above).

As for permitting exemptions above, monitoring is also important.

An expedited assessment approach is more suitable where risks vary significantly between sites.

Centralised management also offers a conduit to more efficiently manage environmental and human health risks and reduce the burden on regulatory authorities. Centralised management will likely minimise the amount of monitoring required by regulatory authorities – as they only need to focus on the management systems of one organisation not numerous independent contractors – and subsequently improve quality control. Central management systems themselves will generally establish and monitor operating procedures. This was illustrated in the Victorian Bushfires case where the managing contractor was delegated authority to manage the environmental compliance of their transport fleet, subject to occasional audits.

Central management can reduce the demands on resource constrained regulatory authorities.

When there are operational resource shortages, risk managers have options to increase the availability of resources. Simply these can be categorised as:

1. Decrease the demands on operators; or
2. Increase the number of resources available (where there are regulatory constraints).

The first method involves reducing the operational requirements for managing risks. For example, following Hurricane Katrina, authorities elected to reduce asbestos handling requirements; following the Bushfires authorities elected to eliminate the need to separate hazardous waste from the Bushfire waste. Both these decisions reduced operational demands and, therefore, labour and equipment requirements. This strategy also allowed for a consistent and streamlined approach across all worksites. In the case of Hurricane Katrina, this allowed demolition times for houses to reduce from an estimated four days to just one day per house (GAO, 2008). The provisions also allowed the US Environmental Protection Agency and the Louisiana Department of Environmental Quality to carry out more programme oversight work. However, the success of this approval depends on whether a risk taking or risk-averse stance is taken (as discussed above).

The second method, to increase operational capacity, is to increase the available resources. In some situations certification of workers is required to carry out certain works: for example, in Italy contractors must be certified as Environmental Managers; in the US, Australia and New Zealand contractors must be specially certified to handle friable asbestos. In the case studies here, a reduction in contractor certification requirements for handling asbestos was made for Hurricane Katrina. In Victoria, the Bushfire single waste classification essentially increased the number of resources available by assuming that only Class B (non-friable) asbestos was present which contractors do not need certification to deal with. The author considers that quality control of the operations (particularly where limited regulatory monitoring is being practiced – see above) may be compromised by increasing the workforce. Contractors who are already, and intend to continue to be, involved in demolition and waste management are likely to have more experience, knowledge and care to preserve their work quality as part of a long term commitment to the industry. Contractors gaining certification for the purposes of the recovery may not be as aware or concerned about long term implications of their behaviour on themselves or others. Experienced contractors also have the skill to assess the risks on a site by site basis and adapt the risk management strategy as necessary (particularly important where a permit exemption risk management strategy has been adopted).

A reduction in certification requirements, however, does increase the possibility of local labourers participating in the recovery which is important from a psychosocial point of view (see Section 8.3.5).

One question from the survey discussed in Appendix C, specifically addressed the issue of operational capacity. The question addressed capacity limitations when dealing with asbestos and asked whether it was more effective to reduce existing risk management processes (to reduce the time taken) or to reduce contractor certification requirements (to increase the workforce). The response was split between the two options, indicating that there are perceived risks in both the strategies.

It is preferable to maintain a skilled workforce for high risk work, particularly if a reduction in peace-time management procedures has been made.

Public perception

The case studies show examples of how poorly considered, or poorly communicated, risk management decisions can lead to public opposition and consequently can affect the recovery.

The public opposition to the opening of Gentilly and Chef Menteur landfills following Hurricane Katrina is a clear example of where authorities did not adequately and transparently include the host community in their risk management decision-making. Decision-makers saw the close proximity of the landfills to the affected community as a positive (as it reduced transportation times). However, the community saw it as risk-loading an already affected community. Decision-makers should have communicated their justification for the decision more clearly, in particular the wider community benefits of the approach and the alternatives considered. In addition, if the community had been involved during the decision-making process such that they understood both the local risks and the community wide benefits – the lengthy lawsuit and delays in operation may have been avoided. Despite the legitimacy of utilising legal waivers and alter risk management approaches to aid recovery, the social impact cannot be easily predicted. Risk communication strategies must be employed to mitigate negative community reaction.

One major challenge in a post-disaster situation is how to achieve community consultation and communication in a time limited situation. The desire to establish waste handling facilities quickly was a major factor in the decision to conduct minimal consultation after the Christchurch earthquake before permitting the Lyttelton Port land reclamation, Burwood Resource Recovery Park and the temporary storage facilities. As a result of the limited consultation, there was some community discontentment over the proposed facilities; however community action was minimal and there was no disruption to the operation of the facilities or the recovery. Given that all these facility permits are now valid for five years (as per the CER Act), some better form of consultation should perhaps have been carried out. Consultation would have likely generated greater community support for the operations and would reduce the potential for future disruption to operations. Consultation also presents opportunities for the public to identify potential risks that authorities may have overlooked. The importance of communicating risk was noted by Esworthy et al. (2006) following Hurricane Katrina also.

Involve community in risk management decisions as far as practical and in particular for activities that will be operational medium to long term.

Maintaining a consistent approach to risk management across the recovery, as discussed in Section 10.3.2, is also very beneficial to public perception of risks and how effectively they are being managed. Instances of illegal dumping of waste and asbestos following the Christchurch earthquake, for example, undermined the good risk mitigation measures being practiced by most contractors, and thus, evoked public concerns. By contrast the single waste classification and single organisation managing the waste following the Victorian Bushfire ensured all waste was handled in exactly the same way. This gave the impression that the risks were being managed appropriately and effectively and the authors are unaware of any public concerns of the management approach.

To improve public perception and trust in a risk management approach, consistent standards across the recovery effort are important.

Further research would be beneficial into how public risk perception changes post-disaster and whether, and in what circumstances, reductions in standards are deemed acceptable to aid planning both pre- and post-disaster. During the author's interviews with community members following the Victorian Bushfires, for example, community members consistently ranked health and safety as a higher priority than environmental protection, thus a reduction in environmental standards in favour of protecting human health and safety would be acceptable.

In the survey discussed in Appendix C, one question directly related to post-disaster risk acceptance. The question asked whether an impact on fisheries was acceptable for post-disaster land reclamation. 44% of respondents indicated they would accept an impact lasting up to 5 years. While no peace-time risk acceptance levels were gauged, it is hypothesised that this acceptance level would be far less for a peace-time activity.

Further research would also be beneficial to determine whether a post-disaster change in standards has any impact on risk management approaches long term. That is, if standards are reduced to meet disaster needs, will standards return to 'normal' and if so how long will this take? Due to the time limitations in this study no longitudinal data have been gathered to assess this impact.

10.3.2 Operational management implications

As discussed in Section 8.3.2, post-disaster, risk ownership needs to be considered in the short and long term. The new landfill cell constructed during the Bushfire recovery in Victoria, for example, was constructed and operated by managing contractor for the demolitions. Immediately after the clean-up operation the landfill cell was handed to the local authority that owned the land (and was therefore responsible for long term environmental effects). Thus the contractor did not necessarily have any incentive to ensure that long term risks were minimised. It is understood that there were no contractual arrangements regarding liability resulting from any future adverse effects. Ideally risks should be managed by those with long term vested interested in good risk management.

Section 11.3.4 examines liability concerns for existing 'long term' waste management facilities that alter operations in light of post-disaster legislative changes.

Short and long term risk ownership should rest with the same entity, where possible.

10.3.3 Funding mechanisms

Funding mechanisms often have policies that require certain regulatory and legislative provisions to be met. As described in Section 7.3.3 in some instances, the legislative/risk management changes that were made to enable the recovery actually threatened funding eligibility. Thus the impact of changing risk management strategies through legislative means needs to be considered.

10.3.4 Legislative and regulatory implications

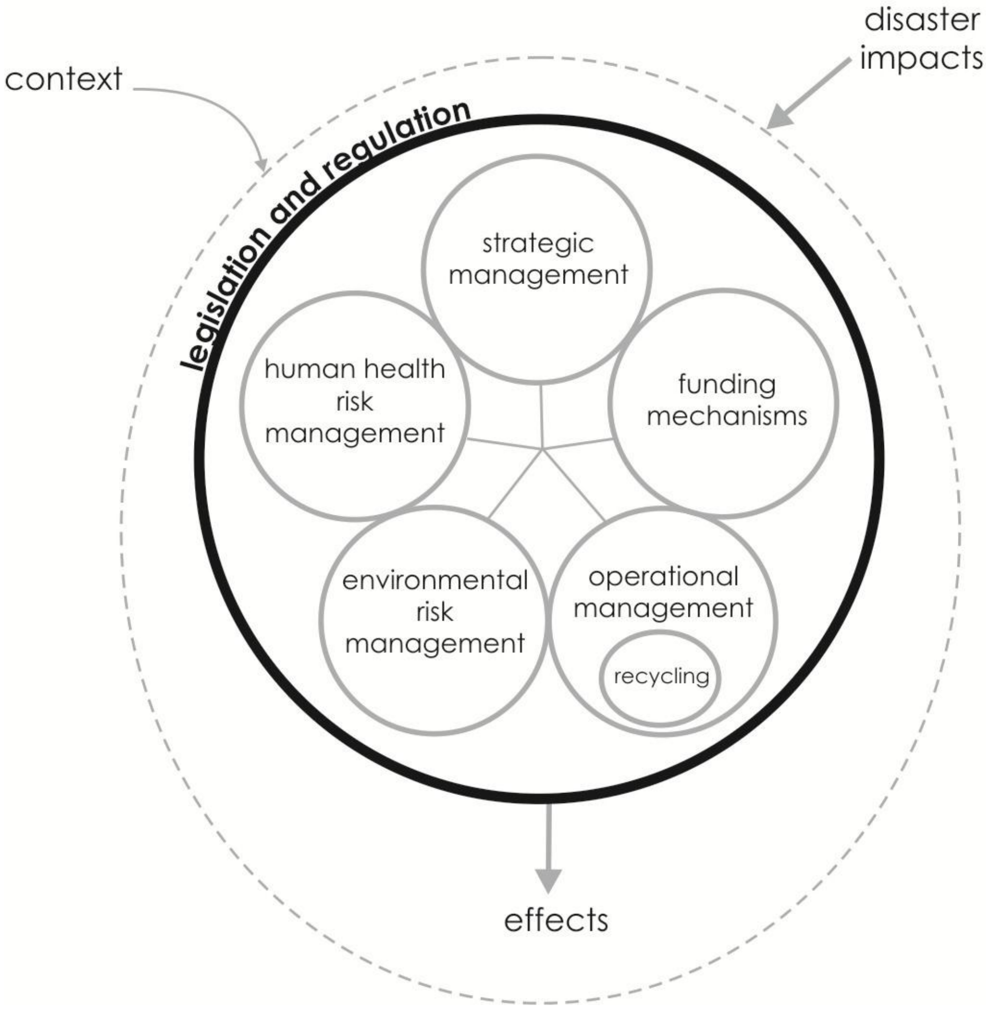
It is interesting to note that in a review of emergency exemptions from environmental laws Gerrard (2006) surmises that legislative changes come in four different categories:

- exemptions from permitting requirements
- relaxation of substantive standards
- exemptions from, or acceleration of, certain processes
- releases from liability

Gerrard's summary more or less aligns with the discussion in this chapter regarding different risk management techniques with the addition of liability considerations. The legislative issues regarding environmental and human health risk management (including liability) strategies are discussed in the following chapter.

10.4 Summary

The challenge of post-disaster risk management is to balance risks against recovery objectives in a time limited situation. It is essential that risks are identified and mitigated where possible. Risk management strategies need to be practical and able to be implemented with limited regulatory and operational resources.



11. Legislation and regulation

11.1 Introduction

Emergency laws often form part of national, regional and local legal frameworks to enable communities to respond efficiently (in a timely manner) and effectively (with quality outcomes) to emergency situations. Emergency legislation is utilised to alter existing regulatory processes and roles and responsibilities to save lives, protect property and the environment by facilitating a quick and coordinated response to an emergency situation.

The mobilisation of emergency laws in emergency response situations where there is an *immediate* threat to lives, property or the environment is unquestionable. In terms of waste, emergency laws can generally enable immediate threats from acutely hazardous waste, unsafe structures, blocked access ways and putrescible wastes. However, the majority of disaster waste management is carried out during the recovery phase. The role of emergency provisions during recovery operations from large scale disasters, after the immediate hazards have been dealt with and waste poses a chronic (rather than an acute) threat to community recovery, is less clear. In some contexts, such as in the response to the Christchurch earthquake, authorities have been moved to develop completely new legislation to enable recovery operations. In the Christchurch case, it became apparent that neither the emergency legislation nor the peace-time legislation in New Zealand was sufficient to enable an efficient and effective recovery. It is interesting to note that researchers had identified this deficiency in New Zealand legislation prior to the earthquakes (Rotimi et al., 2009; Brown et al., 2010a).

Whether or not existing legislation (emergency and peace-time) can be applied to a disaster waste management programme in the recovery phase and how effective it would be is a question worth considering before a potential event. Therefore, this chapter outlines the legal challenges faced in the five case studies. First, the legal challenges are synthesised into the major components of legislative and regulatory requirements necessary to effectively manage disaster waste (divided into the five system elements in the analysis framework of this thesis). Second, there is a discussion of the desirable approach to preparing disaster waste legislation.

Due to the wide range of legislative frameworks in the case studies, and to ensure the observations and recommendations can be transferred between contexts, the analysis and discussion deliberately do not include a great number of legislative details but instead discuss the broader concepts of the various legal and regulatory approaches. The full case studies, in the Appendices, include more specific legislative detail. In addition a detailed analysis of the legislative situation in New Zealand for managing disaster waste (written prior to the 2011 Christchurch earthquake) can be found in the following paper (also included in Appendix O):

> Brown, C., Milke, M. & Seville, E., 2010. Legislative Implications of Managing Disaster Waste in New Zealand. *New Zealand Journal of Environmental Law,* 14, 261-308.

11.2 Case studies

11.2.1 2009 Victorian Bushfires

The main parties involved in establishing the legal standards and processes for management of disaster waste were the Victorian Environmental Protection Agency, the Department of Human Services / Worksafe (demolition, waste handling and disposal); Victoria Roads and Victoria Police (transportation). Legal decisions were made at state and national level; local authorities had little or no input. The legal decisions during the waste management process were reportedly carried out collaboratively.

There were two main pieces of emergency legislation necessary to facilitate the bushfire waste management. The first was Section 30A of the Victorian Environmental Protection Act 1970 which is administered by the Victorian Environmental Protection Authority. Section 30A allows for (temporary) storage, treatment, handling or disposal of waste in an emergency, to relieve public nuisance or hardship. Management of Bushfire waste was deemed to be covered by this definition.

The second piece of legislation related to health and safety. An Order under Section 55 of the Dangerous Goods Act, 1985, was initiated to regulate the removal of asbestos from bushfire affected properties. The Order reduced the storage, handling and disposal standards and stated that this was (Victorian Government Gazette, 2009):

> "to assist with this emergency and the rebuilding of those towns and premises burnt by the 2009 bushfires, it is in the interest of public safety to make an Order that enables the expeditious removal of any asbestos from premises damaged or destroyed by those fires while maintaining appropriate standards of safety"

These two provisions were used to classify all the bushfire waste as a single classification, called "Bushfire Waste". The authorities were able to establish minimum standards for handling, transportation and disposal for the entire waste matrix. That, in turn, allowed the debris management processes to be stream-lined and this facilitated the recovery[18]. The

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[18] It should be noted the single waste classification was possible due to the nature of bushfire waste (low in volume, difficult to segregate for recycling and asbestos that has been subjected to extreme heat). This specific approach may not be suitable to other disasters but the principle of legal flexibility remains the same.

decision-making process behind these legislative changes, however, was unclear and it is uncertain how these decisions would be viewed in a court of law. Neither of the laws appeared to have prosecution and/or liability exclusion clauses.

Prior to demolition and debris clearance from properties, the contractor was required to make property access and waste ownership agreements with the property owners. Unless otherwise agreed with the owner, all waste (including recyclables) was assigned to the Contractor[19].

The construction of the new landfill cell approved through official peace-time legal processes. However, the process was expedited significantly and the normal environmental impact assessment processes were not carried out (as described in the previous Chapter).

Instead of the standard liability period for the landfill cell (30 years) being held by the contractor who operated the site, the landfill was handed back to the local authority (who was also the land owner) for maintenance and monitoring as part of their on-going landfill operations. This may create questions regarding liability in the vent of future negative environmental effects.

There was no legal or regulatory or contractual requirement for the contractors to recycle the debris.

11.2.2 2009 Samoan Tsunami

The Disaster & Emergency Management Act 2006 does not explicitly include waste management as a response function, therefore it is questionable whether the emergency powers within the Act could be used to manage waste even when there is an emergency declared.

In terms of the recovery phase, peace-time legislation and regulation primarily applied. The Ministry of Natural Resources and the Environment's Planning and Urban Management Authority (PUMA) have legislative authority (under the Planning and Urban Management

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[19] In this case the contractor elected to reinvest the recycling proceeds into the community.

Act) to enter property and remove or mitigate the effects of any nuisance (PUMA, obtained 2010). However, the author was advised that these regulations are rarely enforced in peace-time let alone post-disaster. In addition, it should also be noted that the majority of the affected area was on customary land which PUMA does not have authority to enter[20]. Approval to enter, in this case, must be sought through the customary governance structure (Punlenu'u). The Planning and Urban Management Act exempts PUMA employees from liability while acting under the Act (Government of Samoa, 2004).

There were some issues around ownership of the tsunami generated waste but no contractual or regulatory measures appeared to be in place.

11.2.3 2009 L'Aquila Earthquake

In Italy, European Union (EU) and Italian waste laws have to be adhered to. Under EU laws, all waste has to be assigned an EU Waste Code (EWC). In addition, all wastes must have a designated waste 'producer' (under Section 183, Italian Decree Law 152/2006) and this determines who has responsibility for the waste. However, neither the EWC system, nor the Italian waste producer law, had a category suitable for the earthquake waste. It was unclear initially whether the Department of Civil Protection (who was paying for the waste removal) or the municipality (who has peace-time responsibility for municipal waste) was responsible for the waste. Eventually it was decided that the waste should be coded as 20 03 99 (municipal waste) under the EWC system and so that the Comune would be responsible for (or is the designated owner of) the waste. Strictly speaking, the debris (including hazardous materials) did not fall under this EWC code but it made sense from an operational point of view that the municipality was the 'producer' of the waste. If the waste had been categorised with a 17 prefix (construction and demolition waste) the contractors for each demolition site would been the owners of the waste and operation of post-disaster waste separation sites (operated by the municipality) would have required special permission.

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[20] Customary lands are those shared among an aiga or extended family. Each aiga is headed by a matai or leader who is responsible for land and titles. Each community has a fono or council of matai that make decisions on village development and land-use. Customary land is generally awarded through historical claims and or family genealogy.

Unfortunately this meant that most contractors were not authorised to transport the municipal categorised waste until an emergency order in March 2010 authorised suitably qualified contractors to transport the earthquake waste. Before then the army and fire service had to be the primary transporters. An emergency Decree Law was also required to allow for private property access to remove debris.

All demolition contractors and waste haulers had to be certified as Environmental Managers. No specific data were collected regarding this; however, it is understood that the certification process is lengthy and no alternative certification procedures were established.

To increase the number of disposal sites, as mentioned in the previous Chapter, waste handling facility approval regulations were authorised in March 2010. The responsibility for siting new facilities was given to the Deputy Recovery Commissioner in June 2009 (OPCM 3797) after no action was taken by the municipality. No additional sites had been established at the time of the author's reconnaissance (September 2010).

11.2.4 2005 Hurricane Katrina

The law played a critical role in the waste management process following Hurricane Katrina. Hurricane Katrina gives examples where legal waivers were used effectively, used controversially and where emergency waivers were not available when needed.

Emergency management in the US is governed by the Stafford Act and corresponding National Response Plan (NRP). The NRP outlines the roles and responsibilities with respect to management of disaster waste. The NRP is divided into 14 Emergency Support Functions (ESFs) – three of which relate to disaster waste management. Due to the scale of the event, US Environment Protection Agency (USEPA) was given authority to waive any law under its jurisdiction. The USEPA elected to work inside Federal law by changing regulatory procedures and protocols and advocating state or local law changes where necessary.

To enable recovery, the Louisiana Department of Environmental Quality (LDEQ) issued a Declaration of Emergency and Administrative Order (DEAO) and a Disaster Debris Management Plan. Both documents (and subsequent revisions) outlined measures to be taken in order to prevent irreparable damage to the environment and serious threats to life or safety resulting from waste management. The measures included: relaxation in permitting and quality assurance requirements, authority to make disaster damage repairs on solid waste management facilities without prior permitting and general waste management strategies (including siting waste disposal, and waste acceptance criteria, waste separation, burning restrictions, carcass disposal, hazardous waste storage). In total there were 15 DEAOs issued over three years.

The State of Louisiana's decision to expand the acceptance criteria for Construction and Demolition (C&D) landfills was legislated under the second amended DEAO (LDEQ, 2005b) and was sustained through subsequent revisions. Despite the legal authority to make these changes, the Louisiana Environmental Action Network (LEAN) filed two lawsuits to close down two C&D landfills operating under these revised conditions. The first landfill (Gentilly landfill) had been permitted as a C&D landfill prior to the Hurricane but did not begin accepting waste until after the storm. The lawsuit resulted in an out of court settlement which limited the C&D shipments to the landfill to 19,000 cubic yards per day. The other site, Chef Menteur Landfill, was commissioned following Hurricane Katrina through an emergency authority by New Orleans' Major Ray Nagin. The lawsuit resulted in the site being voluntarily closed by Nagin one month later (Luther, 2008).

As discussed in Section 10.3.1, this example shows that despite their availability, legal waivers are not always straight forward to utilise in a disaster recovery situation. Whether the environmental risk was real or perceived, community acceptance of a legal waiver or an environmental or human health risk management approach can be crucial to its effectiveness.

According to a Report to Congress on the debris removal process (Luther, 2008), existing legislation prevented FEMA and the US Army Corps of Engineers (USACE) from expeditiously mandating house demolition and/or debris removal on abandoned properties. Neither organisation had the authority to demolish homes or remove debris from private property without following a multi-step process involving the home-owner and including decommissioning and condemnation. In the US, state and local governments are responsible for right of entry permits for private property; however, with the absence of many home-owners, this process was challenging and it restricted the speed of demolition and debris removal works.

The demolition process (and associated debris removal works) was a balance between eliminating immediate public health and safety risks and respecting property owner's rights in their absence. Mandating demolition of private property without consent, for reasons other than an acute risk to public health and safety, was not considered due to the likely significant social and political opposition. It was believed that many absent residents may opt to repair rather than replace their homes even if there was significant damage (Luther, 2008).

The USEPA identified standard asbestos handling and disposal procedures as a contributing factor to the slow debris removal process. In response to this, the USEPA moved to reduce the handling requirements: "[US]EPA…is providing debris management guidance to ensure minimization of exposures while expediting cleanup." (Luther, 2008). In Louisiana, the USEPA granted 'No Action Assurance' letters (LDEQ, 2006a) which allowed a relaxation in some standard (National Emission Standards for Hazardous Air Pollutants regulations) asbestos demolition and disposal procedures(LDEQ, 2007). LDEQ were also granted delegated authority to use their own Louisiana Emission Standards for Hazardous Air Pollutants in place of the national standards.

Waste separation (e.g. metals, concrete, vegetative debris) was required by local authorities to divert waste from landfill and to comply with existing federal and state laws[21]. However, as discussed in Chapter 9, extensive recycling was not practiced. The author has insufficient data to comment on the legal details of this.

11.2.5 2011 Christchurch Earthquake

New Zealand's Civil Defence and Emergency Management (CDEM) Act provides the legislative framework for managing emergency responses. It also outlines the organisational structures and planning requirements for Civil Defence personnel. The Act is comprehensive for enabling emergency responses; however, it is weak in terms of enabling recovery. As a result, the Canterbury Earthquake Recovery Act was passed two months after the February earthquake. The Act gives authority to Ministers to amend almost any piece of legislation (through an Order in Council) to facilitate earthquake recovery.

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[21] The Resource Conservation and Recovery Act (RCRA) requires States to regulate solid and hazardous waste in accordance with the provisions in the Act.

As well as the authority to change existing laws, the CER Act established quite specific provisions controlling demolition of damaged structures. Most importantly the Act gave CERA the authority to require buildings to be demolished or made safe and to intervene if works were too slow. In addition, the Act gave CERA authority to seek compensation for works carried out on behalf of building owners. During the works, CERA also established contractual arrangements around waste ownership, private property entry and cost recovery.

Prior to the CER Act, some demolition works were carried out as part of the emergency works (rescuing persons, body recovery, clearing streets, making safe). While the CDEM Act gives authority to carry out the works, there is no provision in the Act to recover costs for the works. No waste ownership agreements / procedures were in place either. As a temporary measure, contractor salvage rights were frozen to mitigate loss of personal property.

As discussed in Section 8.3.4, several disaster waste management contracts were let without full peace-time procurement procedures being followed. These contracts were let during the emergency phase but were extended into the recovery phase. The CDEM Act has allowances for expedited procurement procedures; however the CER Act does not.

The primary environmental regulation in New Zealand, the Resource Management Act, is a consultative, effects-based piece of legislation. It is process not outcome orientated and there are few prescriptive environmental standards within the Act. The governing authorities also have discretionary powers as to whether they will enforce certain provisions within the Act. The degree to which these discretionary powers were utilised during the earthquake response phase varied. Neither the regional nor national environmental regulatory authorities gave clear direction on how these powers would be used. It appears that new facilities were expected to go through the peace-time process or apply for a facility specific Order in Council. On the other hand, discretionary powers were used with respect to existing facilities.

Several Orders in Council were passed under the CER Act relating to waste management activities. The orders related to:

- Approval of reclamation activities at Lyttelton Port.
- Establishment of Burwood Resource Recovery Park.

- Permitting of the permanent waste disposal facility at Burwood.
- Permitting of temporary waste storage facilities.
- Allowance for overloading trucks.
- Allowance for changes in operating conditions at the regional landfill.
- Stream-lining of archaeological site management requirements.
- Stream-lining of resource consent requirements for Historic Building demolition.

Health and safety regulations remained largely unchanged. The Department of Labour provided some earthquake specific guidance and flexibility in regulation interpretation for asbestos management; however, the law (or regulations) was not changed.

One concern held by the earthquake waste managers in Christchurch was that there was no regulatory and legislative mechanism to gather data from demolition sites where buildings are three storeys or less (due to a recent Building Act change). This meant that monitoring operations and anticipating waste management demands was difficult. Some have attributed this lack of monitoring and authority visibility to the increase in illegal dumping post-earthquake. The CER Act had provisions for some data to be collected but only for buildings deemed unsafe under the Act. Many residential properties and small commercial properties are being demolished for economic reasons rather than as an imminent threat and therefore are not included in the CER Act 'dangerous building' definition.

The CER Act also provides liability protection for actions taken under the Act.

11.3 Discussion

11.3.1 Strategic management

Legal frameworks for strategic management of waste should be incorporated into disaster recovery legislation. Emergency legislation can, and should, include definitions of roles and responsibilities. Emergency legislation should, importantly, provide authorities with a mandate to take any means necessary to meet recovery goals.

The emergency support functions (ESF) defined in the US emergency regulations (The Stafford Act/National Response Plan) are a good example of how legislation and regulation can be used to develop organisational structures. The US regulations outline the relevant stakeholders and their roles and responsibilities during response and recovery works. The regulations also stipulate who is responsible for obtaining legal waivers where necessary (in this case, local and state governments).

The clarity around roles and responsibilities was less clear for the other case studies. In L'Aquila, the Department of Civil Protection initially set-up the waste management system; the system was altered when the municipality took over. In Victoria, there was no pre-determined organisational structure for recovery; VBBRA was established and a contractor was appointed for the operational works. No strategic planning appeared to be carried out. In Christchurch, CERA, under the CER Act, was given overall authority to manage the recovery but waste management was delegated to the local municipal authority. The CER Act included provisions to intervene when individuals were not acting in the interest of the community. Legislative decisions regarding waste were made at both local, regional (enforcement decisions) and national / Ministerial level (Orders in Council). Clarity around decision-making authority and responsibility was lacking.

Overall authority and clear responsibility for management of disaster waste should be incorporated into legal frameworks for recovery.

If suitable strategic management structures and roles and responsibilities are defined pre-disaster, the number of legislative changes made following many of these case studies (as discussed later in Section 11.3.5) could be reduced. Better coordination structures are likely to improve the quality and completeness of decisions, such that the need for numerous future changes (amendments or additions) to legislation and regulation would be reduced. If there is inadequate strategic coordination, there is a possibility that unnecessary legislative changes could be made or, conversely, necessary legislative changes may not be made. In L'Aquila, necessary legislative changes to enable the establishment of waste handling facilities were not forthcoming as 'ownership' of the waste management activities was divided between various authorities and working groups. This had a significant impact on the speed of demolitions.

Strategic managers should aim to anticipate necessary legislative changes to: minimise the number of legislative changes and avoid unnecessary legislative changes.

It is beneficial for the authority responsible for strategic management of the waste to have legislative authority to make waste management decisions. Following the 4 September 2010 earthquake, an independent group called the Canterbury Earthquake Recovery Commission (CERC) was established (under the Canterbury Earthquake Response and Recovery Act 2010) to oversee the recovery and to consult with Ministers regarding any potential legislative changes. The group had no decision-making authority and was considered by many to be largely ineffective. Major delays were observed in the recovery, in particular, the slow demolition of buildings posing a public health and safety hazard and in some cases blocking roads and preventing others from accessing their buildings. Many found this arrangement inefficient and unsatisfactory. Some decisions took months. The CER Act (enacted following the February earthquake) and the new, temporary, government department, CERA, were born out of the negative experiences of September. Unlike the CERC, CERA has decision-making authority and some operational (primarily demolition) responsibilities.

If strategic management authorities are established without decision-making authority this can sometimes have a detrimental effect on the recovery. In Victoria, some individuals interviewed identified that the Victorian Bushfire Recovery and Reconstruction Authority lacked decision-making authority and had insufficient powers to enable the recovery. In their view, this added another layer of bureaucracy and slowed the recovery.

Strategic management authorities should have legislated mandate to enable decision-making.

If a regional approach to strategic waste management is taken, consideration must be made to allow for intra-regional differences in regulation and legislation. For example, different Parishes within New Orleans, operated independently and had "complex and constraining" rules around operating with each other (Roper, 2008). This made developing and implementing consistent waste management approaches across the affected regions, difficult.

If regional or national strategic waste planning is desired, approaches adopted must account for local legislation.

Legislated or regulated consultation requirements may need to be changed post-disaster to facilitate timely decision-making. Consultation may be particularly challenging where communities have been heavily affected and where a) decisions need to be made quickly and b) the peace-time levels and methods of consultation may not be practical or feasible. Following Hurricane Katrina in Louisiana, LDEQ revised its consultation requirements for permitting actions in acknowledgement of the displaced population. LDEQ established three community impact categories (determined by factors such as newspaper circulation rates, school rolls, operational services, road conditions etc.). Consultation requirements for hardest hit areas were dramatically decreased to "address these [permitting] issues in a manner that offers the opportunity for meaningful public participation and that meets the requirement and the intent of the state and federal permitting statutes and regulations" (LDEQ, 2006c).

Consultation requirements may need to be adapted to the disaster situation, to facilitate timely decision-making.

As discussed in Section 6.3.3, monitoring is an important part of strategic management and managing the environmental and public health risks. Regulatory requirements should be in place pre-disaster to ensure monitoring systems are in place.

Where possible, regulations should ensure that basic data are collected to aid risk monitoring and strategic planning.

11.3.2 Funding mechanisms

Disaster waste programmes, and recovery programmes in general, are highly dependent on funding availability. The case studies have demonstrated several instances where 1) legal provisions have been needed to allow privately funded works to be managed collectively and 2) where legal changes have affected funding eligibility. These are discussed below.

As discussed in Chapter 7, sometimes it is beneficial to manage privately funded works collectively to enable an efficient recovery. For example, in Christchurch, the provisions in the CER Act allow for CERA to coordinate, and where necessary manage, building demolitions and carry out 'make safe' works. In particular, the Act allows intervention where the works, being carried out by individuals, are progressing too slowly. Without this Act, the recovery timeline would be completely dictated by private entity actions. Central management, by CERA, facilitated recovery objectives being met.

Where funding mechanisms are private, legislative powers will be required to ensure funds can be directed strategically toward the recovery objectives.

As part of the CER Act, provisions were included to ensure that, where CERA was forced to take actions on behalf of the owner, CERA would be able to recover their costs. There was no such mechanism in the Civil Defence and Emergency Act and some funds, for works carried out during the emergency response, were subsequently not recoverable. In the US, where property owners have insurance and receive money or in kind assistance through FEMA (such as kerbside collection and demolition services), they are legally required, under federal law, to reimburse FEMA for insurable works carried out (FEMA, 2006; 2007). However, it is unclear what, if any, mechanism is in place to manage this and how much money, if any, has been recovered in the past.

Where central management is desired in a privately funded environment, legislative provisions need to include for cost recovery.

As discussed in Section 7.3.3, funding policies can include conditions which require that waste only be managed under certain legislative conditions. For example, FEMA requires all waste management activities meet Federal laws. If Federal laws are not met, authorities will not be eligible for reimbursement for the works. The provision following Hurricane Katrina, that allowed the US Environmental Protection Agency to change any law under its jurisdiction to enable recovery, as a result, was largely ineffective. Local authorities did not want to jeopardise their funding eligibility. Subsequently, necessary legislative changes may not have been made where they were needed.

Review the impact of any proposed legislative changes on funding eligibility.

11.3.3 Operational management

Waste classification

Following both the Bushfires and the L'Aquila earthquake, the disaster waste was classified as a 'single' waste type. In the Bushfire case, this decision was to enable stream-lining of waste management procedures, in particular, regulations around handling the potentially hazardous components of the waste.

In the L'Aquila case, waste coding was necessary to adhere to European and Italian waste laws, as well as being necessary for funding eligibility (see Section 11.3.2). As there was not an existing European Waste Code (EWC) that matched the earthquake waste (that is: collapsed building stock, including building materials, household furniture, appliances, personal items, potentially hazardous materials), an existing EWC was selected based on how authorities wanted to manage the waste (i.e. who would have responsibility for the waste under Italian Decree Law 152/2006). As discussed in Section 11.2.3 an EWC code with prefix 20 meant that the municipality could assume responsibility for the waste and collect and transport and separate it as necessary – which was the desired approach. This classification meant, however, that demolition contractors were not authorised to handle the waste. A special Prime Ministerial Decree (OPCM) was required to authorise environmental managers to handle the waste.

If a waste classification system exists, a disaster waste category is necessary which reflects the nature of the waste and ownership of the waste.

Classifying the mixed disaster waste as a single waste product may simplify regulatory or legal requirements.

Property entry and remediation

Property entry and remediation is likely to be required in the short term if a hazard is posed to public health and safety or the environment: for example, corpses, rotting food, flammable or toxic substances. In the longer term, if residents are slow to return or to facilitate clean-up of their own property, property entry and remediation may be desired by authorities to repair or demolish structures and remove debris to contribute to the wider social / community recovery. When residents are present and willing, authority to access property is reasonably straightforward to obtain. Prior to debris removal by contractors following the Victorian Bushfires, every property owner was required to authorise property access to the contractor prior to demolition and debris removal commencing. When residents are absent or uncooperative, gaining private property access is more challenging. The process necessary to condemn houses following Hurricane Katrina was involved and time consuming, and was a bottleneck in the disaster waste management process. Only 1000 properties were demolished in the first 15 months of the condemnation process; a further 15,000 properties were demolished in the following three months (GAO, 2008). This indicates the lengthy process required to gain legal right to access properties. In L'Aquila, a special law was passed post-earthquake to enable private property access for debris removal (Decree Law n. 195). In Christchurch, the CER Act enabled CERA to carry out works when necessary for recovery.

Thus, provisions are needed to allow private property entry in a disaster recovery situation where the threat posed by the building is not immediate (as generally allowed for in peace-time regulations) but the intervention is necessary to assist community recovery. This is particularly important when residents are absent or are unwilling to act in a timely manner. There are two possible approaches which could be taken – usurp property rights and act without due process (similar to emergency legislation) or to stream-line process to facilitate a faster approval.

Legislative provisions are needed to allow private property entry in a disaster recovery situation where the threat is not just immediate but may affect the community recovery.

Property debris /waste ownership

In cases where demolition and debris management is carried out on behalf of building owners, legal arrangements around ownership of recovered waste materials needs to be established. This can be done through legislation or contractually.

During the emergency phase in Christchurch, the legal implications of waste ownership were not well understood. As a precautionary measure, under Civil Defence directive (which is legally binding under a State of Emergency), all salvage rights for contractors were frozen. This was a very important and publicly well received initiative but was not always effective. Some contractors were accused of taking and selling private property without building owner consent (NZPA, 2011a; b). Damaged buildings contain personal items, intellectual policy, confidential information etc. which has to be carefully managed, and where possible returned to the owners. There are also insurance implications (where applicable), such as, where contents can be salvaged (even if they are not salvaged) they will generally be removed from the insurance pay-out.

Waste ownership agreements may be difficult to gain where the population is absent, such as following Hurricane Katrina. As discussed earlier, many houses there had to be condemned by the local authority. The condemnation process gave authorities authority to gain entry and ownership of waste materials.

Laws need to clearly assign waste ownership and liability for loss of valuables.

One important step in managing waste ownership issues is dividing the waste into two categories: personal property and building materials.

As the Civil Defence and then the CERA demolition process matured, waste ownership issues were written into the demolition contracts. The two different contract types being used (cost reimbursement and lump sum) required different approaches to waste ownership. As outlined in Section 8.3.4, for cost reimbursement contracts the waste was essentially owned by the Principal (CERA). All proceeds from the sale of recyclables and the cost of disposal would be charged back to the Principal (and subsequently, the owner). Under the lump sum contracts, the contractor assumed ownership of the waste. Despite noting in the contract that personal property must be returned to the building owners and tenants, there was much less control on management of any personal items that were found during the demolition process for lump sum contracts. Regardless of contract type, contracts need to clearly distinguish between personal property and building material ownership.

Demolition and debris management contracts need to include waste ownership clauses. Waste must be delineated into personal property and building materials.

Where disasters involve the movement of property between boundaries, waste ownership issues become even more complicated. The debris resulting from the 2011 Japanese tsunami floating across the Pacific (NOAA, 2011) is an extreme example of waste movement where waste is being carried across international boundaries. Further consideration and research would be valid here.

Waste ownership laws need to be considered where there is <u>movement of waste</u> during the hazard event (particularly across jurisdictional boundaries).

Operational management strategies

Legislative structures need to be written to allow for the desired operational management strategies to be applied. The CER Act, for example, gave enough authority for CERA to partially (but not fully) establish a centralised management process. However, approximately two thirds of commercial property owners elected to manage their own demolitions. If a fully centralised management programme had been desired, then a more directive legislative mandate would have been required. It is understood that the legislation was not necessarily intentionally written to allow for centralised management because there was no mandatory requirement for property owners to allow CERA to manage their demolitions. The legislative framework should allow for implementation of the desired operational structure (refer Chapter 8).

Legislative structures need to allow for the desired operational systems to be implemented.

Programming Flexibility

The long regulatory lead-in times sometimes required are generally not practical in a disaster recovery environment. For example, the 10 day notification period for works involving asbestos in Louisiana was considered too cumbersome following Hurricane Katrina. It was reduced to just 24 hours to reflect the uncertainties in the programming of works post-hurricane. Where possible, regulatory time frames should be designed to account for the uncertainty around post-disaster operations.

Flexibility around notification periods are useful to allow for necessary programme flexibility. Short notification periods are desirable.

Worker certification

As discussed in Section 10.3.1, resources are likely to be stretched post-disaster and there may be a desire to increase the available workforce. As a result, legislation or regulatory processes around worker certification may need to be altered. For example, in Louisiana asbestos worker certification requirements were expedited through a regulatory change.

Legislation or regulations may need to be altered to increase the available labour resources.

Liability

Many people may volunteer their services following a disaster event. However, there are liability issues for authorities to consider where unskilled (and potentially unpaid) persons are involved in demolition and debris management. Many people who participated in the World Trade Centre collapse clean-up have since reported significant health impacts (Landrigan et al., 2004). Many States in the US have Good Samaritan laws to protect people who volunteer their services to help others (Phillips, 2009).

Liability implications of volunteer or community participation need to be considered.

Procurement

Many emergency laws include allowances for expedited procurement processes during the response phase. Use of expedited procurement approaches in the recovery phase has been less considered. In many cases demolition waste contracts will commence in the emergency period (potentially being granted under expedited processes) and then endure through the longer recovery phase. For example, in Christchurch, the CDEM Act allows certain delegated persons to enter into contracts for the purposes of the Act without regard to the Public Contracts Act 1959. The project manager for the CERA managed demolition works, for example, was appointed during the civil defence emergency period. The role, for continuity, was continued through into the recovery phase. The initial appointment and on-going involvement was publicly criticised (Williams, 2011a). The possibility of contracts starting under the emergency phase and continuing through the recovery phase is highly likely for waste management works. Procurement approaches, particularly for activities that transition between the response and the recovery phases need to be considered and included in recovery legislation.

Legislative provisions need to consider procurement requirements for contracts which commence in the emergency period and endure through the recovery phase.

The uncertainty of work scope during the recovery period sometimes makes peace-time procurement requirements difficult to meet. For example, dedicated debris management sites were identified for disposal of debris streams from the CERA managed demolition works in Christchurch. No competitive tender was possible because of the inability to accurately define the scope of the contract. The default alternative was that no tender was carried out. Thus, potential cost savings were lost and the approach was perceived as being anti-competitive. A process for managing procurement when the scope is uncertain needs to be included in regulations.

Procurement regulations during the recovery phase need to account for the uncertainty likely in the recovery works.

Recycling

In many countries a waste disposal levy exists to encourage recycling. Following several disasters, including the Christchurch earthquakes, the waste levy has been removed to reduce the economic burden on the community. While that goal is achieved, the removal of the waste levy, in turn, reduces the economic feasibility of recycling. Thus, where communities are short of landfill space or alternative waste management options this change can cause the selection of suboptimal waste management options.

Other peace-time laws can stipulate recycling requirement which are unfeasible in a post-disaster situation. For example, the State of California has a mandate that requires all Counties to achieve a 50% recycling rate (with no disaster exemptions). The penalty for not achieving this is (in 2003) was a $10,000 / day fine (County of San Diego, 2005). Authorities in San Diego after the Cedar and Paradise firestorm had to balance the effect of this fine against the knowledge that they would not receive reimbursement from FEMA (because of monitoring systems which did not meet FEMA funding eligibility criteria). In this case recycling was deemed to be essential (due to limited landfill space) and the county accepted that they would not receive FEMA reimbursement. In other cases where recycling is unfeasible (as discussed in Section 9.3.1), laws such as this may unjustly penalise a community that is having to balance environmental objectives to meet economic, social and recovery objectives. Recycling mandates must be considered in light of a disaster event and if necessary a disaster exclusion clause should potentially be added.

Peace-time recycling mandates should have disaster clauses.

Transportation

Transportation of waste will be a critical link in the waste management chain following a disaster. All waste (hazardous, non-hazardous, mixed, separated, processed, unprocessed) must be moved from the disaster site to the waste processing, treatment and disposal sites. Flexibility needs to be built into legislation to allow for post-disaster responses. For example, in Victoria the requirement to double-wrap in plastic any asbestos contaminated material was waived to speed-up the clean-up process, reduce health and safety risks (brought about when lining trucks in plastic) and to increase the number of trucks suitable for waste transportation. In Christchurch, restrictions on truck movements (hours, weight, frequency and travel rates) were altered to facilitate debris removal. Licencing and operational regulations may also need to be changed to respond to resource (truck and driver) shortages.

Legislative allowances may be necessary to facilitate higher volumes of truck movements (truck weight, operation hours, location etc.) and increase the available truck fleet.

11.3.4 Environmental and human health risk

Emergency repair to waste handling facilities

Waste handling facilities may need emergency repairs following a disaster event to mitigate any negative environmental effects and to ensure the facility is operational for disaster generated waste. Legislative provisions need to allow for this. Following Hurricane Katrina, the first Declaration of Emergency and Administrative Order made an allowance for all existing waste handling facilities to make emergency repairs to their facilities where necessary. In New Zealand, the author is advocating for solid waste management to become a Lifeline to allow facilities to take advantage of emergency works provisions in the CDEM Act for utilities (Brown et al., 2010b)(and included in Appendix P) which allow emergency repairs to be made to existing Lifeline infrastructure.

Emergency legislation should allow for waste facilities to action immediate repair following a disaster.

Health and safety

Disaster waste invariably contains hazardous material in varying forms and quantities. Health and safety protection for the workers and public is critical. In general, in the case studies in this thesis, health and safety standards have not been altered. Regulations, however, have been streamlined to expedite management of some materials: in particular asbestos following the Bushfires (Dangerous Goods Order / single waste classification) and Hurricane Katrina (NAA letters). Legislative means to do this are important.

Legislative provisions to expedite hazardous waste handling procedures may be necessary.

As noted in Section 8.3.4, contractors have a tendency to cut health and safety corners to return a profit. Regulatory controls are necessary to prevent this. Following the Christchurch earthquakes a number of contractors entered buildings that were deemed unsafe to salvage materials and stripped internal building components. Stronger regulatory control over this may have reduced the risk to workers. As discussed in Section 8.3.4, in lieu of regulatory controls, contractual measures can generally be established.

It is interesting to note that, in Christchurch, there was some negative reaction to the recovery authority, CERA, directing people as to what was safe and unsafe. For example, directing contractors as to which buildings they could carry out an internal strip (as above), or ordering residents to vacate their houses in areas where there was a potential rockfall hazard. Some people did not feel it is the government's role to determine safety and risk thresholds for individuals.

Legislative authority to prevent contractors (and public) engaging in risky behaviour (such as entering unsafe buildings) may be necessary.

Waste handling facilities

Legislative flexibility may be required to ensure existing facilities have adequate capacity and new facilities can be established to manage the disaster generated waste. Facilities will likely include: new temporary waste storage, staging, recycling and disposal sites, and permanent disposal sites (landfill, land reclamation).

Environmental legislative flexibility is required to enable existing and new facilities to cope with the disaster waste.

It is useful to have legislation and regulation prepared for potential waste management options, even if they are not used in peace-time. In previous disasters, for example, incineration has been used as a waste volume reduction method to save landfill / disposal site space where previously it was not an accepted waste management option. It would be useful to have regulations prepared for all options that may be used post-disaster.

Regulations should be prepared for all possible disaster waste management options.

Liability

Liability for adverse consequences associated with environmental or human health legislation relaxation needs to be addressed. As discussed in Section 10.3.1, the high uncertainty involved in managing disaster waste can potentially lead to higher risk taking, intentionally and unintentionally. Where adverse effects eventuate, it may be difficult to determine whether site operators are responsible for adverse environmental effects or it is directly as a result of the relaxed environmental standards adopted. This is particularly important to consider where standards are reduced at facilities which exist in peace-time.

Liability for adverse effects from relaxation of environmental and public health standards needs to be addressed.

11.3.5 Legislative considerations

Emergency versus recovery legislation

Recovery appears to be in a grey area of the law. Many emergency provisions focus on the removal of immediate threats to people, property and the environment. The question raised here is whether emergency laws are still applicable in a recovery situation - where there is a chronic threat such as due to the presence of disaster waste. Should there be a specific tier of laws applicable to disaster recovery as well as emergencies?

From the case studies there are examples of how some emergency provisions have been effectively adapted for recovery efforts. The use of Section 30A for example following the Bushfires is one example. While the decision-makers felt it was possible to use this legislation (intended for emergencies with acute environmental threats) for recovery purposes, others may not. The use of an 'emergency' mentality in a recovery situation is not always suitable either. Ardani et al. (2009) note that there was an unnecessarily extended ' crisis' mentality following Hurricane Katrina and that this inhibited long term planning for recovery works.

In the author's opinion, there is a need to distinguish between emergency action and action taken to enable recovery.

Emergency laws are not always applicable to recovery. Recovery specific legislation is recommended for large scale events.

In many cases, notable difficulty lies in how to manage the transition between the emergency response and the recovery phase. Disaster waste management activities often commence in the emergency period but are required to continue for significantly longer than the emergency phase. A clear distinction needs to be made between those that extend into the recovery period and those that do not. Those that are likely to extend need to be treated accordingly. In Christchurch, the issue around letting contracts, under expedited emergency procurement procedures, that continued into the recovery phase is an example of this transitional challenge. It is likely that a transitional period within legislation would be necessary to account for response and recovery activities that start and end at different times.

A clear distinction between emergency and recovery activities needs to be made and allowance needs to be made for activities which transition between the two phases (and legislative frameworks).

Appropriate legal authority

There are primarily two approaches to legislative authority for recovery works – either individual agencies are given authority to alter their respective legislation; or there is a recovery authority and they are given legislative authority over peace-time authorities. Whichever approach is taken, collaboration between key authorities is essential.

In the author's opinion the latter option (recovery authority having legal authority) is preferable. As discussed in Chapter 6, this approach ensures that all decisions are made with the recovery objectives in mind, rather than individual agencies making decisions without understanding the necessity of the change or the impacts on other recovery activities. This approach also reduces the impact of organisations acting with peace-time 'bounded rationality'. As is demonstrated throughout this thesis, disaster waste management activities have a wider impact on recovery and many different authorities are likely to interface in the management of waste. Decision-making should be collaborative (with all relevant authorities such as environmental and public health officials) but the overall design of the recovery should lie with the recovery authority.

Legislative authority needs to reside with recovery authorities in collaboration with other relevant authorities.

For clarity, and to prevent the blurring of legislative authority, it is also preferable that recovery legislative and regulatory changes are set apart from peace-time regulation. The CER Act Orders in Council, the LDEQ Declarations of Emergency and Administrative Orders and the L'Aquila Decree Laws and Prime Ministerial Decrees (OPCMs) were all documents which clearly delineated recovery decisions from peace-time regulations. This created a clear distinction for contractors and the public. However, in Christchurch the additional use of discretionary powers by some under the Resource Management Act to 'enable recovery' led to some confusion amongst contractors. While the intent was to aid the recovery, there was little or no collaboration with CERA officials and, in the author's opinion, the regulatory relaxations were not necessarily required. The perverse effect was increased environmentally risky behaviour by some contractors, on the assumption that regulatory agencies would be lenient towards violators.

Recovery legislation and regulation changes need to be clearly delineated from peace-time laws.

Empowering the decision-maker

Disaster waste management is one of the first steps in a disaster recovery process, so the ability to make good decisions quickly is essential.

The provision of well-considered legal structures in a disaster response situation is critical to support, protect and empower decision-makers to facilitate an effective and timely recovery process. If legal structures are too rigid, this could lead to a slow clean-up process (Basnayake et al., 2005; Luther, 2008). If legal structures are too flexible, potential for inappropriate decision-making (intentional and unintentional) is increased.

Due to the variability of the nature and impact of disasters and emergencies, current emergency legislative provisions are understandably broad. This flexibility, however, is not necessarily appropriate for a recovery situation. As discussed in Section 10.3.1, affected communities do not always accept regulatory or legislative changes after (or sometimes even during) the emergency phase. If decision-makers fear public disaffection or even prosecution then decision-making could be significantly impaired. Decisions would likely be slowed and a more risk-averse stance might be taken.

New Zealand's legislative framework for managing disaster recovery was significantly lacking prior to the September 2010 earthquake (Rotimi et al., 2009; Brown et al., 2010a). This prompted the development of the Canterbury Earthquake Response and Recovery Act (CERRA) 2010. The broad scope and powers within the Act elicited concern from the New Zealand legal community. The primary concerns were (as quoted in an open letter) (Geddis, 2010):

- Individual government ministers, through "Orders in Council", may change virtually every part of NZ's statute book in order to achieve very broadly defined ends, thereby effectively handing to the executive branch Parliament's power to make law;
- The legislation forbids courts from examining the reasons a minister has for thinking an Order in Council is needed, as well as the process followed in reaching that decision;

- Orders in Council are deemed to have full legislative force, such that they prevail over any inconsistent parliamentary enactment;
- Persons acting under the authority of an Order in Council have protection from legal liability, with no right to compensation should their actions cause harm to another person.

Following the 2011 February earthquake, the CER Act was drafted which usurped the earlier CERR Act. While some concerns have been raised about the revised Act, there appears to be less resistance to the CER Act. It is unclear whether this is due to the greater perceived need for legislative flexibility (due to the large scale event) or whether lessons from the drafting of the CERRA legislation were incorporated successfully into the CER Act. Similar concerns were raised by the American Bar Association's Section of Environmental, Energy and Resources following decisions to allow the USEPA to waive any legislation following Hurricane Katrina. The group submitted detailed comments to USEPA outlining concerns about the expanded environmental law exemptions stating that broad exemptions carry great 'risks and costs' and that individual effects should be considered (Gerrard, 2006).

It is important to note that there is the potential for officials to take advantage of the broad powers in emergency legislation. Allegations of corruption have been made against the Berlosconi government during the response to the L'Aquila earthquake. Legislation must include sufficient checks to mitigate the potential negative effects.

If legal provisions are to empower decision-makers and protect the community and their environment, there needs to be a balance between flexible provisions and certainty of outcome if waivers are used. Figure 11-1 by Myburgh et al. (2008) shows the balance between flexibility and regulation needed to be effective and efficient in an emergency recovery

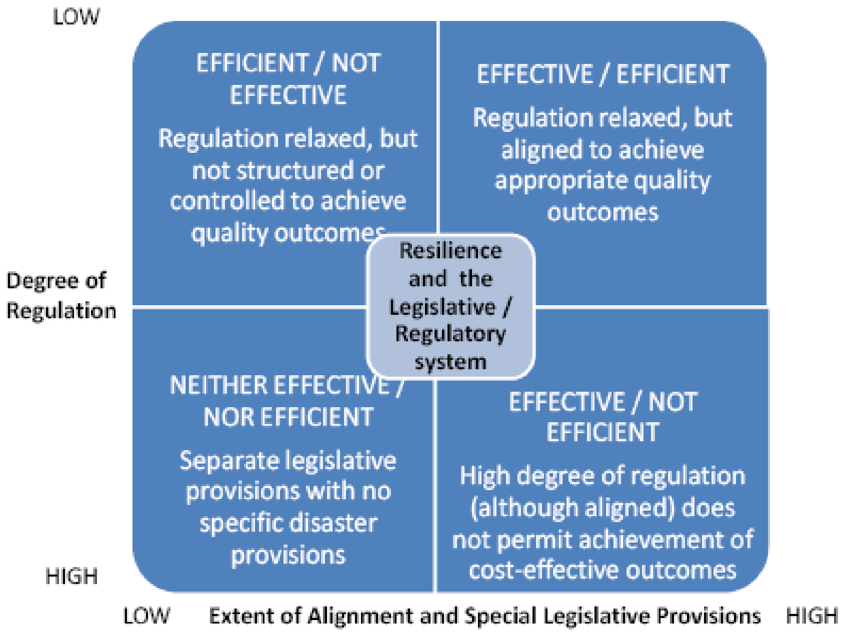

Figure 11-1 The legislative and regulatory system for achieving resilience outcomes (Myburgh et al., 2008)

The author suggests two possible approaches to balancing flexibility and quality of outcome: 1) developing minimum acceptable standards and 2) creating legislation/regulation to guide decision-making rather than to prescribe outcomes. In the first instance, minimum standards could be developed for such activities as: land reclamation, incineration, landfilling etc. In the second case, clear risk assessment processes (similar to those discussed in Chapter 5) could be integrated into the legal process. A greater understanding and certainty about the potential social, economic and environmental risks, identified through a clear risk assessment process, will empower decision-makers to move forward and act quickly to make well informed decisions. Focussing on prescribed outcomes might limit the decision-maker, lead to inappropriate decision-making or generate perverse outcomes. For example, as discussed in Section 11.3.3, following the 2003 Cedar and Paradise Fires authorities were required to meet a certain recycling target by law. Authorities could not meet this target due to time constraints and funding policy regulations. A more appropriate approach may have been to require 'recycling to be maximised while minimising economic, environmental and social impacts' and providing some guidance on measurement of these effects.

Establishing a recovery legislative and regulatory framework before an event will greatly assist the efficiency and effectiveness of recovery works. For example, the haste with which the CER Act was written and accepted has introduced problems in implementation. Poorly written parts of the legislation have at times made it difficult to carry out CERA's duties, particularly in respect to demolitions. An example is the requirement that all parties with financial interest in a property are contacted prior to demolition. In New Zealand, where these records are not routinely kept, this requirement is particularly cumbersome and resource intensive.

The quality of post-disaster legislation will also have an impact on the effectiveness of the recovery. Following the L'Aquila earthquake it took four months for the vague call for 'expedited processes' for waste facility identification and approval to be explicitly described. Without clear guidance on what constitutes 'expedited processes' and with the understanding that peace-time environmental standards had to be met, decision-makers may have felt they were not able to make these decisions quickly. In L'Aquila there are likely to be deeper issues however, as despite the later definition of 'expedited processes', these powers were not fully utilised.

If legislation is prepared in advance there is more time for analysis and consideration. Recommendations in this Chapter, for example could be incorporated. One of the tangential benefits of pre-established legislation (particularly in terms of defining organisational roles and responsibilities) is the development of relationships between stakeholders pre-event. Existing relationships were noted to be extremely valuable during the author's involvement in the response works following the 2011 Christchurch Earthquake.

Clear disaster waste management decision-making processes need to be officially established, such as establishment of minimum acceptable standards, or transparent risk / decision assessment processes.

Where possible, a legislative framework for recovery should be prepared pre-disaster.

It is vital that the right people are empowered to make operational decisions, as also identified in the State of California Integrated Disaster Waste Management Guidelines (State of California, 1997). Having the flexibility to make independent decisions quickly can expedite the disaster response and the recovery operations. Delegation of authority within organisations is also an important consideration to enable effective response and recovery in the event that key personnel are adversely affected by the disaster. This is a critical aspect of an emergency plan.

Recovery legislative provision must include appropriate delegation authority to empower operational personnel to make operational decisions.

It is interesting to note that Italy and Louisiana (the only State in the US to do so) operate under a Civil Law system, whereas the other case studies were in countries with Common Law systems. The reliance on prescribed rules (Civil Law) in a variable and unpredictable post-disaster environment may be more limiting than more flexible principle based systems, particularly if situations have not been predicted or accounted for in the legislation. The difficulty encountered in L'Aquila around coding the waste is a strong example of this. Disaster waste managers could not manage the waste until the law had been written to allow them to act. This situation could make be very disempowering for decision-makers and operational personnel. Conversely, in a principle based system (Common Law), there may be too much flexibility and decision-makers may not feel supported in their decision-making. If there have been no previous experiences in a post-disaster situation and therefore no judicial precedent, decision-makers may be uncertain as to how to implement the law. Again this could be disabling for the decision-maker. A balance between the approaches is needed. This would be a research area worthy of further investigation.

Liability protection

Another tool to empower decision-makers is liability protection. While liability or prosecution protection often forms part of provisions in emergency regulations, there is not always protection for activities carried out during the recovery period (that is, where peace-time laws are adapted for recovery purposes).

Liability was a concern, in some cases, when managing asbestos related issues. Exposure to asbestos can cause mesothelioma - a rare and aggressive form of cancer. The disease can take up to thirty years to develop. After the legal actions that followed the World Trade Centre collapse (Phillips, 2010; 9-11 Research, accessed 2011a), USEPA were cautious about liability issues. Prior to Hurricane Katrina a federal bill was proposed to establish a national fund to compensate persons for exposure to asbestos, and thereby limit the liability of asbestos manufacturers. The bill, called the "Fairness in Asbestos Injury Resolution (FAIR) Act of 2005", was not passed.

To date, the author is not aware of any significant legal action regarding worker or public health and safety following the clean-up efforts following Hurricane Katrina. However, in 2007 Louisiana considered implementing a Bill similar to the 2005 FAIR Act limiting liability of asbestos-related industries for adverse health effects resulting from asbestos exposure. The Bill was spurred by a recent lawsuit against a contractor who had supplied asbestos contaminated soil to a customer. To the authors' knowledge this Bill was never passed.

If liability is not protected, decision-makers will likely be reluctant to make decisions that, while beneficial to recovery, may have personal risks for themselves. The author believes that protection from liability shifts the emphasis from legal obligation to duty of care; or in other words, from a feeling of accountability to responsibility. The CER Act in Christchurch recognises this and includes a clause for protection from liability for those acting under the Act. In the author's opinion, several decisions, such as the authorisation of the land reclamation activities at Lyttelton Port, would have been unlikely to go ahead without this clause.

Liability protection within recovery legislation may empower decision-makers to make timely decisions.

Liability protection, or lack of it, is another reason why the interpretation of peace-time legislation should not be changed post disaster (as discussed earlier). Changing regulatory interpretation of peace-time laws to aid disaster recovery may be a difficult decision to defend should adverse effects materialise.

If alteration of peace-time standards is practiced, liability implications should be considered.

Liability concerns become more complicated when existing facilities (with existing licencing arrangements and approvals) are authorised to alter their peace-time operating parameters. It may be difficult to determine if future adverse effects at the site are as a result of poor site operation or as a result of the reduced legislation. USEPA investigated the possibility of liability over operation of the Gentilly landfill post-Hurricane Katrina and discovered it was impossible to discount FEMA from future Superfund[22] liability (Luther, 2008). One landfill operator in Victoria advised that they would only consider constructing a landfill cell at their facility [post-disaster to assist recovery] if they were assured total indemnity from liability.

The impact on liability needs to be considered for legislative or regulatory changes to existing facilities with existing approvals and licences.

Consistency

The large number of Declaration of Emergency and Administrative Order (DEAO) amendments and legislative changes following Hurricane Katrina was not ideal. While it is important and credible that authorities were prepared to remove legal or regulatory hurdles to facilitate a recovery (and to restore peace-time standards as appropriate), the constant flux of requirements (DEAOs were typically valid for 30-60 days and there were 15 issued over four years) may have affected the efficiency of the waste management process and certainly made planning more difficult. Uncertainty in legal requirements can have a number of impacts:

- Community mistrust in the authority arising from constant changes in acceptable environmental and human health standards.
- Unwillingness of local authorities and contractors to formulate a long-term plan for waste removal if there is a fear that laws may change.
- Inability of facilities to forecast operations, costs, time, personnel requirements, which may have cost implications, especially for recyclers.

As noted after the Cedar and Paradise firestorm in 2003, it also took time to get staff up to speed on current regulations (County of San Diego, 2005) so limiting changes to regulations will help in operational efficiency also.

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22 Release of hazardous substances is governed by the Superfund law (officially, the Comprehensive Environmental Response, Compensation, and Liability Act, or CERCLA). The Act provides the President and USEPA (or delegated officials) broad authority and flexibility to respond whenever there is a release or threatened release of a hazardous substance, or a pollutant or contaminant that may present an imminent and substantial danger.

Recovery legislation, where possible, should be enduring. Best endeavours should be made to anticipate the likely measures required and the duration so that legislative changes can be minimised. Using recommendations, in reviews such as this, to anticipate potential legislative requirement is essential. Strategic and legislative planning must, therefore, be carried out in tandem.

The number of changes to legislation or regulation should be minimised and a realistic duration should be assigned.

Legal complexity

As global awareness for environmental sustainability grows, societies are developing more and more complex environmental standards and operations. This can make responding to a disaster situation increasingly difficult.

Following the Kobe earthquake, Kobayashi (1995) noted that as waste management systems become more complex (recycling and advanced waste treatment methods), society's ability to cope with disaster waste decreases. In particular, Kobayashi was referring to the Japanese waste management system which primarily relies on incineration and disposal of residues to limited landfills. The landfills did not have capacity to accept large influxes of non-processed disaster materials and the processing facilities did not have enough capacity for timely processing of the waste materials. Many incinerators were in fact either damaged by the earthquake or were affected post-earthquake by power cuts. Complex treatment and disposal processes with strict environmental standards are not designed for large acute influxes of materials. Disaster specific facilities and associated environmental waivers in this environment are inevitable.

In New Zealand there are seventeen pieces of legislation and ten to twelve regulatory bodies which could potentially influence disaster waste management. Not only does the amount of legislation affect our ability to efficiently respond in a disaster but the complexity and prescriptive nature of laws can inhibit creative problem solving following a disaster. Some environmental laws impose cumbersome regulatory requirements and some exclude waste management techniques which may become necessary in a disaster situation (for example, incineration or land reclamation). Breadth and flexibility of waste management options are imperative following a disaster. Consequently provisions for disaster waste management need to be considered when establishing peace-time waste management laws and systems.

Clear legislative authority and strategic management will help to cut through this complexity. In some cases clauses may be necessary within peace-time waste management regulations for emergency and response.

Consider disaster waste management requirements when developing peace-time waste strategies and regulations.

Consideration of other laws

No matter what legislative or regulatory changes are made or what waste management strategies are adopted, a considered review of the impacts of those decisions on other legislation needs to be made. For example, in Christchurch the temporary storage Order in Council conflicted with two local bylaws and another Act. It was unclear what the regulatory hierarchy was. In Louisiana, following Hurricane Katrina, the discrepancies between the Civil Law system in Louisiana and the Common Law system in the rest of the US was at times challenging to manage. Approaches taken in the other hurricane affected areas of Mississippi and Alabama, consequently, could not necessarily be implemented in Louisiana.

When preparing recovery legislation legal implications on peace-time legislation and regulation needs to be considered.

11.4 Summary

In general, disaster waste management laws need to: allow for flexibility for adaptation to any situation; be bounded enough to provide support and confidence in outcomes for decision-makers; allow for timely decision-making and action; be collaborative; and focus on responsibility, not accountability.

12. Conclusions

12.1 Introduction

So, where to from here? How can the findings in this thesis be used to better plan for and respond to disaster waste events?

During the case study interviews for the disaster events analysed in this thesis, there were mixed responses as to whether future planning for disaster waste was valuable or not. There are several possible reasons for this viewpoint:

- The perceived difficulty in planning for the unknown.
- The low frequency of such large scale disasters.
- The perceived success of particular past (un-planned for) debris management programmes.

By definition disasters are rare events. Every disaster will have different effects and will require a different type of response and recovery effort. The aim of planning is to try and predict the likely range of these disaster events and to put systems and institutional frameworks in place that can facilitate specific disaster event responses. The challenge is to try to prepare plans and institutional frameworks that are flexible enough to be adapted to every possible disaster scenarios.

This research provides a robust framework and a systems understanding with which to prepare future disaster waste management plans. The findings in this thesis are by no means complete. However, with the foundations provided here, it is believed that base plans can be developed for future improvement as our understanding of disaster waste management advances. Section 12.2, summarises the basic principles and approaches for disaster waste management, based on findings in this thesis. Note that Appendix Q includes a summary of all the Principles developed in this thesis (the italicised summaries from Chapters 6 to 11). Sections 12.3 and 12.4 provide a critique of the research and highlight the key research developments, respectively. This leads into Section 12.5, which outlines some of the areas of disaster waste management that require additional research.

12.2 Application of the research

12.2.1 General

As demonstrated during this thesis, the nature of a disaster and its resultant impacts can dramatically influence a disaster waste management response. In some cases existing plans and processes were found to be inadequate to cope with the scale or nature of the given event and ad-hoc, post-event changes had to be made. As was demonstrated following Hurricane Katrina, some of the rules and regulations failed to facilitate the desired outcome. The comprehensive and well utilised US disaster debris management plans and structures had to be altered in the wake of such an unprecedented disaster event. Some of the challenges faced have led to permanent changes to disaster response in Louisiana and the US.

In an emergency, the objectives are generally quite clear: to ensure life safety, to ensure the community has access to basic life services, and to prevent further loss or damages to property. In terms of waste management this involves search and rescue activities, road clearance and making safe structures. A prescriptive plan, during this phase, is useful. However, during the recovery phase, the objectives are not so clear cut. The objectives will likely change depending on the disaster impacts and corresponding recovery objectives. Disaster waste will inevitably be managed during both the emergency response and recovery phases and a single management approach may not be suitable. Generally, decision-makers need to move away from the 'crisis' mentality of emergency response when dealing with waste during the recovery phase.

As outlined in the research scope (Section 1.12) this research focusses on disaster waste management issues during the recovery phase. Recovery, in general, is poorly planned for internationally. Emergency plans are generally well developed, but most recovery plans and institutional structures (laws and organisations) are formed in an ad-hoc, after-the-event fashion. It was not until 2011, that a National Disaster Recovery Framework was ratified in the US (the country which, arguably, has the best developed emergency response and recovery frameworks) to improve recovery preparedness (FEMA, 2011). Previously 'recovery' had been the last of the 14 Emergency Support Functions under the National Response Plan. Interestingly it appears that debris management has not been explicitly included in the Recovery Plan and it remains as a function under the Disaster Response Plan.

The author believes that the key to make disaster waste management plans, focussed on the recovery phase, applicable to the growing number and complexity of disaster impacts is to focus on guiding decision-makers to a desired outcome, rather than following a prescriptive process.

The approach developed by the author for planning disaster waste management systems is to 1) identify institutional structures that need to be in place pre-disaster to enable effective disaster waste management; and 2) to provide decision-making guidance based on the disaster impacts; the desired environmental, economic, social and recovery outcomes; and the system principles outlined in this thesis and as discussed below.

The author has developed a disaster waste management guidance document for New Zealand based on the findings of this thesis. This is included in Appendix N. The guide aims to balance the prescriptive needs of the response phase and the greater flexibility required during the recovery phase. The document is written so that it can be used in the preparation of a context specific plan, or for use in a post-disaster situation, recognising the fact that many communities in New Zealand lack the resources for planning for rare events. The guide has been discussed with a number of emergency management and waste management personnel in New Zealand; some with experience managing waste from small and large scale disaster events in New Zealand. The document is currently in draft form and will undergo further reviews.

12.2.2 Institutional structures

The institutional frameworks that should be in place pre-disaster are:

- Strategic and operational management organisational structures
- Funding mechanisms, and
- Legislative and regulatory frameworks.

The institutional frameworks need to be integrated into overarching response and recovery structures in the given context. Flexibility and adaptability are critical.

Strategic and operational management organisational structures

Hurricane Katrina was the only case study where roles and responsibility for post-disaster waste management were adequately defined in pre-disaster planning documents. Not even the international UN Cluster system adequately defines who is responsible for management of disaster waste. Determining roles and responsibilities pre-disaster will aid in a more effective recovery. Preferably, these plans should be by position not by person, in the event of specific persons being unavailable. To enable the organisational structures to be adapted to a variety of different scale and type events, it is often recommended that the organisational structures are modular (Auf der Heide, 1989).

Relationship and trust building is important pre-event to reduce delays and increase efficiencies. In New Zealand, the author has been canvassing support for waste management to be included as a lifeline (critical infrastructure service) in New Zealand. This arrangement is advantageous from a legislative perspective (lifeline utilities have an obligation to, and are given special privileges in a disaster to enable them, to restore and continue their service provision); but more importantly from and organisational perspective. Lifeline utilities in New Zealand engage in regular planning and networking which is beneficial in a post-disaster situation (Brown et al., 2010b).

Other strategic and operational structures that may be useful pre-disaster include establishing Memorandums of Understandings to facilitate post-disaster mutual aid (cost and resource sharing) for activities ranging from temporary waste handling facilities (or sites) to personnel and equipment.

Funding mechanisms

Work can also be done to ensure the appropriate funding mechanisms are in place to enable effective disaster waste management. Following the Bushfires, the government was quick to announce that funding would be provided for demolition and debris management. It is unknown if this had been planned for or it was a reactive initiative. Either way, the government recognised that insurance would not be an effective mechanism for this response. Even the established FEMA system was adapted after the catastrophic impacts of Hurricane Katrina, and federal funding was increased to expedite the recovery. Establishing funding responsibilities and funding coverage is essential in achieving recovery objectives and mitigating negative environmental, economic and social impacts.

While there is a need for funding mechanisms to be prescriptive (to prevent misuse as well as to provide clarity and certainty for disaster responders) it is difficult to anticipate all situations to which the funds may have to apply. The author proposes the need to investigate tiered funding mechanisms that can be adjusted to the disaster impacts as well as an outcome rather than a prescribed process approach. In lieu of that, organisational and operational systems need to be established to allow for the chosen funding mechanism to be adapted to enable the most effective response to the given disaster event.

In terms of changing future behaviour and disaster resilience, private funding schemes are potentially more effective than public schemes. Private disaster funding schemes such as insurance can potentially mitigate risk-taking behaviour (such as building in high risk areas, building substandard buildings etc.) through increased premiums (The World Bank and The United Nations, 2010). If individuals are responsible for their post-disaster recovery funds then more ownership may be achieved of the pre-disaster risk. If public funding is provided in place of insurance then less ownership of the risk is taken and mitigation measures (such as relocation) are unlikely to occur. In that case there is greater need for government regulation of hazard prone areas both to prevent exposure to hazards and to lessen the need for costly demolition and waste management.

In Victoria, Louisiana and Christchurch, funds and assistance were provided that were not originally planned for or expected. While external aid can help to stimulate the economy (The World Bank and The United Nations, 2010), some argue that this may set a 'funding precedent'. In other words this may cause an increased dependence on aid and reduce future individual preparedness and capacity to help themselves during the response and recovery. The World Bank and United Nations (2010) refer to this as the Samaritan's Dilemma. In the survey of disaster affected communities in Victoria following the Bushfires, most noted that they expected to receive the same assistance in a similar or bigger size disaster. Commonwealth, state and local government in Australia, now need to consider the precedent that has been set by providing the demolition and debris removal assistance and consider how they want their communities to prepare for future disaster events. At least one author noted that there was a certain expectation of assistance following the 2011 Queensland floods in Australia (Ralph, 2011).

The provision of government funding (instead of relying on insurance) after the Victorian Bushfires, while appreciated by all those interviewed, was not without criticism. Some community members surveyed thought that only insured persons should receive assistance, even though they acknowledged the community wide benefits of the government initiative. Some who were insured felt that they were due compensation from the insurance companies in addition to the services provided by the government. In some cases insurance companies did compensate for this but it depended on the policy type, wording and insurance company.

Before designing a funding strategy, authorities need to consider what message of preparedness it would like to send to its people: does it intend to always provide assistance? If so, how much? Or is it preferred that communities are empowered to facilitate their own demolition and debris management works? The author believes that if communities understand the scope of the assistance and the expected extent of their role in the recovery, from the beginning, this sort of dependence could be avoided. Whatever approach is desired, the message needs to be consistent, well publicised and in-line with insurance company policies. Subsequently, disaster waste management plans need to be designed with the given funding mechanisms in mind.

Legislative and regulatory frameworks

As observed in Christchurch, establishment of legislation post-disaster can be problematic and, if poorly written, has the potential to inhibit the recovery works. Written well, legislative and regulatory frameworks can empower and guide the decision-makers and enable an efficient and effective recovery. The specific legislative measures that are required to manage disaster waste are as discussed in Chapter 11.

12.2.3 Decision-making guidance

It is envisaged that the analysis framework established in this thesis could be adapted as a planning tool.

The disaster impact indicators and waste descriptors established in Chapter 4 could be used pre-disaster to predict the likely waste scenarios following a disaster event. Post-disaster the indicators can be used to rapidly assess a disaster situation.

Using the indicators and the principles developed in this thesis, decision-makers could prepare the framework for managing the waste. In a post-disaster situation the process is likely to follow the decision-path below:

1. Is the existing funding mechanism (private / public; lump sum / reimbursement / direct facilitation) suitable for managing this particular event? For all waste sources? If not, what should it be changed to?

2. Given the funding mechanism, what operational organisational approach should be used for each waste source (individual / central)?

3. If a centralised approach is desired what contractual arrangements should be used (cost reimbursement / lump sum)?

4. Should recycling be included? If so how should it be included (onsite or offsite separation)?

5. Are there any legislative or regulatory provisions or processes that might unreasonably limit the effectiveness of the disaster waste management progress? If so, is it reasonable (and justifiable) to change these? How should those risks and the corresponding legislative changes be managed?

In order to answer these questions, disaster waste management (and recovery) objectives need to be set. Chapter 5 presented typical environmental, economic, social and recovery objectives that may be targeted. To ensure that appropriate and justifiable decisions have been made to reach the desired objectives, it would be useful to use the system effectiveness criteria described in Section 5.2. The criteria would be particularly useful to assess and justify decisions where there are departures from established waste management (and related) standards.

12.3 Methodology critique

A cross-case analysis approach was a necessary approach given the lack of research in this subject area. The literature review demonstrated that no author has developed a comprehensive understanding of disaster waste management, in particular the influence of institutional frameworks. Thus, a high-level study was required to enable the key elements, and respective links, of disaster waste management systems to be identified. As described in Chapter 2, the best way to gather this information was by a case study approach across a wide range of disaster events and contexts. The selected case studies included a wide range of disaster events allowing for good cross-case analysis. The author did note, however, that the Samoan Tsunami case study, the only set in a developing country context, was less easily compared to the other case studies. In particular, the risk management techniques, legislative frameworks and funding mechanisms were limited, and thus, offered little for cross-case comparisons.

The most effective way of gathering the data was through interviews. Because of the range, depth and unknown scope of potential issues involved in this exploratory study, it would have been difficult to use questionnaire or survey as a data collection method. Carrying out these interviews in the affected areas is highly valuable. The interviewees generally appreciate the interest that the research is showing in the disaster recovery (and the effort to come to the affected area). In addition the researcher is in a better position to sympathise and identify with the issues involved. If the author had not been fortunate enough to find funding to visit the case study locations, a survey may have had to be employed. However, it was noted that on the occasions that interview questions were sent to and completed by interviewees (which was sometimes carried out on request of the interviewee) the level of detail in the written response was far less in the face-to-face interviews. Now that a research framework has been established (Section 12.5), more directed lines of inquiry will be possible in future research. Thus, surveys or questionnaires may become more useful. In addition, quantitative as well as qualitative data could potentially be gathered, which will allow a deeper understanding of the issues identified in this research. For example, researchers could put measures in places to monitor recycling and labour markets following a disaster to quantify the qualitative assessments made in this thesis.

One particular weakness of the research methodology was that the data gathering was at a single point in time, or, it was a snapshot. If time and resources had allowed, the author would have considered gathering data over a longer period of time which would have allowed for longitudinal case studies. This approach would have been particularly useful as much of the analysis was based on environmental, economic and social impacts which will take time to materialise.

The author felt that the participatory research approach taken for the Christchurch Earthquake case study was both invaluable and challenging. In terms of developing a full understanding of the issues involved in disaster waste management, there would have been no better approach. The author was exposed to real-time decision-making. Unlike the other case studies, which relied on a (often reflective) snapshot summary of the events, the data was raw and uncensored. While this enabled the author to more fully understand the nuances of disaster waste management decision-making, managing this rich data has proved challenging during the compilation of the case study and thesis. First, the author has felt that she has not been able to fully analyse her experiences due to confidentiality and sensitivity issues around the, still, very active disaster waste management programme. It has been testing to separate the information that is publicly available and that which is private and this has created challenges when obtaining ethical approval from the various persons and agencies involved. As a result, the author has found that, whenever there was a question about the sensitivity of the data, she has self-censored it. Second, the richness of the data for the Christchurch case has affected the balance between the case studies in the thesis. The majority of the examples given in the cross-case analysis chapters stem from the Christchurch case study. There is a potential that the author has generalised some of the experiences from Christchurch where there is perhaps insufficient evidence gathered from the other case studies to verify the validity of the generalisation.

Despite these challenges, the participatory approach was extremely beneficial to the research. In particular, it facilitated the development of practical disaster waste management guidance. Having been directly involved, the author now better understands what information, assistance and institutional frameworks would be useful (both pre- and post-disaster) to manage disaster waste. While involvement in disaster response events, by their nature, can never be planned, the author recommends that disaster researchers embrace this opportunity where it presents itself. Some researchers may shy from a participatory approach due to its lack of formal design and loss of researcher objectivity. However, the value of the experience and real-time observations is immeasurable; particularly where the research aim is to produce a practice-oriented output.

The nature of disasters often means that a researcher's ability to gather complete and representative data is limited. Designing and executing a complete study is difficult when dealing with a (by definition) resource depleted and psychologically affected community. Flexibility in research design is important.

12.4 Key research developments

Disaster indicators

The disaster & disaster waste impact indicators presented in this thesis (Chapter 4) are, in the author's opinion, one of the most important and potentially powerful developments in this research. The indicators demonstrate a method by which disaster managers, planners and researchers can simplify the very large spectra of possible disaster impacts, into some key impacts or variables which will likely influence the management requirements. While there may be a tendency to develop hazard-centric descriptors, the author believes that the general impact-oriented descriptors, such as those presented here, offer several benefits. First, the non-hazard-centric indicators are in keeping with the multi-hazard approach to disaster management, internationally. Second, the general impact indicators will allow transferable lessons to be distilled from every disaster event, regardless of context and hazard type. For example, as demonstrated in this thesis, there are many challenges in recycling following a disaster event. It would be disadvantageous not to heed the lessons learnt following Hurricane Katrina or the Victorian Bushfires and apply them to the situation we are facing in Christchurch just because the waste was generated by a different hazard. The more disaster events we can gather information from, the more rapidly our body of knowledge will grow and our disaster preparedness will improve.

It is likely that different sectors within disaster management (for example, disaster funders, organisational managers, welfare providers, public information managers) would need to develop different indicators. However, eventually it may be possible to develop a condensed list of key disaster impacts which would help disaster management planners from all disciplines. One possible addition (or additions) to the indicators is resource availability (human, plant, equipment and financial). Resource availability has not been included in the list of indicators but, as shown in this thesis, the availability or not of resources is a key decision-driver for managing disaster waste, and likely other aspects of disaster management. In terms of disaster waste, resource availability influences, at the very least, the choice of procurement approach, price escalation, recycling and environmental and human health risk management strategies.

Because the indicators are relatively abstract, further consideration is needed into how these indicators can be included (or not) into operational guidelines. In the meantime, the immediate application of the indicators is, as discussed above, for transferring lessons between disaster events. In addition, the indicators could be used by planners and policy makers to develop a range of diverse scenarios to test plans and policies.

Risk management

It would be relatively straight forward to facilitate the removal and disposal of waste after a disaster. However, simply removing the waste without considering the environmental, economic, and social effects as well as the effects on the overall disaster recovery objectives would be irresponsible. Because of this, many of the discussions in this thesis are based around risk management. It is the disaster waste manager's responsibility to identify and mitigate the many risks involved in disaster waste management (for example, environmental and human health risks, risk of cost overruns, risks to the recovery timeline). How these risks are managed will determine how effective a disaster waste system is.

Therefore, it is important that disaster waste management plans, policies and decisions are formulated with a focus on the risks involved. In general, the recommendations in this thesis suggest that: the greater the risks involved, the greater the level of control (on quality) is needed.

12.5 Future research

12.5.1 Establishing a research agenda

This research has been intentionally broad in its scope. With limited structured research in the area of disaster waste management to date, a structured exploratory research project was required. It is hoped that the holistic, systems-based research framework presented here will set the stage for future research. A common framework will allow for more disaster waste management systems to be studied and compared across a wide range of contexts and disasters so that a richer, fuller, and more robust understanding of disaster waste management can be established.

In addition to establishing a framework for future research, a number of specific research needs have been identified. Some are directly related to the findings of this research, while others are items that are more tangential to the research questions but were noted by the author during the research (in particular during the author's experience working in the Christchurch earthquake response).

By establishing a research agenda here, it is hoped that better quality and more focussed studies will be possible in the future. The limited research that has been carried out in this area to date has been ad-hoc. Much of the research (including this thesis) has been done based on past disasters using the limited information that is available. Knowing the research needs at the time of an event will enable researchers to ensure that the appropriate data are collected. It is also hoped that some of these outstanding issues can be addressed before the next major event, so that communities, in New Zealand and internationally, can be better prepared.

The research areas identified are outlined below.

12.5.2 Disaster impacts

Develop waste quantity estimation techniques (pre- and post-disaster)

A cross-context and multi-disaster assessment of waste composition and quantities would be a valuable addition to the literature to enable the development of better waste quantity estimation methodologies. The development of a standard method of reporting disaster waste composition and quantities would be a worthwhile step toward enabling this.

Develop comprehensive disaster waste classifications

As noted, the waste classification approach and findings in Section 4.3.2 could be expanded to produce a comprehensive set of tables outlining the typical disaster waste characteristics for different hazard types and the different waste streams (by waste source) for each hazard type. Developing a correlation between disaster impacts and disaster waste impacts may also be beneficial to planners.

Investigate the effect of disaster scale and other disaster impacts on disaster waste management approaches.

As outlined earlier, this research has focussed on extreme events. Further analysis would be useful to determine the effect of scale (and other disaster & disaster waste impacts) on the disaster waste management system design: Are different responses necessary for different scales of events? Which disaster impacts are most indicative of the response type required? At what level(s) is a change in response (eg individual to centralised operational management) required?

12.5.3 Effects

Investigate the long term effects of disaster waste management systems

As identified in Section 2.3, this research was limited in that it presented a 'snap shot' of the disaster waste management system and did not investigate the long term impacts of the approaches taken. A longitudinal study of one or more of the case studies investigated here (or others) would be beneficial for validation of the analysis and the proposed system effectiveness measures.

Determine the indirect effects of disaster waste management approaches

While a qualitative understanding of the indirect effects relating to disaster waste management were presented in this thesis, more comprehensive assessment of these effects would be useful. Indirect effects include: the effect that efficient or inefficient debris management have on the economic recovery; and the psychosocial and community recovery implications of the speed of debris removal process.

12.5.4 Strategic management

Investigate context specific strategic management design

Context specific research is necessary to determine how recommendations in this thesis could be integrated into existing organisational structures, that is, disaster response and recovery management structures in different contexts.

Determine community engagement protocols

While acknowledging the importance of community engagement in post-disaster decision-making, this thesis has not fully investigated how peace-time approaches to community engagement may change post-disaster (for example, changes in risk tolerance and expectations). The drivers for, limits to, and possible mechanisms to enable community engagement should be investigated.

12.5.5 Funding mechanisms

Develop flexible funding mechanisms

As described in this thesis, flexible funding mechanisms greatly enhance a community's ability to effectively respond to disaster waste. A recommendation in this thesis is that tiered funding mechanisms could be useful where different levels and types of funding are applied for different disaster impacts. This should be investigated further.

Investigation into how funding mechanisms might be able to change from the current 'lowest cost' approach to 'best cost' options would also be beneficial. This would ensure recovery funds and activities are always directed towards the overall recovery goals. One approach worth investigating is implementing 'outcome targets' rather than 'process constraints'.

Investigate the economics of price escalation

As discussed, price escalation post-disaster is acknowledged but not well understood. However, it must be accounted for if communities are to ensure they have adequate financial resources to recover from disaster events. Research into the factors that contribute to the price escalation; the estimated magnitude of the price escalation; and possible management techniques to prevent, or account for the likely price escalation, would be beneficial.

Research demolition cost estimation

Context-specific research on estimating demolition and debris management costs would be beneficial. Costs could be based on hazard maps, building material, building capital value, etc. This would enable better financial planning both pre and post-disaster. Cost estimation should account for price escalation (see above).

12.5.6 Operational management

Quantify the cost effectiveness of different contract types

While a qualitative analysis of different contract types has been included in this thesis, it would be beneficial to carry out a quantitative study to verify the qualitative assessment. For example, compare the cost effectiveness (considering direct and indirect costs) of the cost reimbursement and lump sum contracts following the Christchurch earthquake.

Investigate the psychosocial effects of participating in recovery activities

Some participants in this research advised that participating in the demolition and debris management programme had psychological benefits. Further investigation into this and the limits to public participation, would be useful so that disaster waste managers can effectively plan their disaster waste management systems.

12.5.7 Recycling

Determine likely post-disaster recycling market responses

As discussed in Section 9.3.1, recycling and reuse markets are likely to behave differently post-disaster, as materials flood the market. Where most markets experience resource deficits post-disaster (for example, large demands for building materials and equipment), recycling and reuse markets are completely the opposite. A quantitative exploration of the likely market response in a post-disaster situation would be beneficial. The research would identify key factors that may dictate the feasibility of post-disaster recycling.

Analyse the economics of post-disaster recycling

As well as a focussed economic analysis of the recycling markets, the economics of recycling (from 'cradle to grave', onsite and offsite) needs to be better understood. In particular the sensitivity to certain variables (for example: the value of labour; the value of recyclables; the volume of waste; the available demolition resources; space constraints and logistics) should be tested and general principles of post-disaster recycling could be derived. A robust model could also be used post-event to help communities to determine the most appropriate level of recycling.

As discussed in Section 12.5.3, a better understanding of the indirect costs (particularly with respect to time delays in the debris and demolition works) would be beneficial to determine whether on- or off-site separation is preferable.

12.5.8 Environmental and human health risk management

Investigate post-disaster risk perception

The survey in Appendix C indicated that in a post-disaster situation many people's environmental and human health risk tolerance increases. A more in-depth study to verify these findings would be useful. In particular, investigating risk tolerance changes depending on community and personal impact. In addition, investigating how risk tolerance changes over time (i.e. with time elapsed from the disaster event) would be worthwhile.

Research into post-disaster waste handling facility design and operation

Research and development of disaster specific guidance for the effective design and use of temporary storage / staging facilities and low-engineered disposal sites is needed. Factors requiring consideration include space requirements, environmental factors, human health risks, noise and dust, pre-disaster site identification, land-use planning issues and cost.

One waste stream in particular that has drawn special attention following the Christchurch earthquake is the potential management of treated timber. Further research into various management options (disposal, waste-to-energy etc.) is required.

Research into likely human health hazards post-disaster

A detailed assessment of human health risks associated with various disaster events would be beneficial. A comparison between the perceived and the actual human health threat (and reasons for any disparity) would be useful. The assessment should consider the public health hazards from: the waste matrix, waste management options and handling the waste. Management of fine particulate matter, in particular, has been identified by some as a priority (GAO, 2008). The effects of open burning post-disaster too (particularly where contamination of the waste is likely) would be worth investigating.

12.5.9 Legislation and regulation

Perform context specific legislative and regulatory reviews

As noted in Chapter 11, legislation and regulation is highly context specific. The recommendations in this thesis need to be manipulated and applied to context specific legal frameworks.

Review issues around waste ownership

One aspect of the legal review in this thesis that required additional attention is the potential issue around disaster waste ownership. In particular, a legal review around trans-boundary (domestic, local, regional, national and international) movement of waste would be valuable.

Compare civil and common law systems

An interesting area of further research would be the comparison on the effectiveness of civil and common law legal systems on post-disaster management. This study would be valuable at a broader recovery level, to see what aspects of each legal system are most effective at enabling recovery.

12.6 Summary

It is hoped that the concepts in this thesis, in particular, the development of a disaster waste management planning approach based around key decisions, will empower decision-makers to successfully manage disaster waste in the future. Understanding the key decisions that need to be made, the main decision-drivers, and their relationships will give decision-makers greater confidence to make timely and effective decisions in a range of disaster scenarios.

It is hoped that the reservations felt towards planning by some of the research participants, will be allayed by the findings in this thesis, and that communities can prepare for and respond to disaster events more effectively in the future.

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Appendix A Disaster waste management: a review article

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Appendix B Disaster waste management: a systems methodology

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Appendix C Disaster waste management perceptions survey

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Appendix D 2009 Victorian Bushfires, Australia, disaster waste management case study report

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Appendix E Disaster waste management following the 2009 Victorian Bushfires

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Appendix F 2009 Samoan Tsunami, disaster waste management case study report

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Appendix G Disaster waste management for the Samoan tsunami

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Appendix H 2009 L'Aquila Earthquake, Italy, disaster waste management case study report

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Appendix I Disaster waste management on the road to recovery: L'Aquila Earthquake Case Study

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Appendix J 2005 Hurricane Katrina, United States, disaster waste management case study report

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Appendix K 2011 Christchurch Earthquake, New Zealand, disaster waste management case study report

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Appendix L Disaster funding mechanisms: a demolition and debris management perspective

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Appendix M Implementing a disaster recovery programme: a demolition and debris management perspective

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Appendix N New Zealand Disaster Demolition and Debris Management Guidelines and Policy Recommendations

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Appendix O Legislative Implications of Managing Disaster Waste in New Zealand

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Appendix P Waste management as a 'Lifeline'? A New Zealand case study analysis

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Appendix Q Disaster Waste Management Principles

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