MASTER'S THESIS

POST-DISASTERS SOLID WASTE MANAGEMENT

Case studies and Thematic Analysis

Ranim Kaja

University of Jyväskylä

School of Business and Economics
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JYVÄSKYLÄN YLIOPISTO

ABSTRACT

Author: Ranim Kaja	
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Abstract:
This thesis presents four case studies as examples of how different countries around the world deal with their disaster waste management. These case studies are the Great East Japan Earthquake, Hurricane Katrina, Sri Lanka earthquake and tsunami, and finally man-made conflicts. Disaster solid waste management is not old in the management planning. In the past, the countries facing disasters used to struggle, and they focused more on removing the debris from streets and sensitive places like main roads and hospitals. However, they did not really have any plan about how to deal with the generated waste and debris, where the stressful situation of the emergency phase right after the disaster made the case even more complicated.

Disasters can generate extremely massive amount of debris and waste depending on its nature and the affected area's nature. Additionally, there will be also the daily generated waste, which means that disasters will significantly affect all life aspects, especially the economy. Therefore it is important to have a well prepared disaster waste management plan to limit the potential damage and to minimize the cost and the time needed for the recovery phase. Moreover, the waste and debris in the affected area will cause a significant environmental impact. Therefore, the responsible authorities have to manage the disaster waste sustainably and work on bringing the area to an environmentally accepted situation.

By presenting different methods of disaster solid waste management in four different countries, it will be possible to spot the best practices and the wrong practices in the management system. The removal of debris is the most important factor at the emergency phase in the waste management, as it will help reaching the victims and prevents the spread of diseases. However, the authority should be prepared with the place of where to take the debris and waste, and what to do with them in the next stages. In this thesis more detailed information about the disaster solid waste management practices will be explained to clarify the fundamental differences in facing different types of catastrophes in countries with different levels of development.

Keywords: Disaster waste management, solid waste, debris, catastrophe, planning, removal, temporary storages, waste handling.

Location Jyväskylä University School of Business and Economics

Author's address: Ranim Kaja
Corporate Environmental Management
School of Business and Economics
University of Jyväskylä
ranimkaja@gmail.com

Supervisor: Tiina Onkila
Ph.D. Post-Doctoral Researcher
Corporate Environmental Management
School of Business and Economics
Jyväskylä University
tiina.onkila@jyu.fi

ACRONYMS

CBOs	Community-Based Organizations
C&D	Construction and Demolition
CNO	Center of National Operation
COWAM	Construction Waste Management
EPA	Environmental Protection Agency
GIS	Geographic Information System
INGO	International Non-Governmental Organizations
KEED	Kabul Environmental Engineering Department
Kg	Kilogram
Km	Kilometer
NGOs	Non-Governmental Organizations
OCHA	Office for the Coordination of Humanitarian Affairs
ROE	Right Of Entry
ROW	Right Of Way
TDSRS	Temporary Debris Storage and Reduction Sites
UNCHS	United Nations Centre for Human Settlements
UNEP	United Nations Environment Programme
U.S.	United States

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1 INTRODUCTION

Disasters are the unusual changes occurring all of a sudden in a certain area, and causing significant damage and loss of life and property, which requires more effort to move back to the normal situation. Disasters can be natural, like earthquakes, or man-made, like wars and incidents (Brown, Milke, & Seville, 2011). In the event of disaster, the government will have to face crises on several levels. On the humanitarian level, there will be cases of death, injury, lost people, and population displacement. Where on the financial level, there will be a massive loss in properties, and high repairing cost for the damage caused by the disaster (Brown, Milke, & Seville, 2011). Obviously, the human dimension of the disaster has the major priority after it occurs, and then comes the physical damage in the properties and the waste resulted of the destroyed buildings. The destruction residues in the residential areas resulting from natural or man-made disasters are usually in the form of debris and waste. Debris is a term taken from the French word "débris" that refers to the broken remains of buildings and other infrastructures, and need to be deported after the catastrophe (Gissen, 2011). These wastes and debris are usually very challenging for both government and civilians. Obviously, there will be a massive environmental damage in the affected area, and a huge load of mixed waste consisting of all kinds of wastes which are difficult to separate and recycle (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009).

It is very important to work on removing debris earliest possible, as it blocks the roads in most cases, which makes rescuers mission very difficult, and prevents displaced people from going back to their homes. Therefore, life in the inhabited areas cannot go back to normal until debris is removed, and removing and handling debris are the first steps to bring stable life back to the affected residential areas. In some cases, the volume of the debris can reach up to 15 times more than the waste generated in normal cases for the same area. Wherefore, the destruction will have some consequences such as the spread of different types of pathogens, as the poor hygiene and the piles of debris will provide an ideal environment for diseases and insects (Brown, Milke, & Seville, 2011; Indrawati & Steer, 2005; Karunasena, Amaratunga, Haigh, & Lill, 2009).

Generally, developing countries suffer the most from natural disasters, especially in Asia, as it appears that natural catastrophes hit that region more often. The difficult situation in these countries comes from the fact that they are not prepared to face such crises, and solid waste management in these countries might not be adequate to meet the daily waste collection and handling. As a result, the lack of preparation will lead to the increase of losses in lives and properties that can be avoided by proper planning (Perry, 2007). However, *"Every disaster is different, but a plan will give you a place to start."* – Marc Bruner, Solid Waste Authority of Palm Beach County (EPA, 2008). In order to handle the catastrophic event in an efficient way, strategies and plans must be prepared earlier to limit the potential destruction of the disaster (Brown, Milke, & Seville, 2011). Usually, disaster waste management plans vary a lot from one country to another, due to the fact that each country has its own unique way of handling solid waste. Hence, it is not possible to apply the disaster waste management plan of a country in another country. For example, it is not possible to apply the plan of a developed country that has sophisticated solid waste management, in a developing country that has inadequate waste management system. Obviously, these differences must be considered while preparing post-catastrophe solid waste management plan in any country (Karunasena, Amaratunga, Haigh, & Lill, 2009). Clearly, the first step for preparing a disaster solid waste management plan is collecting information and estimations about the potential debris. In fact, debris vary depending on the type of the catastrophe, so it is essential to know the approximate amount of it, the expected types of wastes it contains, and the area needed for it in landfills (Rafee et al., 2008). After collecting information about the debris, the collection of the debris and transporting it to the proper sites and landfills will be needed to know. In fact, fast waste transportation can save more lives and bring life back to normal in the area. Finally, the waste will be handled in temporary storages and handling sites to be recycled or sent landfills (Karunasena, Amaratunga, Haigh, & Lill, 2009; Kovacs & Spens, 2007).

In the developed countries where catastrophes happen frequently, further studies can be held to improve the disasters waste management system. Since the repeat of the disasters events give the researchers better chance to improve the disaster management system by learning from previous mistakes (Ikeda, 2012). On the other hand, in the developing countries where disasters occur frequently, the solid waste management is not adequate. These countries have the problem with their regular solid waste management system, which means that the situation will be even more difficult in the event of a catastrophe. They will face several problems such as the lack of enough space in the landfills for dumping the huge loads of waste which are several times more than the normally generated waste, and other problems that will lengthen the recovery phase. In fact, one problem can lead to another, and as a result, private owners will have to solve their problems by themselves, which they might do by removing the waste and debris falling in their property and place them in any other place causing significant environmental impacts. In other cases, their behavior might lead to the generation of toxic gases, like the case of waste burning (Karunasena, Amaratunga, Haigh, & Lill, 2009). In fact, Most of people have never faced any catastrophe and that makes them believe that it will not happen to them. Therefore, they do not prepare for such an extreme event, which leads to increased losses. The truth is that catastrophes can hit any area of the world no matter how much people think it will not happen, so it is better to be prepared (Perry, 2007).

In this thesis, the Theoretical chapter will explain about post-catastrophes strategic planning in the ideal conditions. This means that it will not be following the specifications of any country. The information will be gathered from researches done in this area like journal articles, and also the information available in some countries environmental ministries when available, like the Japanese Ministry of the Environment. As the thesis proceeds, four case studies will be provided as examples of different handling methods for disaster waste management by the local governments and organizations. These cases will be: The Great East Japan Earthquake, Hurricane Katrina, Sri Lanka Earthquake and Tsunami, and finally man-made conflicts case study that will include the waste management situation in each of Afghanistan, Iraq and Kosovo after the war. In the end, there will be a discussion about the work of each country, and a comparison between the results of their work methods, and then a comparison of these results with the theory and similar studies for this study.

In each case study, several issues will be explored to give an adequate idea about how the responsible authorities handled the disaster waste management in each country. Background information will be given about solid waste management in developing countries to state the reasons behind some of their activities. After that, more information will be stated about the destruction, and the amounts and types of the generated wastes. The most important part will be about the way each country handled the physical work. In other words, we will find out how the waste and debris were collected, where they were taken to, what kinds of handling methods were used (recycling, incinerating... etc.). Finally, more information will be found about the time management of the disaster waste management. In this way, an adequate idea will be obtained about how to practice the disaster solid waste management in different areas around the world.

1.1 Research task

The key purpose of post catastrophe waste management is to have a ready plan of how the competent authorities should act in the critical situations. At the time when catastrophes occur, people tend to behave randomly as they panic, but knowing what should be done at the time of panicking can save time, money, effort, and even lives when debris is blocking the rescuers' roads.

Therefore, the main question of this research will be "*What are the most essential stages in the disaster waste management plan that will help returning the affected area back to an acceptably normal situation*?" To answer this question I divided the research into two parts. In the first part, the theoretical information will be explained. Where in the second part, five different cases about catastrophes waste management in different countries will be presented to show the real practices.

Nevertheless, answering the main question can be achieved by answering the following questions:

a. What should the first action after the disaster occurs be? Do different countries practice the same post-catastrophes waste management?
b. What can be suggested in order to improve the work?

1.2 Motivation

The idea of writing a thesis about the post-catastrophes waste management came to my mind after watching large number of photos and videos about the amount of damage occurring different cities in Syria. As a Syrian citizen, it was very touching for me to see how the places I grew up in turned into piles of debris. That was the point when I asked myself *"If I want to clean these wastes, where should I start from?"* I asked this question to some of my classmates, and I was not able to get a satisfactory answer. Therefore, I decided to combine my personal question with my educational research, and find the answer for the question. Based on that, the main aim of this thesis is to find the best mechanism to collect and handle debris after catastrophes, and find the right way to prioritizing the work. However, as the damage after catastrophes affects many sectors, especially different types of waste management like waste water and nuclear wastes, I will focus in this research on the solid waste management.

1.3 Thesis outline

The structure of this thesis will be as follows:

Chapter 1	Introduction. In this chapter the research task, the questions of the thesis, and finally the thesis outlines will be given.
Chapter 2	Methodology. In this chapter information will be provided about the research technics and case studies background.
Chapter 3	Theoretical framework, where the disasters waste management pre-planning will be explained in the ideal situation. The main questions will be answered in this chapter.

Chapter 4 Case studies, where four cases studies will be described as examples of how different disasters were handled in different countries. Results and findings will be also clarified in this chapter.

Chapter 5 Discussion, where different practices between developing and developed countries will be discussed.

Chapter 6 Conclusion.

2 METHODOLOGY

2.1 Research design

This research is conceptual in nature, therefore, the qualitative testing seemed to meet its requirements and provide adequate information about how the response to disaster should be planned. However, the topic of this work is, usually, part of the general disasters risk management that should be prepared by the responsible authority (Perry, 2007). The research aims to provide a general idea about how planning should be done, and what are the factors that should be considered. Hence, for preparing a full debris management plan, different stakeholders must be involved in the work, such as, local contractors, the government, and different other concerned agencies (EPA, 2008). The research was conducted by exploring the researches that covered the area, and the theory was supported by four different case studies in order to see whether the real practices went as planned.

2.2 Thematic analysis

The thematic analysis type of research seemed to serve the purpose of this paper. By collecting information from different sources and matching them to find the similarities, then arranging them together, it will be possible to make a full picture of how the planning should be conducted. The thematic analysis qualitative research will be applied through exploring the secondary data available about the topic from different literatures and cross analyzing them. The outcome of this analysis will be in form of suggestions and recommendations. In this type of researches there can be several ways to conduct the research. Hence, in this paper, and in order to support the final conclusion reliability, four different case studies will be presented as real-life practices (Guest, MacQueen, & Namey, 2011, pp. 10-11).

2.3 Case Studies

Case study is a methodological analysis that explains complicated phenomenon by performing a detailed analytical study of its complex affairs in order to enrich the understanding of its different issues and the relations between them, and also to reinforce the known information about these issues by providing another example (Dooley, 2002).Therefore, using case studies was found to be the best method that can serve the goals of this paper. In case studies, there will be a deep analysis for the situation in different parts of the world and that can help us see the overall view from different angles. In case study methodology, the type of analysis defines the case study characteristics, and it can be analyzed on one or many levels. Also, it can be combined with other research methods if that can support deeper answers to the questions of the research (Merriam, 2002). Based on that, thematic analysis in this research was combined with four case studies in order to explore the theory in the ideal case, and then evaluate the real practices. The case studies were selected carefully to provide wider vision about how the disaster waste management is accomplished. The comparison will be between developed and developing countries facing the same type of natural catastrophes, two developed countries facing different natural catastrophes, and finally comparing the disaster waste management in the cases of natural and man-made catastrophes.

2.3.1 Cases selection

The case studies were selected carefully to serve the aim of this research, and in order to achieve it, certain requirements were needed to be in each case study, to serve the comparability purpose. The cases needed to have similar time range of occurrence, and this occurrence needed to be within about 20 years, as the idea of disaster waste management is not old after all. Moreover, the disasters should have approximately similar strength of hitting in order to give similar circumstances, to enhance the comparison. Furthermore, information about the handling procedure of the disaster waste management should be available. Therefore, three of the very famous disasters that have occurred in the last twenty years were selected. The first one is the Great East Japan Earthquake 2011. This disaster was significant in its strength, the damaged it caused, and the way Japan handled it. According to the World Bank (2013) "*Other countries can protect themselves from major disasters by adopting – and adapting as necessary – some of the measures taken by Japan, and by understanding the strengths and weaknesses of Japan's response to the Great East Japanese Earthquake.*" (WB, 2013). That can give a clear view about the impressive work that Japan accomplished. The second case study was The Indian Ocean earthquake and tsunami that hit Sri Lanka, 2004. The disaster was huge and affected many countries which gave it an international dimension. Sri Lanka was one of the countries that suffered the most from the hit (Leclerc, Berger, Foulon, Sarraute, & Gabet, 2008). By selecting Sri Lanka, the chance will be given to compare the disaster solid waste management process in developing and developed countries, which will provide clear image about the gap between them. In the third case study, the selection was done in order to compare two different developed countries disaster solid waste management, hence, Hurricane Katrina 2005 in the U.S. was chosen. In fact, both Japan and the U.S. have faced similar disasters events before, based on that, the comparison between their practices should be relevant. The last case study was aimed to show the disaster solid waste management practices in the case of man-made disasters. Therefore, war conflicts were chosen to explain the situation and compare it with the practices in the cases of natural disasters. Accordingly, the case needed to be not very old so it falls before disaster solid waste management was clearly known, and also not very new so there are no available information about the waste management yet. The problem with this case was that there was not always enough information, so combination of several war conflicts was needed to show the entire picture of the situation. Hence, Afghanistan, Iraq, and Kosovo conflicts were selected.

Nevertheless, it is important to notice that there is about 7 years difference between Sri Lanka and Japan cases, and also 6 years between the cases of Japan and the U.S. which can affect their practices. On the other hand, it is also important to know that countries like Iraq and Afghanistan are still facing tough situations, which means that we are assessing the disaster where the disaster is still on going. These issues should be kept in mind when we compare each case to the other.

2.3.2 Case studies background

2.3.2.1 The great east Japan earthquake and tsunami

On 11th of March, 2011, an earthquake hit the east of Japan and causing a tsunami in the pacific coast. In Japan, where these kinds of catastrophes are more common to hit the area, the earthquake and the tsunami, were recorded as the strongest hitting the area from the perspectives of strength and the size of the affected area. The earthquake magnitude reached 9.0, whilst the tsunami wave reached the height of 39 meters (Mimura, Yasuhara, Kawagoe, Yokoki, & Kazama, 2011). According to the Ministry of the environment government of Japan (2012) annual report, approximately, 16,000 people died, 6,000 people were injured, and 3,000 were missing. Close to 130 thousands buildings were totally destroyed, and about 258 thousands buildings were partly destroyed, with an approximate cost of the damage reached up to 16.9 trillion yen Distributed among the various actors.

2.3.2.2 Hurricane Katrina

Between 23rd and 30th of August 2005, the coasts of Louisiana, and Mississippi in the United States of America were hit by one of the strongest five hurricanes that hit the United State, Hurricane Katrina. It was very strong and covered huge area. The hurricane wind force reached far to 170 km from the center, and the storm wind force reached far to 370 km from the center. The velocity of the wind reached up to 280 km per hour with a central pressure of 902 millibars, where the highest central pressure reached up to 928 millibars with a velocity of 190 km per hour (Fritz, et al., 2007). Furthermore, the estimation of the affected area by the hurricane reached close to the total area of the United Kingdom. Hurricane Katrina killed more than 1300 people and displaced more than a million, causing financial losses that exceeded 80 billion Dollars (Cutter, et al., 2006).

2.3.2.3 The Indian Ocean earthquake and tsunami: Case of Sri Lanka

On 26th of December, 2004, an earthquake of 9.0 magnitudes hit the coast of Sumatra island of Indonesia, followed by more than 67 aftershocks that lasted for 3 hours after the first earthquake hit. This earthquake caused giant tsunami waves, where the first wave had a height between 5.5 and 6 meters (Srinivas & Nakagawab, 2008). These waves moved with the speed of 500 km per hour, and reached even the coastal areas of Somalia and Tanzania (Pilapitiya, Vidanaarachchib, & Yuenb, 2006). The United Nations Environment Programme (UNEP, 2005) estimated that 31-37 thousand people passed away in this tragic catastrophe either by drowning, or they were killed by the debris, where about 27 thousands of the victims were fishermen. According to Leclerc, Berger, Foulon, Sarraute, & Gabet, (2008), that tsunami was very significant in the history. It actually managed to affect about 15 countries. Where, Sri Lanka was one of the countries that suffered the most from the tsunami affect with about 32,000 Fatality, 100,000 destroyed buildings, and nearly 50,000 of partly destroyed buildings.

2.3.2.4 Man-made conflicts

2.3.2.4.1 Kosovo

Kosovo is a European country with an area of 10,887 km^2, and 29 municipalities (EC & WB, 1999). According to The European Commission & the World Bank, in 1999, Kosovo had the population of about two million people. About half of them were less than 20 years old, with an average of 6–7 people per house and a GDP that could reach US$400 per capita according to non-official estimations. About the time of the conflict, two thirds of the population lived in the rural areas in 1500 villages and only nine towns had a population of more than 20,000 people.

During 1998, the conflict between Serbia and Kosovo reached a breaking point, where Serbia used the force against Kosovo causing the death of 1,500 people, and 400,000 people were forced to leave their homes. Moreover, by the beginning of 1999, NATO used their air force against Kosovo for 77 days. Consequently, by April of the same year, the United Nations High Commission for Refugees declared that the number of refugees escaping from the air campaign reached up to 226,000 people (NATO, 1999).

The conflict has had significant impacts on all life aspects in Kosovo. Many towns and villages were destroyed by the Serbian forces systematically (UNEP & UNCHS, 1999). Approximately, 30% of the houses were totally damaged all around the country by the conflict, and 50% of the agricultural properties were lost or damaged. Also, the conflict damaged the infrastructure that already was suffering from the lack of maintenance. Furthermore, the robbery cases were widely reported, and these cases included the robbery of the solid waste management' equipment and vehicles (EC & WB, 1999). Finally, estimated cost for building waste management system programme reached 2.35 million U.S. dollar (Brown, Milke, & Seville, 2011).

2.3.2.4.2 Afghanistan

Afghanistan is a country southern Asia with an area of 652,864 km^2; about half of it is an agricultural land, but unfortunately, there is not much of information about solid waste management over there. In 2010, Afghanistan had the population of 31,412,000 with a population growth rate of 3% from the previous year (UNSD, 2013) and rather low income and widely spread poverty. Moreover, the war directly and in directly related deaths reached significant rate. In fact, at least 21,000 civils were killed directly because of the war (Cost of War, 2014) where in 2004, it was estimated that the life expectation for people in Afghanistan is 42 years, and 25% of the children died before reaching 5 years old (Lawrence, 2012).

Since 1979, Afghanistan has been facing the complexity of continuous war that was subsiding in some periods and becoming more violent in others. It was a land of settling of old scores between several local and international forces (Maass, 1999). Actually, after 1992, estimations showed that 90% of the villages in the country and 60% of the cities were damaged (Amanullah & Furedy, 1994). Within 6 months between the years 2001 and 2002 only, the American air force dropped 26,000 bombs. 1,228 out of them were cluster bombs containing 248,056 bomblets. These bombs targeted several military points, and some of these points were villages were civil people lived, and Taliban and Al-Qaida troops hided. In fact, it was reported that in one case one bomb killed 9 people (Human Rights Watch, 2002).

2.3.2.4.3 Iraq

Iraq is a country in the Middle East with an area of 437,072 km^2, and estimated population of 35 million people in 2014, where the rapid growth reached 2.9% from the year before (WPR, 2014). Iraq has been suffering from different conflicts in the last two decades like the Gulf War, and later there was the American invasion (Economic Analysis Unit, 2013). At the time of the American invasion in 2003, the estimated population was about 25,175,000 people (WPR, 2014).

On 20th of March 2003, The United States started invading Iraq with the support of several countries like Brittan Australia, Poland, and Denmark, clamming that Saddam Hussein had nuclear weapons (The library of Congress, 2011). As a result, about 2 million Iraqi people were forced to leave the country, and 1.7 million moved to another placed inside the country. In fact, according to the United Nations, about 50,000 people escape from their homes every month (Raghavan, 2007). However, the estimated number of war victims who were killed in the war is not certain, and it varied a lot from 100,000 people to more than one million people (McDonald, 2014) while the cost of war reached about one trillion American dollar (Kamrany & Taft, 2011).

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3 THEORETICAL FRAMEWORK

3.1 Background

Historically, the waste management after disasters was confined to the clean-up work after the disaster, and it was mainly addressing the problem after it has occurred. The countries that face disasters more than the others, tend to work on preparing plans for the emergency phase of the disaster. They also tend to understand the problems and accept them in order to find practical solutions for them (Pearce, 2003).

However, developed countries were able to recognize the importance of having a disaster waste management plan in mid-nineties. At that time, the United State Environmental Protection Agency published its plan in the document "Planning Disaster Debris" (Brown, Milke, & Seville, 2011). Australia and New-Zealand, for example, adjusted their disaster management strategy to move from responsive practices to pro-active practices and from after-shock management to risk management, where these kinds of changes covered many managerial aspects in there general disasters risk management plans (Pearce, 2003). Therefore, the pre-disaster management should focus on minimizing the amount of potential waste that can result from the disaster rather than finding ways to handle it only. Although this strategy might not be practical in some cases, it must be taken into account to the extent possible (Karunasena, Amaratunga, Haigh, & Lill, 2009).

Furthermore, it is important to understand that the type of waste management plan prepared by each authority depends on the circumstances of its region. Based on that, in the developing countries, where there might not be an appropriate waste management system in the peaceful days, the plan focus will not be on how to minimize the amount of generated waste before the catastrophe. As they might not even have a disaster waste management at all, the focus will be on how to use the available tools and infrastructures in each particular country. Nevertheless, several guidelines have been published about handling debris in developing countries, but no guidelines was able to cover the managerial and institutional considerations of the management plan, which are essential for any plan to be practiced properly (Brown, Milke, & Seville, 2011).

3.2 Pre-disaster planning

Preparing disaster waste management plan has to go through certain phases, regardless weather it was prepared for a developing or developed country. These phases can be reflected through a cycle, where post-disaster waste management plan is presented with the general post-disaster management plan. With this division, studying the work related to each phase will be easier for the planners (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009).

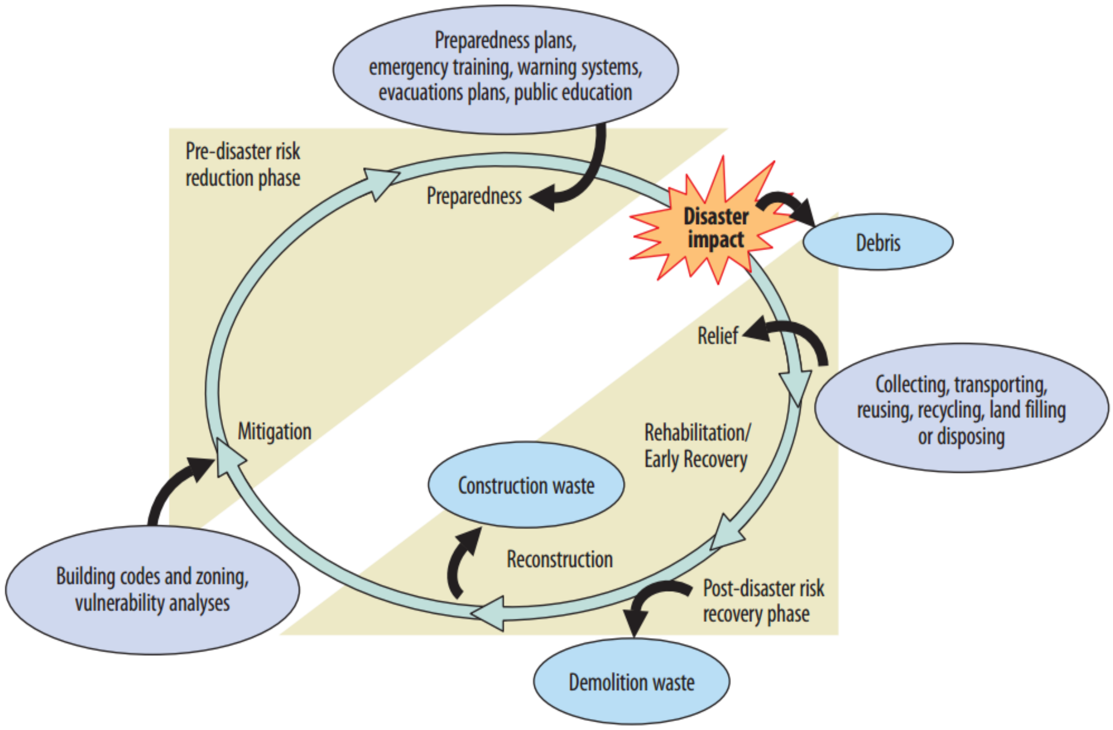


FIGURE 1 The general disaster waste management cycle of handling debris (Karunasena, Amaratunga, Haigh, & Lill, 2009)

According to EPA (2008), the post-disaster waste management plan responsibilities are divided over three different phases of the general post-disaster management plan. These phases are: the preparedness phase (risk reduction), the response phase (emergency), and the recovery phase. Where in other researches there is an additional phase, which is the mitigation phase (reconstruction). The phases were also divided by other authors to be emergency, relief, recovery and reconstruction (Pheng, Raphael, & Kit, 2006). The structure of the phases will depend on the responsible planning authorities and their vision about how to face a potential disaster. From figure 1, it is clear that most of the post-disaster waste management work exist in the relief and recovery phases. Yet, the other phases include the planning, analyzing, assessing, and other risk management work that is important to improve disaster waste management plan.

In the beginning of the response phase, the emergency actions will take a place. These actions usually involve the work of the volunteers who participate in the manual debris removal in order to help in the rescuing activities (Henstra, 2010). This phase also includes collecting debris from the most important areas first and transporting it to the temporary storages (in case the plan includes them), or any other place prepared by the authority (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009). The beginning of the recovery phase starts from the end of the emergency phase with removing debris from the most important places like main roads, hospitals, and fire stations (Henstra, 2010). This phase continues with the work of recycling and other debris management activities, involves the demolishing activities, and extends to the end of all debris handling process (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009). In fact, it was noticed that the division of the work share between different phases varied between different planning models. Hence, the work considered as emergency work in one model, can be considered as recovery work in another model.

Table 1 Elements of general disaster management plan in the ideal situation (example) (Henstra, 2010)

Preparedness
1. Emergency manager
2. Program committee
3. Hazard identification and risk assessment
4. Emergency response plan
5. Plan review
6. Emergency management by-law
7. Training
8. Exercises
9. Mutual aid agreement
10. Critical infrastructure protection
11. Planning for people with special needs
12. Engagement with business community
Mitigation
13. Mitigation plan
14. Warning system
15. Public education
16. Dangerous goods routing by-law
17. Risk-based land-use planning
Response
18. Emergency operations center
19. Incident management system
20. Evacuation plan
21. Emergency shelter arrangements
22. Volunteer management
23. Community emergency response teams
24. Search and rescue
25. Emergency public information
Recovery
26. Recovery plan
27. Continuity of operations planning
28. Damage assessment
29. Debris management
30. Rehabilitation

The preparedness phase, or the reduction phase, focuses more on how to minimize the waste generated by the disaster and how to reuse the waste resulted from this disaster in the scope that insures financial and environmental gains. In this phase, the planners use the information from the previous disasters to prepare a better disaster-waste management plan for the future (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009). In the mitigation phase, the work will focus on executing different analytical activities, in order to find the best ways to minimize waste generation. Such as spreading knowledge among people about how to improve their property in order to resist the various disasters effects (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009).

3.3 Types of debris

The types of debris depend on the type of disaster hitting the area and the nature of the occurred area. Therefore, collecting information about the materials that make up the disaster waste can help in making the work more efficient, and direct each kind of waste to the correct recycling point (EPA, 2008). Preparing enough information about the components of the disaster waste can help on saving time and money on the collection side, and the quick removal of the debris will allow the life to go back to normal fast which will help the stability to come back to the area, and it also help to move the economic wheel in the region (EPA, 1995).

3.3.1 Earthquakes

Generally, earthquakes are results of the interaction between two tectonic plates at the fault. The strength of the earthquake depends on the type of friction occurring between the plates, and the elasticity of the surrounding area (He & Wong, 2014). Nevertheless, the main strike of the earthquake is not the only reason of damage, but the aftershocks will cause damage as well. However, bigger earthquakes generate more aftershocks (Helmstetter, 2003). Another important debris generator to consider is the secondary catastrophe that happens after the earthquake, and it might cause the major damage, such as heavy raining (Liu & Sun, 2009).

The massive amount of earthquake debris comes from destroyed buildings especially in the countries where buildings are not designed to stand for earthquakes. This debris can vary from few tons to hundreds of tones. Additionally, the hazard wastes resulting from the earthquakes are usually different chemicals that are used in the inhabited areas like pesticides and fuels that might leak (Rafee et al., 2008). On the other hand, there is the debris resulted from the landslide and different collapses, where the amount of this debris depends on the size of the affected area (Jianqi et al., 2010). When a secondary catastrophe occurs after the earthquake, like heavy rain, it can cause a debris flow. In the debris flow, all different types of debris like soil, rocks, and buildings remains can accumulate to make a massive mud-rock. This flow can make more damage to the infrastructure, transportations and building than the earthquake itself (Liu & Sun, 2009).

3.3.2 Tsunamis

The damage of the tsunami strike comes from the high rise of the tsunami wave then the hard landing on the affected area, where the damage caused by the wave attack depends on the length, the height, the depth of the wave, and also the debris carried by this wave. On the other hand, there is also the effect of the earthquake itself (Como & Mahmoud, 2013).

The debris resulting from a tsunami consists mainly of marine sediments like sand and mud, and wreckage parts of the residential areas like wood and metal. Also, it can contain oils and hazardous chemicals. Dead humans and animals' bodies, and other livings like trees and vegetation will be, also, existing in the debris (Sakai & Bettencourt, 2012). The hazardous materials might not be very dangerous but it still needs to be handled carefully, where handling the falling buildings will be one of the most challenging parts especially from the humanitarian perspective (Indrawati & Steer, 2005). However, the main load of debris consists of vehicles, destroyed homes, boats, and other objects (Como & Mahmoud, 2013) that can be carried by the waves for hundreds of kilometers for more than an hour time depending on the severity of the tsunami (Indrawati & Steer, 2005).

3.3.3 Hurricanes

The hurricane is a tropical cyclone consists mainly of very heavy rain and wind that can reach the speed of nearly 300 kilometers per hour. It is usually formed at the depth of 50 meters under the sea, where the temperature is 27^0 Celsius at least. Whereas warm water, high humidity, and the lack of wind, feed the hurricane strength and make it lasts for longer periods (Bedient, 2012). Hurricane debris can pile up to reach almost 5000 Kg of waste. One of the most problematic wastes are sand and salt of the sea, as the beaches sand can be totally removed by the storm. Additionally, the other materials carried by the hurricane can cause more damage to the buildings and the infrastructures. These materials can be uprooted trees, houses, ceilings, boats, etc. Also, tens of vehicles can be carried and destroyed by the hurricane (Bedient, 2012). Trees and other vegetation form a large part of the degradable debris, considering that broken branches, fallen leaves, uprooted trees, and other vegetation can make 70% of the hurricane debris in some areas, or even more (Escobedo et al., 2009). On the other hand, there are different types of plastics, chemicals, and petrochemical materials that can be toxic if not handled in the right way. (Bedient, 2012)

3.3.4 Floods

When heavy rainfall exceeds certain limits it can turn into catastrophic flood, where this rain might be seasonal or annual. When floods occur in a certain area, the water carries the different objects it meets on its way, and with these objects it can hit buildings, people, and vehicles etc. causing significant damage

(Roghair, Dolloff, & Underwood, 2002). Beyond that, when floods happen after another catastrophe, like an earthquake for example, the water will carry all the debris resulted from the other catastrophe. The debris in this case will contain mud and rocks as well as cars and building remains (Liu & Sun, 2009). On the other hand, trees and other vegetation will be also carried by the flood. This mix of water and debris will form what looks like a huge rock that will cause more damage, and hold more debris on its way as it moves with a speed of approximately 10 meters per second (Roghair, Dolloff, & Underwood, 2002).

3.3.5 Wars

Unlike the natural disasters, wars do not have scientific reasons usually, and they can last for longer time, causing worse damage than natural catastrophes, which is not easy to fix.

The wastes of wars contain usually more hazardous materials than other catastrophes. Waste weapons, chemicals, vehicles, and other military wastes will be present. Nevertheless, in the man-made conflicts, the affected country will receive different humanitarian aids. These aids generate different kinds of waste such as medicinal, plastic, food, clothing, etc. They can pile up making tons of waste that can be very hazardous, especially the expired chemicals and medicals that can leak to the underground water (Calo & Parise, 2009). One of the big waste generators in the conflict cases is the everyday waste that should be collected regularly in normal cases. Clearly, in the conflict cases they are not going to be collected, transferred, or dumped properly. This waste consists of bio wastes, plastics, and other household wastes. On the other hand there are the industrial wastes and the waste resulted from destroyed buildings like stones and soil (UNEP, 2003).

3.4 Estimating the amount of debris

The amount of debris depends generally on the area affected by the disaster. Also it depends on the strength and type of catastrophe hitting this area. Generally, the reports mentioning debris volume in different disasters event do not clarify the method of calculating these numbers (Brown, Milke, & Seville, 2011). However, finding out the real amount of debris resulted from the disaster is an important factor for planners to be considered. Knowing this information will help preparing different handling stages facilities to cover the debris volume. However, there are several ways to estimate the amount of debris, such as some software programs that can calculate the approximate loss in buildings and other infrastructures. There are also other ways to estimate the volume of debris like using geospatial analysis that uses different equations to calculate the volume like the amount of debris generators like the number of buildings for example, and these generators vary according to the nature of the area.

Moreover, the density of the vegetation will be included in the calculation, and also the information of the catastrophe hitting the area such as the strength of it and the expected area it will hit. Another important way to calculate the amount of debris is the information about the volume of debris estimated from previous experiences in the same country, or from different countries. Actually, this method can give a clue about the amount of generated debris (EPA, 2008). One post-disaster way to calculate the waste volume is by measuring the number of trucks loads transporting debris, and the space it occupies in landfills. Additional way is by calculating the waste resulted from one unite of measurement (the unit can be a house or a floor), in this method it was estimated that one house hold can generate from 30 to 113 tons of waste. Finally, GIS/hazard maps can also be used to estimate waste volume (Brown, Milke, & Seville, 2011).

3.5 Collecting debris

Collecting debris and waste resulted from the disaster is essential in the disaster waste management plan, and it can be divided into two stages. The first stage is the emergency collecting, and that is important to save people's lives immediately after the catastrophe hit. The second stage is about collecting the rest of the waste, and it continues until the points where collecting waste go to the routine process (Karunasena, Amaratunga, Haigh, & Lill, 2009). Generally, the municipality of each area is responsible of collecting the waste in its region. Nevertheless, governments in some cases might require from the private owners to collect the debris by themselves if there is no potential risk of doing that. Also, the army might participate to help with the physical work, and private contracting companies can provide their services to make the work more efficient (Brown, Milke, & Seville, 2011). Finally, Brown, Milke, & Seville (2011, p. 1093) draw attention to the fact that there are no deep studies about the factors should be observed to prepare the physical work of the disaster waste management plans.

3.6 Transporting debris

For efficient logistical work, the planner should consider the distance between the affected area and the sites where the debris will be taken to. Therefore, the temporary storages, or the separation sites should not be too far to save fuel, and avoid unnecessary environmental impacts and financial cost (EPA, 2008).

3.7 Handling debris

Handling catastrophes debris is usually achieved in two main ways, either by recycling or composting, where composting is considered as a practical solution for the mixed waste that is hard to separate (EPA, 2008). However, developed countries usually tend to recycle the maximum of the debris they have, especially the buildings debris that can be used for rebuilding the area. Where developed countries tend to send these debris to landfills, although landfills in most cases do not have enough capacity to take all the debris. Additionally, the composting of the debris in landfills can cause some serious environmental impacts, due to the gases released in the composting process, or by contaminating the ground water in the landfill area. These reasons pushed the developed countries to move towered incinerating their waste, by using uncontrolled open air incineration, controlled open air incineration, and air curtain pit incineration. Nevertheless, the best way of handling debris is minimizing its amount from the beginning, then recycling it in the proper ways like chipping and grinding, where each material should be handled appropriately according to its properties (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009). It was noticeable that most of the disasters debris comes mainly from the destroyed and demolished buildings. In developed countries, this debris is usually recycled and used to cut the use of raw materials for rebuilding the affected area. On the other hand, the materials classified for burning can be used to provide energy, while in some cases it might be necessary to handle these wastes by open burning in case of dangerous hazard removal (Brown, Milke, & Seville, 2011).

In some cases, mainly in developed countries, the process of separating disaster debris starts by sending it to temporary storages, and before reaching its final destination. Nevertheless, some primary separation might take a place even before sending the debris to the temporary storages. These storages provide the time and space needed to handle the waste properly and away from the inhabitant areas. Nevertheless, using temporary storages method is costly, and it needs the authority to make enough studies about the place to establish these storages. That is due to the fact that the storages will be huge sources of environmental impacts, which means that the surrounding area of these storages will have a great chance of contaminations and other impacts (Brown, Milke, & Seville, 2011).

3.8 Stakeholders

Generally, in order to achieve the maximum of a disaster waste management plan, different stake holders should be strongly involved, and prepared to response with the needed reaction when the disaster occurs. The stakeholders in this case can be construction industry, volunteers, welfare organizations, non-governmental organizations, civil engineers, and architectures, etc. (Pheng, Raphael, & Kit, 2006). Furthermore, empowering public participation and increasing awareness among people about the key issues related to disaster waste management, has a huge effect on the disaster-waste management plan. Clearly, to achieve the best public and stakeholders' participation, a strong pre and post disaster communications should be established between different parties. Usually, this part of the work is very challenging to waste managers (Brown, Milke, & Seville, 2011).

In general cases, the shareholders relationship is between the governmental authorities such as national authorities, local authorities and local public departments, and the privet sector or individual sector such as privet companies providing waste management services on the large scale, and waste pickers, itinerant buyers, and traders in waste materials on the small scale. Moreover, there are also the local community such as NGOs and CBOs. Of course, the number and type of actors would vary from country to country and from case to case. The following figure shows the potential relationship between different stakeholders in the general case (Baud, Grafakos, Hordijk, & Post, 2001).

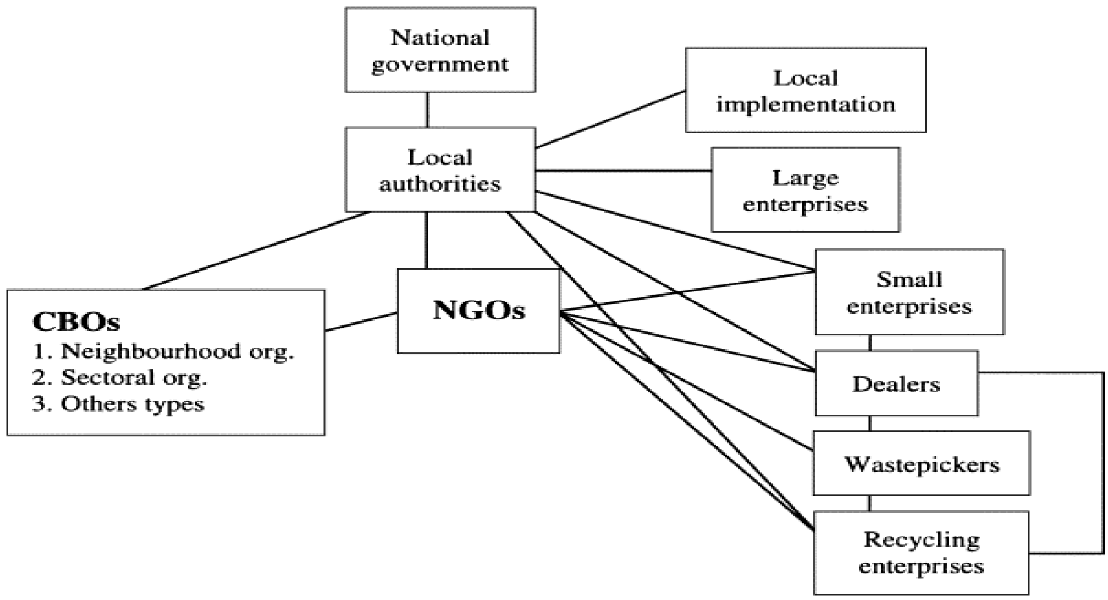


FIGURE 2 Waste management stakeholders relationship in the general case (Baud, Grafakos, Hordijk, & Post, 2001)

3.8.1 NGOs

NGOs are usually involved in the disaster waste management work as a part of their work to achieve their goals and beliefs. Away from disasters, they usually get involved in waste collection, spreading knowledge and information about waste management, and also researching and presenting new technologies.

They work close to the community they are presented in, which gives them the advantage of understanding the problems of this community and helps them building trust with local people. However, one of the main problems these organizations face is the funding and the interference of the sponsoring parties (Ahmeda & Ali, 2004). In fact, the problems NGOs face in the disasters cases are more challenging which makes their achievement less than what they planned in some cases (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009). Yet, they have the experience to improve the work in the case of disaster and in some cases they were able to invent new methods for disaster solid waste management (UNEP & OCHA , 2011). The following table shows some examples of the solid waste management work achieved by different NGOs.

TABLE 2 Examples of the waste management work of different NGOs (UNEP & OCHA , 2011)

The name of the NGO	Solid waste management work
Oxfam GB	- Implements disaster waste management projects (i.e. Indonesia (Banda Aceh), Haiti and Grenada) - Developed a suite of Technical Briefs for disaster waste management
MSF	- Healthcare waste management focus - Typically establishes healthcare waste handling systems and constructs small-scale incinerators
Islamic Relief	- Implements debris recycling projects
Cash-for-work	- Several INGOs implement cash-for-work programmes with focus on removing wastes, i.e. CARE, Oxfam and World Vision.
National NGOs	- Local and national NGOs can often help implement disaster waste projects - Often supported by INGOs through funding - Useful implementing partners.
Disaster Waste Recovery	- NGO established specifically for disaster waste management - Waste assessment and recommendations - Disaster waste management

	workshops - Implementation of disaster waste management
ProAct Network	- Environmental NGO with network of professionals - Experience in developing and implementing waste capacity building and management
Promise Consulting	Environmental NGO with a focus on developing countries and some post-disaster situations

3.8.2 Privet sector

In the normal situations, hiring privet companies by the government to handle solid waste management has lots of benefits. For example, the cost of the machinery and operating will be saved, and the potential corruption will be lowered. However, it is also important for the government to put enough regulations to control the entire procedure and at the same time provide a good environment for the companies to compete. In other words, the regulations should not be too loose so companies will work entirely independently, and it should not be too hard that company might leave the solid waste management market (Baud, Grafakos, Hordijk, & Post, 2001). In the case of disaster, these companies will continue their work which will give the government enough time in the shock period of the emergency phase. Nevertheless, more companies of the privet sector might be participating in the tendering process, which includes the machinery and the physical work with debris (UNEP & OCHA , 2011).

3.8.3 Informal waste recycling in developing countries

In many developing countries, it is common to see waste pickers who search the waste to find recyclable materials they can sell, or to find what can help them surviving their everyday life. In fact, it was reported in 2000 that about 2% of people in Asia and Latin America collect recyclable materials as a work for living. The poor solid waste management system provides income opportunity to the (1) itinerant buyers, who ask for waste from door to door, (2) waste pickers, who take the recyclable waste left under streets, (3) Municipal waste collection crew, who take the waste at the transporting stage, (4) and finally, waste pickers who take the waste from the dumps (Wilson, Velis, & Cheeseman, 2006).

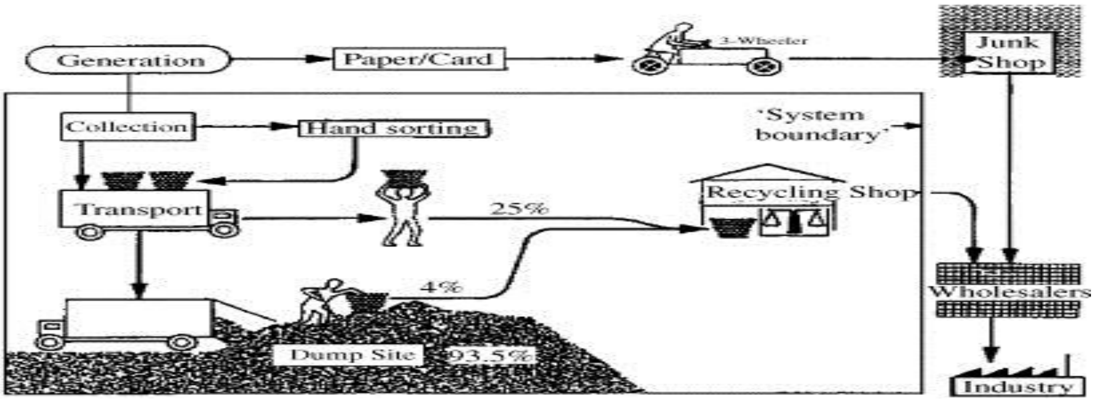


FIGURE 3 Example of an informal recycling system in the general case (Wilson, Velis, & Cheeseman, 2006)

3.9 Moreover

Different challenges might face practicing disaster-waste management plans. For example, the time needed to collect and handle the waste until the end of the recovery phase is long, and that will cause additional financial burden to the government budget. Also, the lack of adequate equipment, and the proper waste separation and disposal sites can limit the possibility of proper handling. Other challenges can be the huge amount of recycled materials that the market cannot deal with all of it, or not willing to deal with it at all (Brown, Milke, & Seville, 2011). Nonetheless, problems might come up while the disaster waste cleaning activities are ongoing. See table 2.

TABLE 3 Different disaster waste management strategies and their challenges (Karunasena, Amaratunga, Haigh, & Lill, Post disaster waste management strategies in Developing countries: Case of Sri Lanka, 2009)

Place	Amount	Strategies	Remarks
Marmara earthquake, Turkey	13 million tons	• Recycling plant • 17 Dump sites	• High level of reinforcement, bars in the demolition waste causes operational problems in plant • Illegal dumping at coastal line
Kobe earthquake, Japan	15 million tons	• Minor proportion recycled • Majority disposed or land reclamation	• Separation of recycling material time consuming and costly
Beirut, Lebanon	4 million tons	• A stationary recycling plant	• Problems arising with the "cleanliness" of the demolition waste
Kosovo	10 million tons	• A mobile recycling plant • Decentralized depots collection and storage	• Spread of damage over a large rural area

4 CASE STUDIES

4.1 The great east Japan earthquake and tsunami

4.1.1 Secondary catastrophe (Fire)

After the earthquake and the tsunami, and for various reasons, about 278 fires approximately, broke out in the regions of Tohoku and Kanato. Where, about 30 of them broke out during summer 2011 period in the waste storages of Tohoku (Murasawa, et al., 2013; Tanaka, 2012).

Generally, it is common for firs to occur after earthquakes that hit inland areas, but it is not common for the fires to occur after event that is oceans related like tsunamis. However, the large amount of fallen buildings after a strong earthquake can also cause fires to break out. The fires in different areas of the country were caused by reasons related to the type of the area where the fires occurred. Hence, some fires in the inland areas happened because of the building shaking, where in the coastal areas some of the fires were because of oil plants or oil refining (Tanaka, 2012). In contrast, the amount of mixed debris piling in a waste storage can provide suitable conditions for the microorganisms to increase its reproduction. Furthermore, the heat of the decomposition process within the waste can make the fire ignite easily (Murasawa, Koseki, Iwata, Suzuki, Tamura, & Sakamoto, 2013).

4.1.2 Collecting waste

Generally, the process of collecting and transporting the piles debris went without unsolvable problems. There were many volunteers from in and outside Japan who came to help in different relief activities. Some of these volunteers had already had some experience of handling catastrophes debris from other countries. These volunteers gave a great help in removing debris to the local workers (Murasawa, et al., 2013; Kamiya, 2011). However, the number of workers, machinery, storages, and landfills were not enough to handle the massive amount of disaster debris. Therefore, more workers were employed after the catastrophe to cover the shortfall in the number of workers (Ministry of the Environment, 2012). On the other hand, to cover the shortfall in machinery, construction machineries were recruited to help in the process of removing and transporting debris (Egawa, Kawamura, Ikuta, & Eguchi, 2013). Moreover, in the areas where it is difficult for heavy machines to work, the work was achieved manually by using simple tools like shovels, and then machines were used to load the trucks with the waste, and finally, the waste was transported to the temporary storages. Additionally, septic tank pumper trucks were used to remove mud and the debris mixed with water (Sakai & Bettencourt, 2012).

After the disaster hit, the debris was collected from the roads and stored in the temporarily storages, then it was decided which buildings should be demolished and which buildings should be fixed. That was done to ensure that debris will not continue to pile up randomly, which made the removal process smother. At the beginning, the rescuing missions had the priority, so the work focused on making sure that there are no people left under the debris, and then debris was removed entirely. At the time of demolishing buildings, people were asked to take as much as they can from their belongings, and all the identical personal belongings that were found, were handed to the responsible authority (Kamiya, 2011; Ministry of the Environment, 2012). Later, heavy equipment was brought to handle the debris, and the construction machinery handled the big items especially the big parts of destroyed buildings. However, both, the solid debris that formed the mud-rock, and the normal piled debris, were handled by hydraulic excavators, wheel loader, and hydraulic excavator (Egawa, Kawamura, Ikuta, & Eguchi, 2013).

4.1.3 Temporary storages

The amount of debris resulted from the disaster was very massive, and the regular waste management facilities were not able to handle it. Therefore, there was a need to have temporary storages where the mixed waste can be collected and separated, and then transferred to the appropriate places (Murasawa, Koseki, Iwata, Suzuki, Tamura, & Sakamoto, 2013). For this reason, the government established several waste storages that could be used temporarily to collect debris. The storages needed to have large areas to handle the debris coming from different regions, as sometimes the amount of waste was more than what could handle by one municipality (Ministry of the Environment, 2012). However, in some cases the debris went through a primary separation process before reaching the storing area. Where in other cases, the waste brought to the storage without any separation, so there was an urgent need to handle it (Inui, Yasutaka, Endo, & Katsumi, 2012).

4.1.4 The generated waste

Approximately, about 23 million tons of debris was collected after the disaster, and more than 12 million m^3 of tsunami deposits (Inui, Yasutaka, Endo, &

Katsumi, 2012). This amount of waste varied between 3 and 12 times more than the regular waste depending on the area (Ministry of the Environment, 2012).

FIGURE 4 Example of mixed earthquake debris in Minami Sanriku (UNEP, 2012)

These waste consisted of regular waste, such as household waste and office waste, and the waste resulted from the landslide like soil and sand (Mimura, Yasuhara, Kawagoe, Yokoki, & Kazama, 2011; Inui, Yasutaka, Endo, & Katsumi, 2012). On the other hand, there was the debris of the destroyed infrastructure like buildings and bridges, and also the fire debris (Inui, Yasutaka, Endo, & Katsumi, 2012; Tanaka, 2012). Therefore, the waste consisted of general wastes which were mainly different types of fabrics and plastics, mixed with the wood debris, metal, and other materials with the concrete debris and soil. Additionally, the waste resulted from the tsunami hit was consisting mainly of different types of soil and sand with different grain sizes. More debris was generated after the catastrophe due to the need to destruct the damaged buildings which could not be maintained. The amount of these buildings debris reached up to 50% of the generated debris in some areas of Japan (Inui, Yasutaka, Endo, & Katsumi, 2012). Another waste component that was clearly visible among the generated waste was the wrecked cars. They piled on the roads, and mixed with other types of waste, which represented a potential source of fires. Additionally, oil plants and oil tanks are located along the coastal region of japan, so they were affected by the tsunami which caused oil spillages and resulted wildfires in some cases. Even when they did not end up with fires, the impact of those spillages was significant (Tanaka, 2012).

Moreover, there was a huge load of marine sediments that reached the coastal areas and mixed with different marine creatures. On the other hand, lots of debris ended up in the ocean. Some of this waste sank, where lighter objects floated on the water surface, causing damage to the marine life that might continue for years, where part of this debris came back to the shore line. Moreover, the most problematic solid waste generated in the coastal area was the big amount of the fishing nets (UNEP, 2012).

FIGURE 5 Tsunami debris in a stockyard in Iwate Prefecture (Inui, Yasutaka, Endo, & Katsumi, 2012)

4.1.5 Classification of debris

Classifying the huge amount of debris started with the big objects of the waste, like big pieces of metal or concretes. These objects were recyclable as they were possible to identify. On the other hand, there was the demolishing debris and big part of it was also possible to recycle (Egawa, Kawamura, Ikuta, & Eguchi, 2013).

The mixed waste was classified in general to burnable and unburnable wastes. Lots of the household materials like wood, fabric, plastic, etc. were sent for combustion, where metal and soil did not. Tatami, which is the traditional Japanese mat that can be found in almost every home in Japan, was also classified as unburnable waste (Inui, Yasutaka, Endo, & Katsumi, 2012). Furthermore, handling debris washed with the ocean salty water was difficult as it was not easy for the bio-waste to degrade when it is covered with salt, and also, incinerating it was difficult (UNEP, 2012). Thus, about one thirds of the waste was considered to be burnable, where two thirds were considered as unburnable. However, it is important to know that applying the methods of classification and separation was not the same in every separation location (Inui, Yasutaka, Endo, & Katsumi, 2012).

4.1.6 Handling debris

After the waste arrival to the temporary storages, the processes of recycling, burning, or landfilling will start. As mentioned previously different materials were classified as burnable, and hence, temporary incinerators were established to handle the huge load of debris. Generally, lots of effort was put to reuse the maximum amount of debris rather than sending it to landfills. Therefore, all responsible parties were contacted in order to find a use for waste such as wrecked cars, and parts of destroyed roofs. In This way, it was possible to minimize the amount of waste reaching landfills. The simple primary sorting that was possible to do in some cases before reaching temporary storages, and separating hazard wastes and recyclable wastes, increased the recycling efficiency and decreased the cost of landfilling (Ministry of the Environment, 2012). On the other hand, in some areas, piles of wastes were separated manually to insure high level of separation, though it was not always practical to do so, like the case of separating fishing nets which were made out of nylon (UNEP, 2012).

Moreover, both, the solid debris that formed a mud-rock, and the normal piled debris, were handled by hydraulic excavators, recycling machineries, and track mounted machines. Where, the hydraulic excavators collected the debris from the ground and moved it to the track mounted crushers, where it will be turned to be recycled material. More machinery were used to handle and recycle the mixed debris, especially track mounted machineries such as track mounted wood grinders, and track mounted screens. Additionally, hydraulic excavators, wheel loaders, and also forklifts were also used for recycling purposes (Egawa, Kawamura, Ikuta, & Eguchi, 2013).

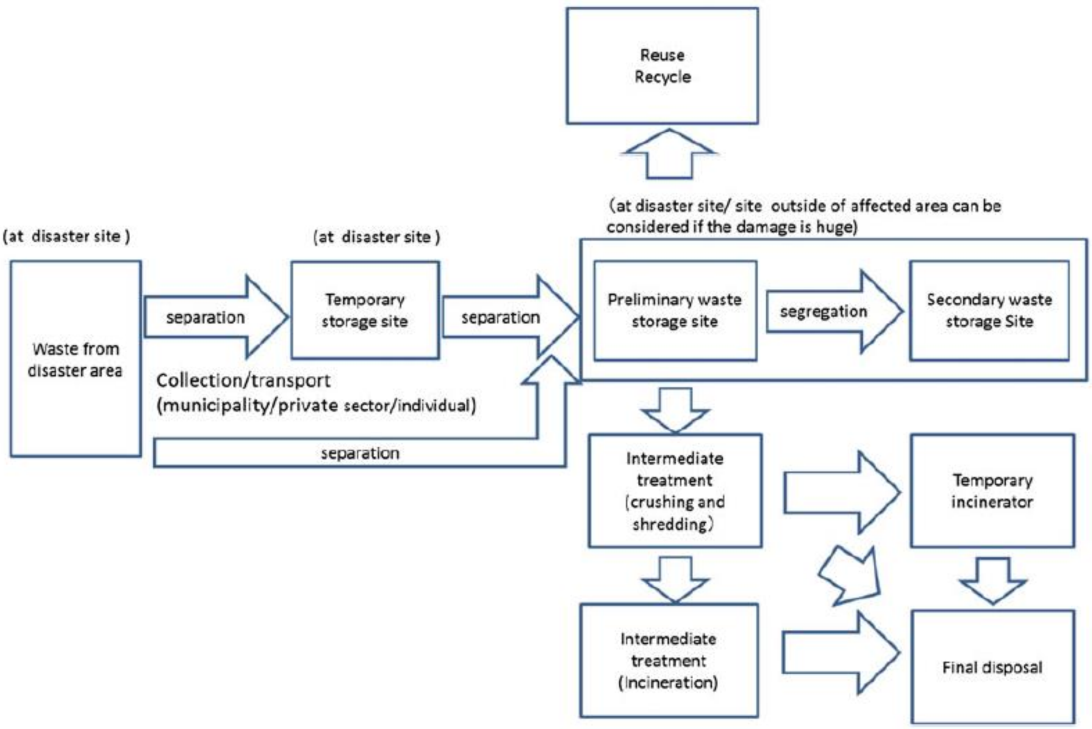
However, about two months after the catastrophe, the Ministry of the Environment (2011) published a master plan with clarification of how municipalities should handle the debris. In this plan the ministry worked on promoting recycling as much as possible. Hence, some of the wastes were sent to other municipalities to be handled there in order to shift the over load of debris in the affected areas. All the recyclable materials like concretes, wood, vehicles, and homes' big devices like air conditioners and televisions were sent to recycle. For example, waste wood was used as a fuel for boilers, where usable parts were taken from devices like televisions when possible. Metal scrap was separated and ended in the landfill when it was not possible to reuse it. Cars were handled according to the regular rules for disposing destroyed cars, where usable parts of ships like batteries were removed and the metal part was handled as metal scrap. Tsunami sediments were classified to toxics, which were burned or buried in landfills, and non-toxics, which were screened to remove alien objects from them then used as backfills in the civil engineering field, or put back to the ocean. Finally, the fire debris was also classified and ended buried in landfills or molten.

4.1.7 Recovery

According to Ministry of Environment annual report (2012) almost all the work of delivering debris to temporary storages, disposal of debris, and even full-scale decontamination in the residential areas, are scheduled to be finished in different periods of 2014. However, the last documents published on the Ministry of the Environment (2014) website, explained the progress of debris treatment by 2014.

The debris handling progress for general debris and tsunami debris in the affected areas ranged between 46% and 100% in different areas, and constantly continued. Moreover, the removal of debris was completed in most of the costal municipalities, and all the debris was sent to the temporary storages. Most of the new coming debris to the temporary storages is generated from the uncompleted demolishing building work. Therefore, many of the temporary incineration points and storages were removed. Additionally, the incineration work was completed in some areas (Ministry of the Environment, 2014).

In the non-affected areas that helped handling the debris, about 99% of the waste was already handled, and 87 projects of treatment were ready out of 91 projects, and in some municipalities the treatment work was finished. Finally, 85% of the recycling work was done and. The rest of the unfinished work in different municipalities should also be finished before the end of the year, so the waste management system clearly will go back to proceed normally soon (Ministry of the Environment, 2014).



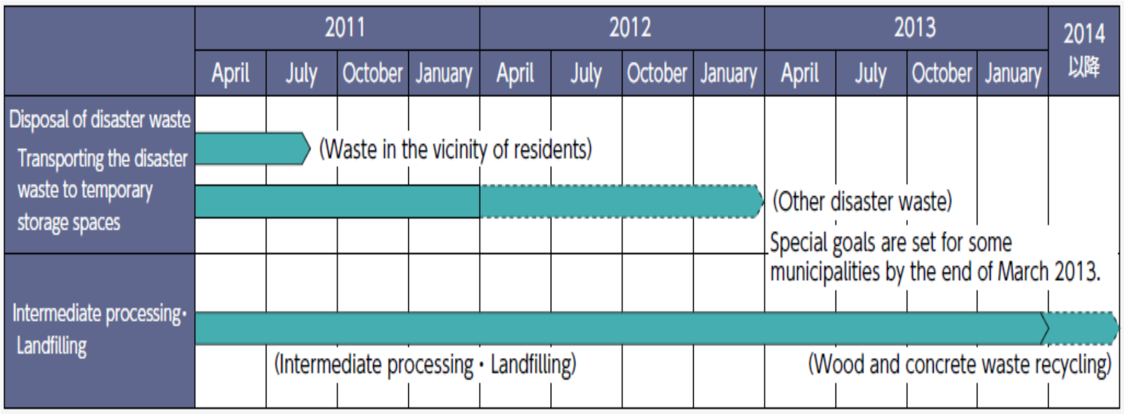
FLOWCHART 1 The general process of Great East Japan Earthquake disaster waste management (Asari, et al., 2013)

4.1.8 Time management

The Ministry of Environment (2012) scheduled the disaster waste management work to ensure the use of time that serves finishing the work properly in the shortest time possible. Hence, the catastrophe occurred on 11th of March 2011, and the plan was to deliver the majority of debris from the residential areas to the temporary storages by the end of August 2011. The rest of the debris was supposed to be delivered to the temporary storages by the end of March 2012. Generally, most of the municipalities managed to achieve these targets, where the municipalities in Fukushima Prefecture areas were not able to achieve the targets due to other challenges in that area. Finally, the ministry estimated the end of March 2014 to be the time where all the debris should be disposed. However, some municipalities faced some exceptional conditions like having huge load of debris more than other areas, so they had their own additional targets. Anyway, they had to finish delivering their debris to the temporary storages by the end of March 2013. Finally, all different activities related to the waste management like burning and recycling, etc. were supposed to be finished by March 2014.

Some of the prefectures managed to finish almost all of the debris treatment by February 2014 according to the estimations of the Ministry of the Environment (2014), where other prefectures might need to continue until the end of the year. In the following table (table 3) we can see the estimated work progress by the Ministry of Environment (2012) that explains how the time management was scheduled.

TABLE 4 Debris waste management timetable after great Japan earthquake. Estimated by 29th of November 2011 (Ministry of the Environment, 2012)



4.1.9 Results and findings

The Great East Japan Earthquake was considered to be a significantly huge catastrophe. That is due to the fact that it combined different types of disasters in one event. The earthquake followed by the tsunami, and then the significant number of fires following them, put the government face to face with several catastrophes. The consequences of the disaster included debris floating in the ocean, spreading pollution, health and different Humanitarian challenges, financial challenges, and on the top of all that there was Fukushima accident (Mimura, Yasuhara, Kawagoe, Yokoki, & Kazama, 2011).
What draw the attention, was that Japan in general, and northeast Japan especially, were continuously preparing for a natural disaster as the disasters are not unfamiliar in this part of the world (Mimura, Yasuhara, Kawagoe, Yokoki, & Kazama, 2011). Yet, the government did not have any ready plan to face the sudden situation. Therefore, they had to combine the guidelines they had for the years 1998 and 2005 that handled earthquakes and floods waste

separations, but none of these guidelines was able to suggest a full-scale plan for the catastrophe (Kamiya, 2011). Nevertheless, soon after the disaster occurred, the Ministry of the Environment (2011) managed to publish Master Plan guidelines on 16th of May 2011. In this guidelines they explained how collecting, separating, and handling the debris should go (Ministry of the Environment, 2011). However, the previous experience that local governments had before with the past earthquakes, had very much helped handling the situation properly even when the guidelines did not cover the situation in the first days of the catastrophe hit (Kamiya, 2011). Another important factor that helped facing the emergency phase effectively was that the workers were able to adopt the shocking situation fast and go back to work, even though they were victims themselves (Egawa, Kawamura, Ikuta, & Eguchi, 2013).

After the disaster, there was a great need for heavy machinery to help handling the piled debris. That made the authorities order the machinery companies to produce more of the machines that can cover the municipalities' needs, and in some cases they even asked for the machines to be adjusted to their needs. This situation made the heavy machinery market grow, and provided jobs opportunities to people who lost their jobs, or were not able to reach their jobs. On the other hand, the companies faced some problem with the untrained worker who had low or no experience at all in that field, and they also faced some problems with the preparing machineries that can handle mixed and unsorted debris (Egawa, Kawamura, Ikuta, & Eguchi, 2013).

The time management varied from area to another due to the amount of debris each area had to handle, but the speed of handling should not be the most important factor in this case. Even though the fast dealing of the debris will have a strong financial effect, and will help moving back to normal fast, but handling the debris properly considering not causing any future problems should be the most important factor (Kamiya, 2011). An important issue that japan local government should consider is the oil tankers that are imported to the coastal area. These tankers are a potential risk in case of any catastrophe that might hit the coastal area, so the environmental pollution resulted from them was not a surprise. Hence, this matter has to be considered in the future disaster risk management plan (Tanaka, 2012).

4.2 Hurricane Katrina

4.2.1 Secondary catastrophe (flood)

As expected, the disaster of hurricane Katrina lead to another disaster, which is flooding that was responsible for more than 1300 mortality case in the City of New Orleans where the flood occurred (Colten, Kates, & Laska, 2008). The center of New Orleans, the eastern part of it, and St. Bernard, were the main areas affected by the flood. Within about two hours before the storm landfall, the floods started to occur in New Orleans, and soon after that the water was rising in the Industrial Canal. During the same morning, small and major gaps started to appear in the Industrial Canal due to the fast moving flood causing catastrophic damage to the nearby neighborhood. As a result, about 260 km^2 of New Orleans suffered from the flood that reached the depth of about 4 m in some areas (Jonkman, Maaskant, Boyd, & Levitan, 2009). Furthermore, 70% of the city residences were damaged, and 100,000 people were displaced, with financial losses of 40 to 50 billion Dollars (Colten, Kates, & Laska, 2008).

4.2.2 Collecting waste

According to Luther (2008) the debris removal activities after the catastrophe had been done based on the instructions of the Robert T. Stafford Disaster Relief, Emergency Assistance Act, and National Response Plan. Hence, the collection of waste may be done by the local government, or by the Corps. However, when the work capacity exceeds the local government's ability to deal with, it was possible for them to ask for support from federal agencies (Esworthy, Schierow, Copeland, Luther, & Ramseur, 2006).

The main objective of debris removal was to accomplish it in environmentally friendly way, and also with the minimum possible cost and time. Therefore, the removal was obtained in two ways. The first is Right Of Entry (ROE) that gives the Army Corps Engineers the right to enter a private property without legal consequences. The second is the Right Of Way (ROW) which includes the public lands where facilities like highways and railroads are placed. Where, these lands are most probably public or included, up to a private property line. Nevertheless, it was the local government responsibility to decide the debris types that can be removed via ROE or placed in the ROW (Brandon, Medina, & Morrow, 2011). On the other hand, the Crops mission was to handle the technical assistance in the clearance, removal, and disposal of debris, also providing the needed technical assistance in order to clear the roads and water paths. Where, the physical work is mainly handled by contractors (Esworthy, Schierow, Copeland, Luther, & Ramseur, 2006). Furthermore, the Army Crop Engineers accomplished removing vehicles and boats from some areas, and also removed the accumulated debris from swimming pools (Brandon, Medina, & Morrow, 2011).

Nevertheless, the major physical work was done through contractors directly or indirectly (Fickes, 2010, p. 1). In fact, private contractors took the biggest part of the removal activities, such as AshBritt, but in the case of AshBritt contract for example, there was no specification about how the debris removal should be performed (Brandon, Medina, & Morrow, 2011). The wet heavy debris was handled also by the workers of construction industry field who participated in the emergency and recovery phases of responding to the hurricane. Those workers were employed by Federal, State, local, and private employers (OSHA). Moreover, heavy equipment was needed to remove the debris from the roads and important areas. Therefore, machineries like bulldozers, backhoes, front-end loaders, dump trucks, and powered industrial trucks like fork-lifts were used (OSHA).

4.2.3 Temporary storages

Forty-four temporary debris storing sites in 16 different areas southern of Mississippi were established by the Army Corps Engineers on private and public properties, and also in regular landfills (Brandon, Medina, & Morrow, 2011). Additionally, contractors established other temporary storages, like the case of AshBritt that established 59 temporary storages (Fickes, 2010, p. 2). In fact, these numbers can give a clear example about the number of temporary sites established by different parties in the affected areas.

Vegetation debris that usually takes lots of space in the landfills was taken first to the temporary storages to be handled. Also white goods and electronic wastes were sent to temporary storages but separated from the rest of the wastes. This method of handling debris was very successful in hurricane Katrina's case, as it provided a better opportunity to reuse and recycle different materials, and also reduce the space needed for these materials in landfills (Brandon, Medina, & Morrow, 2011). Furthermore, while collecting and delivering waste to the proper sites, they made sure not to mix between the hurricane debris and the municipalities' solid waste. Hence, they stopped handling the everyday solid waste when the storm arrived, planning to continue with it after the storm leaves (Fickes, 2010, p. 1).

4.2.4 The generated waste

According to Brandon, Medina, & Morrow (2011) the estimated amount of debris was estimated to be more than 90,2 million cubic meters in both of Louisiana and Mississippi. It was reported in Louisiana that the number of damaged and destroyed vehicles was over 350,000, and 60,000 different kinds of boats. Within one year after the disaster, AshBritt contractor handled the removal of 12,500 vehicles, 1,900 tons of food waste, 24,045 stumps, 180,940 trees, and 332,079 tree limbs. Also, they handled the activities of demolishing and disposing over 3,500 unsafe structures like the case of partly destroyed houses (Fickes, 2010, p. 2).

In general, the debris consisted of different kinds of vegetation in the forms such as leafs, whole tree, tree stumps, tree branches, and tree trunks. However, like the case of each disaster, the demolition and construction activities were responsible for the biggest mass of the generated waste with materials like wooden materials, gypsum, glass, metal, roofing material, tiles, carpeting different products, window coverings, pipes, concretes, asphalt, equipment, and furniture. Debris also includes what so called white goods, and this term covers different houses' electrical devices that are essential in every home and comes usually in white. Such as refrigerators, freezers, air conditions, heat pumps, ovens, ranges, microwave ovens, space heaters, dishwashers, washing machines, clothes dryers and water heaters. Furthermore, debris includes also different electronics like computers and televisions, vehicles like cars, trucks, and busses etc., and vessels like boats and jet skis. Additionally, hazardous household waste that can contain for example latex, oil based paint, cleaning solvents, and gasoline (Brandon, Medina, & Morrow, 2011). The following table shows the types of generated debris with the estimated amount of debris in the counties of Mississippi.

TABLE 5 The debris removed in Mississippi (Brandon, Medina, & Morrow, 2011)

County	Debris type@	Total debris	ROE	ROW	No. TDSRS	Vegetation reduction
Clarke	V; CD	72,509	0	72,509	2	I (2)*
Covington	V; CD; HH; WG; EW	346,223	56,497	289,726	3	I (3)
Forrest	V; CD; HH; WG; EW	1,876,870	255,422	1,621,448	5	I (1); G (5)
George	V; CD; HH; WG; EW	480,970	165,658	315,312	2	G (1)
Greene	V	3,782	0	3,782	1	I (1)
Hancock	V; CD; HH; WG; EW;VV	4,137,377	1,617,215	2,520,162	6	I (1)
Harrison	V; CD; HH; WG; EW;VV	1,046,314	548,391	497,923	1	G (1)
Jackson	V; CD; HH; WG; EW;VV	3,324,483	609,073	2,715,410	6	G (1)
Jones	V; CD; WG	1,474,217	0	1,474,217	4	I (2); G (2)
Lamar	V; CD; HH; WG; EW	1,122,628	212,905	909,723	4	I (1); G (3)
Leake	V; CD	28,602	0	28,602	1	I (1)
Lincoln	V	82,301	0	82,301	2	G (2)
Newton	V; CD	79,820	0	79,820	1	I (1)
Perry	V; CD; HH; WG; EW	417,439	70,006	347,433	2	I (1); G (1)
Pike	V	252,811	0	252,811	2	G (2)
Walthall	V	395,686	0	395,686	2	G (2)
Grand Total		15,142,032	3,535,167	11,606,865	44	I(14); G(20)

@V: vegetative; CD: construction and demolition; HH: household hazardous waste; WG: white goods; EW: electronic wastes; VV: vehicles and vessels.
*I (#): incineration reduction method (no. TDSRS where incineration was used).
G (#): grinding reduction method (no. TDSRS where grinding was used).

TDSRS: Temporary Debris Storage and Reduction Sites. Volume is in m^3.

4.2.5 Classification of debris

The classification of debris was achieved according to the provided debris management plan, and this plan explained how each type of debris will be handled. The debris was classified to be chipped, burned, recycled, or sent to landfills based on its type (Luther, 2008). The materials of demolition and construction were classified as recyclable (Fickes, 2010, p. 2) but in some cases they were sent to landfills (Brandon, Medina, & Morrow, 2011). Nevertheless, in the recycling case, the demolition and construction wastes were divided into hazardous waste and non-hazardous waste, and handled separately (Fickes, 2010, p. 2). Furthermore, white goods, electronic wastes, tires, vehicles, and vessels were recycled by the suitable method for each one of them. Keeping in mind that some white goods like refrigerators needed to be recycled in a special ways, as they contain hazardous materials like mercury, or compressor oils, and also ozone-depleting refrigerants. Also, household hazardous waste was classified under four different categories depending on its nature; these categories were reactive, ignitable, corrosive, or toxic.

On the other hand, vegetation was handled by incineration or gridding reduction method, but for example, when a whole tree presents a threat to people’s lives it was considered to be hazardous waste (Brandon, Medina, & Morrow, 2011).

4.2.6 Handling debris

At the location where demolition will take a place, the responsible authority needed to perform site inspections to evaluate the situation there on several levels. These assessments are intended to identify the risks in the location, such as private wells and septic tanks, and also the hazardous materials, such as asbestos and flammable products. Later, the materials of demolition are collected from demolition, structural collapse, or other places, and then transported to landfills where they will be separated to different materials and then recycled according to the regulation of each type of waste (Brandon, Medina, & Morrow, 2011). Generally, the authority needed to lower the standards of disposing site in order to meet the new requirements after the disaster. Like the case of changing the criteria of waste disposal at the construction and demolition landfills (Brown, Milke, & Seville, 2011). In particular, some materials were not separated for recycling at the ROW sites, and these materials are asphalt shingles, metal roofing and siding, bricks, some kinds of treated wood, untreated wood, and flooring materials. Moreover, Privet properties' owners were allowed to bring their concretes to the ROW sites, and these concretes were sent to the temporary storages to be used later for making aquatic habitat (Brandon, Medina, & Morrow, 2011). Surely, some materials were not safe for privet owners to handle by themselves, like the case of asbestos (Brown, Milke, & Seville, 2011).

For household debris, the materials were separated after collecting them and then sent either to hazardous waste handling sites or to normal handling sites. Household metals were classified and separated in the temporary storages, pressed to be in the form of packets, then handled as metal scrap. White goods were moved from the ROW sites to temporary storages where hazardous like mercury and refrigerant gases are removed, and also the leftover food. Later, they were handled by compressing to packets, and then handled as metal scrap. Further, the hazardous chemicals were also handled according to the regulations of each substance. Similarly, electronic wastes were sent to the temporary storages after collecting them from ROW, wrapped on pallets prior, and finally, sent to the proper recycling facilities (Brandon, Medina, & Morrow, 2011).

Tidal surge water, flooding, and wind had dragged the vehicles and boats for far away distances causing leakages of different hazardous chemicals like gasoline, and diesel. However, they were gathered in the ROW and ROE, and then transported to the temporary storages where they were handled by commercial towing contractors who brought them to the proper locations. Finally, they were recycled as a scrap metal. On the other hands, tires were also collected and then separated from other debris materials at the temporary storages. Later they were sent to their proper recycling facilities (Brandon, Medina, & Morrow, 2011).

Vegetation wastes were challenging to handle as they take big space in the landfills. Hence, they were gathered in the ROW and ROE sites before sending them to the temporary storages were 85% of these wastes were handled. Later on, they were handled either by incineration or grinding. At the temporary storages the air curtain pit method of incineration was used to reduce the volume of the waste by 95%. Yet, big wooden pieces of debris were in some cases given to privet properties owners. The rest of the vegetation wastes were chipped which reduced their volume by 75% then used by residents and local industries in the recovery phase. Additionally, the chipped vegetative chips ground was used for making landscaping mulch in some cases, and in other cases they were used as fuel (Brandon, Medina, & Morrow, 2011). After all, there was a use for the hurricane generated waste in energy producing, but that was on a small scale, and there is no information about how successful the work went (Brown, Milke, & Seville, 2011).

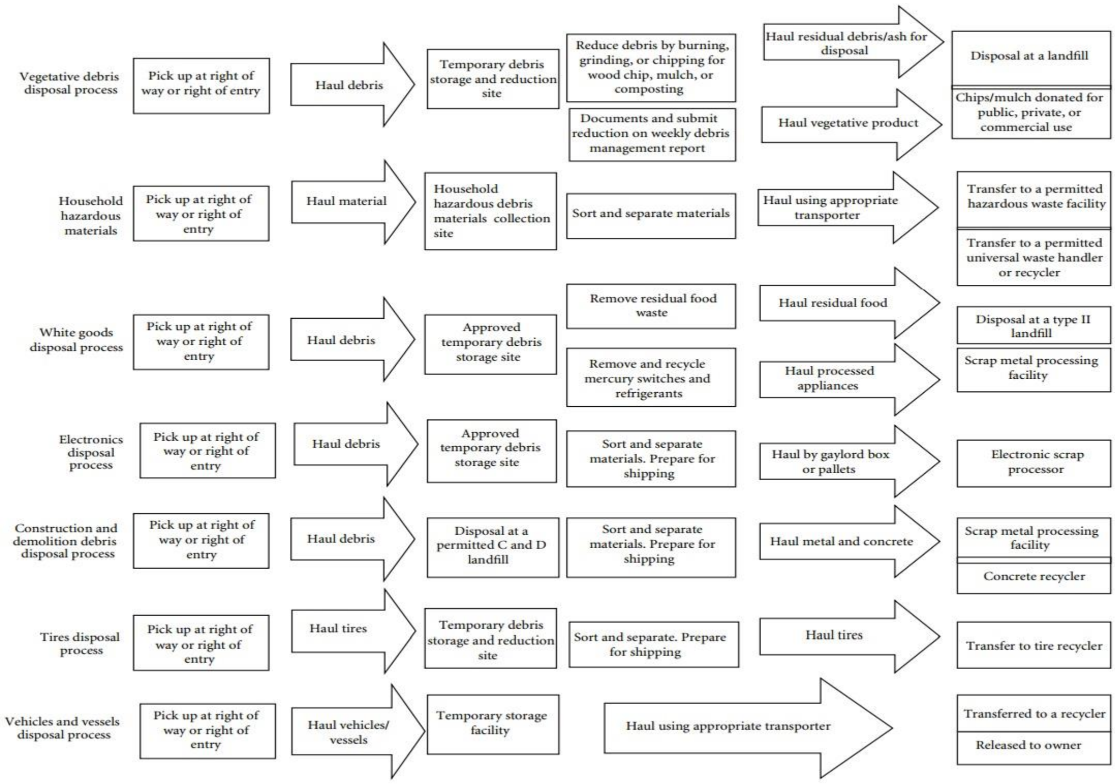


FIGURE 6 The way each type of debris was handled after hurricane Katrina (Brandon, Medina, & Morrow, 2011).

4.2.7 Recovery

Less than a year after the disaster, the Mississippi Departments of Environmental Quality decided that they do not need to establish new temporary storages anymore. They ordered their local governments to be prepared for closing the temporary storages and sites they have, and transport the remaining debris to the regular disposal sites (Luther, 2008). Within three years after the catastrophe, the affected areas were going back to normal life.

Levees were rebuilt partly and about two thirds of the replaced people came back (Colten, Kates, & Laska, 2008). On the contractors' side, and one year the catastrophe, AshBritt managed to remove and handle over 21 million cubic yards of debris, remove over 1,900 tons of spoiled food, remove and drag 24,045 stumps, 180,940 trees and 332,079 tree limbs. Also, 59 temporary storages were brought back to their normal situation. Additionally, over 650,000 loads of debris were dragged, 12,500 dragged vehicles were handled, and over 21 million cubic yards of debris were removed and handled (Fickes, 2010, p. 2). In the later part of the recovery phase, temporary storages brought back to their situation before the catastrophe as much as possible after removing all the remaining debris from them. That was achieved by planting grass or trees according to land owners' choices (Brandon, Medina, & Morrow, 2011).

4.2.8 Time management

Generally, the recovery phase after the hurricane lasted for five years in New Orleans's case (Luther, 2008). Boxer, Inhofe, Oberstar, & Mica claimed in 2008 that in Mississippi, about 3,364 observations were held at 13 landfill and temporary storage starting from October 2005. In Louisiana, the demolition of 8,706 building was observed by the responsible authority from March 2006. Furthermore, starting from 19th of February 2006 until the 25th of July 2008, about 16,900 building with no special demolition requirements in Louisiana were demolished. While the demolition activities held by privet owners were slow. For example, between June 2007 and July 2008, only 5000 buildings were demolished by privet owners in Louisiana (Boxer, Inhofe, Oberstar, & Mica, 2008). After the end of the emergency phase, and on the 14th of April 2006, the Mississippi Departments of Environmental Quality (MDEQ) gave the orders to local governments to be ready for moving all the debris from temporary storages in order to return them to their normal cases (Luther, 2008). As mentioned in the recovery part, contractors like AshBritt managed to do massive amount of work with the debris, and that work was ready during one year after the hurricane (Fickes, 2010, p. 2). Finally, it is important to know that the management of health and safety requirements in the cases of hazardous material presence caused the work to need more time. Like the case of demolishing and cleaning activities of the buildings that contain asbestos. In fact, each building needed an average time of four days to handle it in these cases (Brown, Milke, & Seville, 2011).

4.2.9 Results and findings

In the beginning, it is important to know that facing a flood in New Orleans was not a surprising event. In fact, it was expected to happen long time before the disaster. Hurricane Katrina was not the first disaster occurring in this city. The city has already faced similar events in 1915, 1947, and 1965 (Jonkman, Maaskant, Boyd, & Levitan, 2009). Hence, it is expected from the responsible authorities to be prepared for this disaster, and in fact, they were prepared with Robert T. Stafford Disaster Relief, Emergency Assistance Act, and National Response Plan (Esworthy, Schierow, Copeland, Luther, & Ramseur, 2006). However, each affected area had its own needs and requirements regarding debris removal and handling, so there were some variations between different areas. In some cases, the methods of removal and disposal varied in the same area over tome (Brandon, Medina, & Morrow, 2011). Although chipping and gridding the vegetative waste had a great positive affect on landfills, but they had also some negative effects, as the vegetative turned to be a potential source of fire. Actually, some fire accidents have happened in Lincoln and Pike counties, and therefore, the piles of vegetative wastes were not supposed to be higher than 4.57m (Brandon, Medina, & Morrow, 2011). Additionally, the ash resulting from the incineration handling method could have some use like making bricks, or roads construction, instead of sending it to landfills (Brandon, Medina, & Morrow, 2011). Furthermore, lowering the standard of landfills requirements had positive effects on facing the emergency phase after the disaster, but it also can have a long term negative impacts (Brown, Milke, & Seville, 2011).

Undoubtedly, as a result of the regular observations to temporary storages and landfills, the occurring problems were spotted soon after they happened. Hence, the mistakes were solved in many cases at the time of happening, like finding trucks with inadequate debris load and sending them back from the entrance of the landfill, and in the cases where these loads were already unloaded inside the site, they were collected and sent back again (Boxer, Inhofe, Oberstar, & Mica, 2008). In fact, the relocation of the population had also some negative effect on the waste management procedure, as people could help in the basic debris removal and separation (Brown, Milke, & Seville, 2011).

Generally, it was noticed that there were more than one top authority, there were at least FEMA, the Corps, EPA, and state and local government (Luther, 2008) See table 7. Moreover, having contractors and subcontractors can have a negative impact on the waste management procedure, for instance the responsibilities will be split over many actors. According to Fickes (2010, p. 2) over 1,230 subcontractors were brought to work by AshBritt who hired them and managed their working activities. Some of these subcontractors' activities were rehabilitating the damaged roads and remove the debris from them to allow trucks to pass. However, although the preparation and the systematic work went well, yet there were still some mistakes (Fickes, 2010, p. 2). In some extreme cases, there were lawsuits like the illegal dumping lawsuit case of a landfill in New Orleans (The Nguyen, 2007) and also the lawsuit of using privet lands as landfills for the hurricane debris (Gretna, 2015).

TABLE 6 Summary of selected governmental roles in post-Katrina debris removal activities (Luther, 2008).

Agency	Role/Responsibility Under the Stafford Act/National Response Plan	Comments
FEMA	Provide assistance to respond to the disaster, including funding debris removal and the "demolition of unsafe structures which endanger the public"; provide funding from the Disaster Relief Fund to agencies with various Emergency Support Functions (ESF) specified in the National Response Plan (NRP); FEMA receives requests for assistance from state representatives, and "mission assigns" the Corps to perform specific tasks that are deemed eligible.	Debris removal missions under ESF#3, Public Works and Engineering, and ESF #10, Oil and Hazardous Materials Response, involve an interagency and inter-governmental team that includes, among many, the following agencies: FEMA, the Corps, EPA (including regional offices), the states of Louisiana and Mississippi, local Parishes and counties, and the American Red Cross.
The Corps	The Corps acts as the coordinator for ESF #3. The Corps' mission includes right of way clearance, curbside pickup, private property debris removal (PPDR), and property demolition. Included within its ESF #3 mission is providing personnel for the Corps' debris removal team, obtaining a contractor to execute the mission, and coordinating landfill and burn site and the final disposal of debris. The management of *contaminated* debris is coordinated with EPA under ESF #10.	Debris removal may be entirely the mission of the Corps under its authority, or it may be done by the local government and reimbursed by FEMA (under the Stafford Act's Public Assistance [PA] program). In Louisiana, the Corps has the ESF #3 mission in 21 parishes, while 19 other parishes are conducting debris removal on their own through the FEMA PA program. In Mississippi, the Corps has the ESF #3 mission in 15 counties, and 75 other counties are conducting debris removal on their own through the FEMA PA program.
EPA	Under ESF #3, EPA assists local agencies in locating disposal sites for debris clearance activities and assists with contaminated debris management activities by coordinating and/or providing resources, assessments, data, expertise, technical assistance, monitoring, and other appropriate support. EPA is the lead federal agency under ESF #10. Under the mission, FEMA funds EPA's retrieval and disposal of orphan tanks and drums and the collection of household hazardous waste; the collection of liquid and semi-liquid waste has also been tasked to ESF #10.	EPA has worked with other federal agencies (particularly the Corps), state agencies, and local governments to facilitate the collection, segregation, and management of household hazardous waste. EPA has provided guidance on identifying and disposing of electrical equipment that may contain PCBs and on the handling and disposal of debris containing asbestos. EPA has also provided the affected states with guidance on burning debris.
State and local government	The states help coordinate local governmental requests for federal assistance and work with FEMA to define the mission. The Corps coordinates with state representatives regarding operational issues. Local agencies are responsible for providing Rights-of-Entry permits to allow the Corps or its contractors to enter private property for debris removal activities (within the Corps' authority); establishing criteria and procedures for classifying different types of debris; selecting disposal methods and approving disposal operations; condemning properties; providing demolition plans, and designating the appropriate type of landfill. Each state is conducting debris removal operations in accordance with declarations of emergency issued by its respective Department of Environmental Quality (DEQ) and in accordance with specific debris management plans issued after the storm.	The Louisiana and Mississippi Departments of Environmental Quality (LDEQ and MDEQ, respectively) are the environmental regulatory arms of the state government. Each state is authorized to implement its own solid and hazardous waste management program, including siting and permitting debris disposal sites. State or local governments may choose to accept the debris removal mission and apply for reimbursement from FEMA (see the Comments section regarding the Corps, above).

4.3 Sri Lanka earthquake and tsunami

4.3.1 The fundamental problems of the waste management in Sri Lanka

Generally, the waste management system provided by Sri Lanka different municipalities is not sufficient. Hence, even in the peaceful time, random waste is clearly visible in most of the areas, especially country sides. Where, the wealthier areas get a better waste management services than other areas in the country. The daily waste generated in the country in the normal days is about 6400 tons, consists mainly of organics, plastics, papers, and a small amount of metal and glass. The highest collecting percentage of this waste reached about 59% of the waste in best cases, and it dropped down to 2% in the countryside. Also, the available vehicles for transporting the waste are not enough at all, and many of them need to be replaced. At the same time, the vehicles are not covered, which allows the wind to spread the waste gain. The first separation step starts with individuals separating their own waste, especially organic and dry waste. Moreover, the recycling is carried out by individuals also, as it is a traditional activity for them to reuse different materials before putting them into the waste system. Actually, there are people who would buy these wastes. Most of the disposal sites in Sri Lanka are open dumps and located in environmentally inappropriate places, or close to the residential areas. In many areas, especially in countryside, handling the waste is done individually as the waste will not be collected. Therefore, organic waste ends in the homes' back yard dumps and pits, while plastics, papers, and general garbage ends up burned in regular bases. Other wastes like glass bottles are usually reused or sold to garbage collectors. From the local authority perspectives, and since the waste contains big percentage of organic wastes and moistures, composting tend to be the best solution for municipality handling of the waste, as it minimize the space needed in landfills. Where other materials in the wastes, such as metals, are taken away from the organic part and ends up in open dumbs (Vidanaarachchi, Yuen, & Pilapitiya, 2006).

In fact, lots of costly researches were carried out about Sri Lanka waste management since the eighties of the last century, but there were not sufficient solutions so far. That was due to the fact that the founded solutions are either too expensive, or not fully regarding the public opinion about their practices. Nevertheless, it will be hard to achieve any improvement for the waste management system if the in charge authorities are not motivated enough to make the change (Vidanaarachchi, Yuen, & Pilapitiya, 2006).

4.3.2 Collecting waste

The immediate response of the government was through the military forces that helped in removing the debris, and opening the main roads for the rescuers (Yamada, Gunatilake, Roytman, Gunatilake, Fernando, & Fernando, 2006). Lots of materials were collected by civil people in order to be used for rebuilding their homes, reusing these materials, or selling them to others who can use them like waste collectors. Actually, these practices provided sort of primary waste separation at the collection part of the work. Moreover, there was different non-governmental organizations activities that helped in collecting debris in the emergency phase (Pilapitiya, Vidanaarachchib, & Yuenb, 2006; Karunasena, Rameezdeen, & Amaratunga, 2012). Volunteers and the regular workers worked on removing debris from the most important areas, like main roads and important buildings, and they used the municipalities' trucks for that. However, there was a remarkable lack of machineries and workers for the debris collecting work, and also, there was no clear instruction about the separation method that needs to be used (Karunasena, Rameezdeen, & Amaratunga, 2012). Nevertheless, it is important to know that these waste collection services were not provided in all the country wide as the waste management system does not cover the entire country in the normal cases (UNEP, 2005).

4.3.3 Temporary Storages

In Fact, the idea of temporary storages in this case is not like the case of Japan. What was used in Sri Lanka was temporary storing rather than temporary storages. The collected waste and debris form the affected area were deposited in every possible free space, such as play grounds, and open areas (UNEP, 2005). Moreover, the waste collected in the emergency phase was placed sometimes in areas that are environmentally sensitive, like beaches, drainage ditches, waterways, and low lands (Srinivas & Nakagawab, 2008). Also, wetlands, lagoons, and flood retention got also some share of the waste disposing practices (Pilapitiya, Vidanaarachchib, & Yuenb, 2006). There were some temporary dumbing sites placed near by the affected cities were the debris was transported after collecting it. However, the waste was supposed to stay in these temporary storages until the time of handling it (Karunasena, Rameezdeen, & Amaratunga, 2012). Of course, this random way in waste storing may result in significant environmental damage in the long run if it was not removed from the sensitive areas and handled properly (Srinivas & Nakagawab, 2008).

4.3.4 The generated waste

Just like the case of Japan, the debris resulted from the demolished buildings after the disaster was highly significant. In Fact, the official authorities announced their debris estimation of about 200 million kg, but the real number can be a lot higher than that (Pilapitiya, Vidanaarachchib, & Yuenb, 2006). The debris of building materials resulted from each home reached approximately

3000 kg of waste. However, when taking into account that about 100,000 homes were destroyed, we can find that the total amount of debris, resulted from homes only reached up to 3 million kg. Additionally, there were the damaged houses and shops' belongings like furniture and products. Moreover, wrecked vehicles, boats (about two-thirds of fishing boats were destroyed), and damaged roads and bridges, were also big sources of debris (Pilapitiya, Vidanaarachchib, & Yuenb, 2006; UNEP, 2005).

The coastal cities suffering from the tsunami faced the problem of sand removal from the beaches, where this sand damaged the close metal roads, and farms of palms. Furthermore, dark minerals covered about 50% of the beaches of the affected areas, where about 25% of the vegetation were uprooted, beside the damaged vegetation. Where, the rest of the debris consisted of homes goods, and plastics (IUCN, 2005). Nevertheless, according to the UNEP (2005) the amount of debris resulting from this disaster can reach more than 500 million kg of debris and waste.

TABLE 7 C&D waste type's percentage in Galle's recycling plant (Karunasena, Rameezdeen, & Amaratunga, 2012)

Material	Composition (%)
Cabok	29.85
Bricks	28.67
Mortar	15.24
Concrete	6.77
Clay	2.36
Timber	1.57
Asbestos roofing sheets	1.17
Clay roof tiles	0.94
Ceramics	0.82
Plastic	0.50
Wires	0.25
Steel	0.05
Glass	0.01
Mixed waste	11.80
TOTAL	100.00

waste that could contain hazardous substances

Material	Composition (%)
PVC, uPVC	21.28
Electrical waste	19.75
Asbestos materials	18.68
Paint	15.43
Treated timber	13.26
Gypsum boards	6.23
Waster proofing material	3.09
Sealants, varnish, etc.,	1.83
Roofing cement	0.44
TOTAL	100.00

4.3.5 Classification and handling of debris

As mentioned before, the amount and kind of debris that the waste management authors needed to deal with in Sri Lanka was more than what they can handle. Many of the cleaning up-activities were accomplished inappropriately causing high environmental impacts on the long run, such as open dumbing and burning. However, some scale of recycling was possible to attempt, like crashing building waste for reusing purposes (Srinivas & Nakagawab, 2008). Clearly, the distinctive feature of the debris handling was the randomness (IUCN, 2005). In the emergency phase, sometimes the situation was handled by disposing the debris in an environmentally sensitive areas like waterways, and that was supposed to be temporary until proper sites are ready (UNEP, 2005). That was due to the fact that the existing landfills capacity is small and they are not enough for the tsunami waste. Nevertheless, even in about a year after the tsunami, the waste was not removed from the temporary sites, as it was not in the way anymore, it was simply considered to be not a problem (Pilapitiya, Vidanaarachchib, & Yuenb, 2006).

There was a small scale of recycling accomplished by individual owners who collected the usable materials from the debris. The materials were taken from their own homes and used for rebuilding them, such as concretes and wooden building materials. Also, reusable materials were collected and sold to the waste collectors. However, these efforts were for personal reasons, and even though they were significant and successful, but amount of these activities was not big. Moreover, non-governmental organizations put an impressive effort on the recycling aspect, like the case of the programme "crash for work" (Pilapitiya, Vidanaarachchib, & Yuenb, 2006). On the other hand, there were waste management projects in some cities of Sri Lanka funded by the European Union, like the case of the city of Galle. The project of the Construction Waste Management (COWAM) took a place between 2005 and 2009, focusing on Construction & Demolition activities. In the rebuilding part of the recovery phase, the waste was transported to the project center coming from the temporary sites where it was separated. The materials that can be used directly were sent to the recycling market. The rest of the materials were handled in the center by crashing them after removing hazardous substances (Karunasena, Rameezdeen, & Amaratunga, 2012).

4.3.6 Time management

The Center of National Operation (CNO) was formed by the government during the first 24 hours after the tsunami in order to face the catastrophe consequences. Nevertheless, the center was not able to fulfill its mission before two more days (Yamada, Gunatilake, Roytman, Gunatilake, Fernando, & Fernando, 2006). In the next two months, the best available sites for disposing the tsunami waste were identified. Still, even after nine months had passed after the tsunami, the waste in some temporary sites was still there (Pilapitiya, Vidanaarachchib, & Yuenb, 2006).

4.3.7 Results and findings

Generally, the responsible authority in Sri Lanka did not give the observes the impression of being enthusiastic about solving their day to day problem, and they did not prepare reliable plans that can help them to face such an extreme disaster. Obviously, the different negligent activities will result a serious environmental impacts on the long run, especially in the sensitive areas where the impact can reach the ground water for example (Pilapitiya, Vidanaarachchib, & Yuenb, 2006).

The fact that there was no vulnerability and hazard mapping resources and other needed information (Srinivas & Nakagawab, 2008), and also no proper engineering landfills (UNEP, 2005), made assessing the environmental impact of the tsunami waste more difficult (Srinivas & Nakagawab, 2008). Also, the fact that there is no proper waste management system, as the current one lacks the needed knowledge and technology, or having no solid waste management at all, reduced the local governments' ability to deal with the disaster (UNEP, 2005).

It was noticed that the disaster waste management work conducted by NGOs on the local level did not reach the expected achievement, as they did not have a ready guidance, available resources, or proper working system. In fact, it was noticed that the NGOs and the INGOs were competing rather than cooperating. One of reason for the competition was rapid growing of the INGOs, and also the fact that different participating NGOs needed to show the work result to the donors and other observers. Generally, the main challenges faced by NGOs and the government were managerial, additionally to the lack of knowledge and information. Moreover, when the donors did not get a proper guidance, NGOs and CBOs faced financial difficulties that could be avoided (Karunasena, Amaratunga, & Haigh, 2010).

4.4 Man-made conflicts

4.4.1 The situation before the conflicts

As Afghanistan conflict is very old, looking at the situation before the conflict means that we are looking at the situation before 1978. At that time, Kabul was served with solid waste collection that was paid by the municipality and people benefiting from the services. Kabul was divided into 11 waste collection areas, where the achievement of the work depended on the demography of the area, and the amount of available fund for it. In the wealthier areas, the solid waste was collected once a month, while in the lower income areas the solid waste was collected once every three months. On the other hand, countryside areas, and slum dwellers did not receive any services at all. Generally, the waste was left on the roads as there were no garbage bins, and the municipalities were collecting the garbage from there using simple old tools such as twig brooms and small rakes, actually, in some cases they just used pieces of wood. Then, the waste was put in carts and delivered to certain places on the road sides, where all collectors bring the waste to, later on, a truck will come to take the garbage from there. The truck will come to take the garbage once in 1 to 3 months due to the fact that there were only 30 open trucks in Kabul which were not in a very good condition, and any of them might be taken out of the service in any moment. Moreover, there was an open dump site about 5km from Kabul were the garbage was dumped with no coverage at all. However, people in Kabul used to practice recycling themselves through selling the recyclable materials to the waste buyers who used to come to each door. In fact, lots of those recyclable materials ended in Pakistan. The rest of the usable waste was collected by the street pickers who collected the recyclable materials like paper and glass for selling purposes. Actually, in 1977 it was estimated that only 25% of Kabul wastes were collected by the municipality. On the other hand, there was the Kabul Environmental Engineering Department (KEED) that was formed to support the municipalities' effort and it was supported by 22 organizations by the year 1979 in order to improve the solid waste management in Kabul (Amanullah & Furedy, 1994).

Before the war in Iraq, equipment of solid waste management were not maintained or renewed. Which caused the obsolescence of equipment, and decreased there services achievement. Additionally, different types of wastes were in need for assessment to find more information about them, and find proper ways to handle them, as their problems kept building up with no proper solution provided, like the case of medical waste and hazardous waste. Municipalities handled the collected wastes by dumping them in unregulated open dumping landfills all around the country, without regarding the environmental impacts. Whereas, the small number of formally constructed landfills, were actually missing even the minimum requirements. In fact, even the liner systems, daily cover, leachate, and gas collection were missing from those landfills (Knowles, 2009). Kosovo landfills have had the same problems, where landfills before the war did not have any kind of covering or compacting. Indeed, there was no planning for waste disposal in the old landfills (KEPA, 2009).

4.4.2 The situation during and directly after the conflicts

During the war in Afghanistan, The Soviet authority was not interested in solid waste management in the country. Based on that, they stopped the waste collection activities and sent the waste collection workers to serve the military, where they had to deal with the destroyed military equipment. On the other hand, KEED lost its international financial support, and the available equipment was able to work for another two years only. After that, the activities of KEED had to stop. As a result, the waste was simply not collected during the war, and it was just placed in any empty space available in the city (Amanullah & Furedy, 1994). In contrast, Kosovo's cadastral information faced the removal of about 80% of it, either before or during the war. Nevertheless, the assessment showed that most of the municipalities did not have a functioning digital cadastral system (UNEP & UNCHS, 1999). Moreover, it was reported that the equipment and vehicles of the solid waste department were robbed during the war (EC & WB, 1999). In the Iraqi case, the situation in general went out of control as there was no responsible authority. As a result, people had to solve their solid waste problems independently, so they used every available place to put their garbage, like public gardens and the sides of highways (Kharrufa, 2007). In fact, people in Afghanistan solved their waste problems in a similar way, where even schools yards were used for dumping wastes (Amanullah & Furedy, 1994).

4.4.3 Collecting waste

The recyclable materials in Afghanistan were collected by wastes sellers. Those sellers had to walk for very long distances, and scam the piles of waste to collect metals. Actually, they had to face serious dangers while seeking among military hazard wastes, as these waste made the solid waste situation worse in the quantity aspect and also the hazardous aspect (Amanullah & Furedy, 1994). Nevertheless, even in the recent years where Kabul municipality has 2000 workers and 110 trucks for solid waste collection, it still cannot meet the needs of the city waste collection (Rahimi, 2011). In contrast, the U.S. occupation of Iraq had no option but to seek for debris and wastes removal as the fighters against the American soldiers were hiding behind them to attack them. Therefore, The U.S. Army had to pay for removal of the debris piles that represent a risk for soldiers, and in some cases these areas were turned into gardens to stop the attacks. However, the problem of the rest of wastes and debris was not solved. On the other hand, the debris of demolishing and constructing the building after the war represented a problem as the amount of it was significant. Indeed, the removal of this debris needed between 0.27% and 1.44% of the total cost needed for one building (Kharrufa, 2007). The situation in Kosovo was not better. In fact, debris was needed to be removed also from water sources, and it was reported that more than 2000 wells were cleaned by NGO from humans and animals' dead bodies, this NGO (Médecins Sans Frontières) had also to educate people about cleaning wells and preparing them to be reused (Ashford & Gottstein, 2007). Furthermore, in in the U.S. base in Kosovo, Camp Bondsteel, the waste of the base was collected by using 10 collecting trucks (Martel, 2003).

4.4.4 Temporary storages

As mentioned earlier, the waste was in most cases just collected in random empty areas. For example, in Kosovo, reliable information about the places where the waste was collected before reaching landfills was not available. Nevertheless, it was clear for the observer that the waste was just placed in any available space, especially the demolishing and constructing debris. Indeed, the problem became more complicated when the waste was randomly mixed (KEPA, 2009). However, storing waste was used by the American Army in Camp Bondsteel in Kosovo, where they stored their wastes in dumpsters (Martel, 2003).

4.4.5 The generated waste

Kosovo's conflict resulted about 100,000 tons of building debris alone (Brown, Milke, & Seville, 2011). The regular waste was present in the war generated wastes, such as organics, plastic, metals, oils, acids, batteries and hospital waste (KEPA, 2009). In fact, the waste after the conflict included also military wastes like bombs and other weapons that contain depleted uranium, but that was not officially documented according to UNEP & UNCHS (1999). While in Camp Bondsteel, plastics, glass, lumber wastes were generated in addition to hazardous and exploding materials (Martel, 2003). Moreover, there were contaminations of PCB (Polychlorinated Biphenyls), mercury, and dioxin, where it is important to know that not all of these hazards resulted from the war, but they were also building up over year (UNEP & UNCHS, 1999).

Furthermore, expired medications reached massive amount in pharmacies and the medication factory, as the random humanitarian medication aids that were sent to the country made the situation even more challenging (KEPA, 2009). In the Afghani conflict, war different materials such as unexploded bombs and bio-chemicals accumulated in the city of Kabul with human waste and mixed wastes (Amanullah & Furedy, 1994). Moreover, the construction and demolition activities generated massive amount of waste and debris in Kosovo and Iraq (KEPA, 2009; Kharrufa, 2007). In the Iraqi case, the waste included concrete, plaster, sand, broken bricks, and building's waste materials like cement, packaging, and rubble, where in some cases there were some furnishing objects, different devices, and hazard materials. Additionally, there were windows and doors leftovers, metals, and wood. In fact, the estimated amount of construction and demolition debris in Iraq, reach about 320 tons, which means that every 10 m^2 approximately generated 2.15 tons of debris (Kharrufa, 2007).

4.4.6 Classification of debris

In Iraq, lots of construction and demolition waste materials were considered to be non-recyclable like concrete, plaster, sand, and broken bricks. While doors and windows materials such as wood and metals were reused without putting them in the solid waste system, except for some very limited cases where the materials were too damaged and not possible to be reused. Yet, wood would be recycled even after it is totally damaged (Kharrufa, 2007). In Camp Bondsteel in Kosovo, the wastes were all classified for incineration after removing hazardous and exploding materials. The only exception was for some wooden materials that were sent to be burned in pits for military training purposes (Martel, 2003).

4.4.7 Handling debris

26 municipalities in Kosovo used open surface landfills that did not follow any kind of restrictions or requirements, not even drainage systems, and they were near by the residential areas and water sources. Furthermore, the waste did not go through any separation process in these landfills, so all different types of waste were just dumped there without any sort of planning (KEPA, 2009). Nevertheless, it was reported that composting some types of solid waste like organic waste, paper, paperboard, plastics, glass, ceramic, metals, and textiles has been done some years after the war (Karak, Bhagat, & Bhattacharyya, 2012). On the other hand, in the American bases in Kosovo, different kinds of wastes were incinerated to minimize their size, and to prevent diseases. However, the incineration procedure did not follow the American standards used in the Stats regarding emissions and other environmental considerations. The locals were asked to search the waste pole barn for the hazardous and exploding wastes and remove them. Then, the wastes were incinerated in enclosed bum pit, cooled down, and finally dumped in landfills (Martel, 2003). In Iraq, most of the municipalities did not have information about the types and amounts of wastes, and also the way of handling these wastes and the amount of waste under each

handling method. However, the available information in most cases was non-official estimations (Knowles, 2009). Moreover, as matter of culture, people in Iraq reuse the wood and metal as long as they are usable, and that is due to the fact that the country weather is dry, which protects the metals from rust. Wood would last for shorter time in Iraq, and in case of being totally damaged and not usable, it will be chopped and used as a fuel (Kharrufa, 2007).

4.4.8 Recovery

The recovery phase in Kosovo started right after the war stopped in 1999 (EC & WB, 1999). Within the next 10 years after the war, they worked on correcting the situation of several municipalities' landfills, and some landfills were rehabilitated and closed. In 2009, which is 10 years after the war in Kosovo, some municipalities had several privet companies worked on collecting solid waste, and the following table shows their infrastructures estimations (KEPA, 2009). Although the situation of some open landfills was slightly corrected, by covering them for example, but the environmental impact of these landfills is still occurring. Moreover, they cannot be used, neither for gas production nor for producing energy as the wastes have been there for long time already (KEPA, 2009).

TABLE 8 Privately owned waste collection infrastructures in Kosovo (KEPA, 2009)

Nr.	Company	Region	Nr of transport trucks	Nr of Containers 1.1 m^3	Nr of containers 5. 0 m^3	Nr of containers 7. 0 m^3
1	Ambienti	Pejë	16	1130	16	28
2	Çabrati	Gjakovë	5	146	-	22
3	Eko-Regjioni	Prizren	17	1070	12	47
4	Higjiena	Gjilan	11	1291	16	-
5	Pastërtia	Ferizaj	8	738	78	-
6	Pastrimi	Prishtinë	56	2400	-	135
7	Unitetit	Mitrovicë	15	890	30	117

Actually, even 10 years after the war, the solid waste management in Kosovo was still not as it should be. Mahir Yagcilar, the minister of the Environment and Spatial Planning ministry, wrote in 2009 "*We have to admit that we are not satisfied with current waste management system. Difficulties and problems are evident in all system's components as in waste collection, selection, storage, and that these problems are evident in management process of all types of wastes as: household waste, industrial waste, hazardous waste etc.*" he also clearly mentioned burying everything in landfills for that time (KEPA, 2009).

In Iraq, about two years after the war, the construction and demolition activities continued to increase, generating massive amount of debris with almost no control at all. At that time, the authorities still did not have any

control over the solid waste management. As a result, dumping debris in any available place continued to happen (Kharrufa, 2007).
In Afghanistan, the situation continued to be worse as the daily generated wastes accumulated with the war generated waste and debris. Until 2011 it was reported that the daily generated waste in Kabul reaches about 3000 tons of solid wastes. Unfortunately, the municipality of the city cannot collect this amount of wastes, which means that the waste will simply remain there (Rahimi, 2011).

TABLE 9 Example of estimated data about the C&D generated debris in Iraq (Kharrufa, 2007)

House number	Built up area, m^2	Cost of building ID	Cost of debris removal ID	Percentage of cost (%)	Weight of debris in ton	Weight of debris per 10 m^2
1[a]	570	143,978,150.00	2,085,500.00	1.44	260.70	4.57
2[b]	610	68,709,195.00	633,000.00	0.92	79.13	1.30
3	420	20,596,125.00	350,000.00	0.70	43.75	1.04
4	840	152,145,150.00	1,177,000.00	0.77	147.13	1.75
5	240	30,004,925.00	80,250.00	0.27	50.03	2.08
Average	536	83,086,709.00	865,150.00	0.82	116.15	2.15

[a]Plot had existing structure which was removed increasing amount of debris from site.
[b]Plot had existing structure which was removed increasing amount of debris from site.

4.4.9 Time management

In the case of Kosovo, the recovery of the war started right after the war stopped. The initial estimations expected that between 4 and 5 years are needed for the recovery phase (EC & WB, 1999). The following table shows the estimated cost needed from external parties for the recovery phase after the war and the time division for it.

TABLE 10 External financing requirements after the war in Kosovo (in US$ million) (EC & WB, 1999)

Activity	First Phase (until December 2000)			Second Phase (2001-2003)	Total
	Until March 2000	April to Dec. 2000	Total		
Housing	36	270	306	214	520
Water and Waste	30	49	79	181	260

In fact, fixing the situation of the open landfills in Kosovo was put in action after the Kosovo Environmental Action Plan 2006-2010, and the plans of preparing special utilities for handling hospitals' wastes were decided to be in practice only in 2009 (KEPA, 2009).

TABLE 11 Completed projects for rehabilitation of old landfills 2004-2008 (KEPA, 2009)

Project name	Project status	Year of project realisation
Rehabilitation of landfill in Suharekë	Completed	2004
Rehabilitation of landfill in Prizren	Completed	2007
Rehabilitation of landfill in Gjakovë	Completed	2007
Rehabilitation of landfill in Kaçanik	Completed	2007
Rehabilitation of landfill in Ferizaj	Completed	2008
Rehabilitation of landfill in Gjilan	Uncompleted	2008-2009
Rehabilitation of landfill in Lipjan	Completed	2008

4.4.10 Results and findings

As noticed, all of the three countries did not have adequate solid waste management already before the conflicts, and that what made the situation even more challenging. The challenges were mainly due to the fact that the problem is not about handling the solid waste management after the disaster, but it was because of the accumulating solid waste problems that existed already before the catastrophe and became worse after it (Amanullah & Furedy, 1994; Kharrufa, 2007; UNEP & UNCHS, 1999). Indeed, the lack of adequate information made the assessment of the real damage difficult like the case of Kosovo (Karak, Bhagat, & Bhattacharyya, 2012). Also, having no responsible authority like Iraq (Kharrufa, 2007) or no clear division of responsibilities and overlapping like in Kosovo, lead up to the irresponsible behavior from civilians who had to solve their problems by themselves (UNEP & UNCHS, 1999; Kharrufa, 2007). Moreover, the absence of strict solid waste regulations before the conflicts -like the case in Kosovo for example- meant that there are no legal consequences for any improper action (UNEP & UNCHS, 1999). On the other hand, the financial limitations and the need for external support limited the municipalities' ability of solving their problem efficiently and independently as seen in Kosovo and Afghanistan (Amanullah & Furedy, 1994; UNEP & UNCHS, 1999). Generally, the focus on the solid waste management is in the big cities mainly, where smaller areas in the countryside receive less or no solid waste management at all. Consequently, disease spread in these regions, and the rapid increasing the population pushed the problem to new limits like the Afghani case (Amanullah & Furedy, 1994). While in Kosovo there was the problem of removing the information in some cases, like removing 80% of the cadastral information (UNEP & UNCHS, 1999) or no studies were done to tell about the problem and how to solve it like the case in Iraq (Kharrufa, 2007). Issues like these made solving the problem even more complicated. Nevertheless, solid waste management does not have the heist priority in the war conflicts. Yet, when a country like Afghanistan depends on up-ground water, the solid waste management priority should increase (Amanullah & Furedy, 1994). Otherwise, the citizens will face a huge health risk, especially that the wastes in these cases contain military wastes (Amanullah & Furedy, 1994) where the debris resulting from rebuilding the country can cause a big health problems and environmental impacts due to the generated debris from C&D activities like the case in Afghanistan and Iraq (Kharrufa, 2007; Amanullah & Furedy, 1994).

5 DISCUSSION

Previous researches in the area of post-disaster solid waste management tended to discuss the regulations and the financial burdens mainly. Also, they discussed the theory backed with examples of different cases which are ideal for their case. In contrast, this thesis went through four case studies from the beginning of the emergency phase to the end of recovery phase in order to compare different situations with each other, and with the theory behind them. Collecting information was conducted via secondary data collection of reports and researches, aiming to find the real solid waste management practices of each case study after the catastrophe. Special attention was paid to distinguish between "how the work went" and "how the work was supposed to go" as some reports were focusing on the expectations more than the real practices. Therefore, the "expectations" of the work were presented in the first stage of the thesis in the theoretical chapter, and then the real practices were presented for each case study. In this way, the concept behind each stage of the management system in the case studies will be clear to compare and evaluate. The findings and results of each case study were presented to spot the significance of the case study, and draw the attention to its unique practices. At the end, the systematic management differences between developing and developed countries, also between natural disasters and man-made disasters were clearly visible.

5.1 Developed countries

In both cases of Japan earthquake and Hurricane Katrina catastrophes were not unfamiliar (Jonkman, Maaskant, Boyd, & Levitan, 2009; Mimura, Yasuhara, Kawagoe, Yokoki, & Kazama, 2011). Also both of the countries faced at least one secondary catastrophe (Colten, Kates, & Laska, 2008; Mimura, Yasuhara, Kawagoe, Yokoki, & Kazama, 2011). According to Brown, Milke, & Seville (2011) countries usually do not have ready plans for how to face the solid waste problems after a catastrophe hit. Indeed, that problem was clearly visible in the case of Japan. The ministry of environment used the guidelines they had from 1998 and 2005 which did not cover the entire management needs. Actually, they prepared their plan about two months after the great earthquake (Kamiya, 2011). In contrast, the United States used the guidelines of Robert T. Stafford Disaster Relief, Emergency Assistance Act, and National Response Plan to face their critical situation (Esworthy, Schierow, Copeland, Luther, & Ramseur, 2006).

In the case of collecting debris in the emergency phase, the focus of the two countries was slightly different, although the general practice was similar in the end. In Japan, special attention was paid to civilians' belongings and memories while collecting debris (Kamiya, 2011). They also paid attention to the fact that the employees working in the emergency phase were also victims, yet they went to work right after the catastrophe without a significant delay (Egawa, Kawamura, Ikuta, & Eguchi, 2013). On the other hand, the United States was more focused on the legal side of the work. They paid special attention to the ROE and ROW to avoid any legal consequences in the future (Brandon, Medina, & Morrow, 2011).

Generally, collecting waste and debris after the disaster is the responsibility of the local authority (Brown, Milke, & Seville, 2011). In the Great East Japan Earthquake, the head of the responsible authority was clearly the Japanese Ministry of Environment. They were responsible of managing the entire process as they assigned the work, calculated the different estimations, and evaluated the achievement (Ministry of the Environment, 2012). In the cases where the government needed extra support from the privet sector, they tended to ask for their specific need from the companies. For example, when the government faced a lack in debris removing machineries, they recruited the machineries from privet sector. Also, they worked on developing the construction machinery to meet the needs of the critical situation, so they made the double-arm machines. Yet, all the work was achieved under the supervision of the authority (Egawa, Kawamura, Ikuta, & Eguchi, 2013). In the case of Hurricane Katrina, there were several responsible authorities at the top of the pyramid and not a single authority like the case of Japan. FEMA, the Corps, EPA, and state and local government were the main responsible authorities which the work was divided over them according to the guidelines. The states responsibility was to coordinating the work among different stake holders such as directing a certain agency to help local governments meeting their needs (Luther, 2008). On the other hand, there were many subcontractors and private waste companies who worked with lots of independence in this case (Fickes, 2010). As suggested by Baud, Grafakos, Hordijk, & Post (2001) the regulations in these cases must be well prepared to avoid complexes. In fact, as it was expected in the theory (Baud, Grafakos, Hordijk, & Post, 2001) having contractors and subcontractors can save time and limit corruption in this case. Nevertheless, there were some negative affect of this policy as mistakes happened (Fickes, 2010). In this case, the responsible authority will have to face the consequences, where in some cases these consequences can be facing the court. For example, the case where privet land was used as landfill (Gretna, 2015). However, better preparation of contracts can improve the contractors' working quality, and minimize or stop the potential prohibited activities like illegal dumping (Brown, Milke, & Seville, 2011). However, the main difference between the Japanese case and the U.S. case goes back to the fact that the Japanese municipalities are responsible of the solid waste in the general case, where in the U.S. they count more on privet waste-companies to handle the operating work (Ministry of the Environment, 2012; Louis, 2004). However, even in the general cases there is no enough information about how the physical work has to be accomplished due to the lack of deep researches covering this area of the disaster waste management (Brown, Milke, & Seville, 2011).

Due to the fact that the amount of generated wastes and debris after the catastrophe is more than what the regular facilities can handle, temporary storages and sites were used in both case studies (Luther, 2008; Murasawa, Koseki, Iwata, Suzuki, Tamura, & Sakamoto, 2013). As mentioned the theoretical chapter, the places where the temporary sites will be stablished should be selected carefully regarding the environmental impact on the area of the temporary site, and also regarding the environmental impact of the distance between the affected area and the temporary site (EPA, 2008). In Japan, the temporary storages were selected to be "*in the vicinity of the residential areas*" according to the Ministry of Environment in 2012, without explaining how the temporary storages areas were selected. On the other hand, the government in the United States had a ready plan before the disaster occurred. Therefore, the local governments and the responsible agencies followed the requirements specified by the solid waste management plan to select the temporary storages (Luther, 2008). Moreover, the separation process in the Japanese case was done mainly in the temporary storages with primary separation in some cases (Inui, Yasutaka, Endo, & Katsumi, 2012; Ministry of the Environment, 2012). Where in the U.S. case, large part of the separation work was accomplished already before reaching the temporary sites like the case of separating white goods and electronic from other wastes (Brandon, Medina, & Morrow, 2011). They also separated the regularly generated waste apart from the hurricane generated waste when they stopped handling the household wastes at the time of the storm (Fickes, 2010, p. 1).

By comparison, the area affected by Hurricane Katrina is greater than the area affected by Great East Japan Earthquake (Fritz, et al., 2007; Mimura, Yasuhara, Kawagoe, Yokoki, & Kazama, 2011). Therefore, it is not surprising that the generated debris and waste in the U.S. case (more than 90.2 m^3) (Brandon, Medina, & Morrow, 2011) is greater than the debris and waste Japan (23 million tons, and more than 12 million m^3 from tsunami) (Inui, Yasutaka, Endo, & Katsumi, 2012). Generally, the types of waste generated in both cases did not vary in the inhabited areas. Most of the waste came from destroyed homes, devices, and vehicles etc. (Brandon, Medina, & Morrow, 2011; Tanaka, 2012). Yet, as it was suggested in the theory, a big part of the generated debris after the hurricane came from vegetation and up rooted trees (Escobedo et al., 2009). Actually, AshBritt contractor alone handled about 24,045 stumps, 180,940 trees, and 332,079 tree limbs (Fickes, 2010, p. 2). According to Sakai & Bettencourt (2012), the main elements in the tsunami debris are marine sediments like sand and mud, and wreckage parts of the residential areas like wood and metal. Also, it can contain oils and hazardous chemicals. Clearly, these elements were found in the coastal areas in Japan after the tsunami. It was noticed that a huge load of marine sediments reached the coastal areas and mixed with different marine creatures (UNEP, 2012). Furthermore, the oil plants and oil tanks located along the coastal region of japan faced spillages which added extra hazardous chemicals to the generated waste and debris in the region (Tanaka, 2012).

EPA (2008) suggested that there are two main types of handling debris after the catastrophe which are recycling, and incinerating and recycling. They believed that developed countries would put great effort toward recycling. Indeed, both countries put an impressive effort in waste recycling. In Japan, although one third of the waste and debris were incinerated (Inui, Yasutaka, Endo, & Katsumi, 2012) but a high level of separation was applied in the temporary sites, including manual separation (Ministry of the Environment, 2012). In U.S., there was a clearer division of waste depending on its type, and the expected handling process for each type was done according to the available plan (Luther, 2008). Yet, after Hurricane Katrina the authorities tended to lower their waste management standers such as the landfills standard (Brown, Milke, & Seville, 2011).

According to Colten, Kates, & Laska (2008) life went back to normal within three years after the hurricane and the rebuilding of some infrastructure already began. In contrast, Luther (2008) claimed that the recovery phase in New Orleans will last for five years. On the other hand, the estimations of the Japanese Ministry of Environment (2014) expected the recovery phase to end in 2014, which is less than four years after the disaster. Generally, the recovery phase can take several years to end as most of the physical work will be handled in it. Also, there might be external factors affecting the recovery process and slowing it down, like the case of New Orleans where different kinds of investigations concerning police work and coroner resulted in a delay of the waste management activities. Moreover, it is important in the recovery phase of the waste management to distinguish between handling the waste generated directly by the disaster, and the waste generated by the rebuilding activities. That is due to the fact that the rebuilding activities might last for many years that can reach up to 10 years period without having a clear end of it (Brown, Milke, & Seville, 2011). Calculating the amount of debris after the catastrophe is very important for the planners, and as mentioned in the theory, there are several ways for calculating these amounts in order to prepare the needed estimations (EPA, 2008). The Ministry of Environment in Japan published the progress of the recovery phase in 2012 and 2014 annual reports. In these reports information about the finished and unfinished work was clearly presented in the form of percentages which gave a clear idea about the progress of their work (Ministry of the Environment, 2012; 2014). After Hurricane

Katrina, Linda Luther published two CRS reports for congress in 2006 and 2008. Both reports displayed the achieved work regarding waste management in the form of the amount of finished work in the appropriate unite such as cubic yards and load of debris, without giving an estimation about how much debris still needs to be handled (Luther, 2006; 2008). Furthermore, regarding the time management part of the disaster waste management, the Japanese Ministry of the Environment prepared a time table of its waste management achievement regarding the finished and unfinished work with the expected time to finish it (Ministry of the Environment, 2012). In fact, many municipalities managed to finish handling all the waste and debris they had to treat by the beginning of 2014 (Ministry of the Environment, 2014).

5.2 Developing countries

Usually, developing countries do not have a ready plan to face catastrophic situations, and in some cases they do not even have a plan to face the normal situations. Indeed, there are some general guidelines and handbooks published to cover at least the first reaction after catastrophes, including general information about solid waste management response. Guidelines for Safe Disposal of Unwanted Pharmaceuticals in and after Emergencies (published in 1999), and Engineering in Emergencies (published in 2002) are examples of two available guidelines. These publications and other publications were available to provide a clue about how the solid waste management after the disaster must be handled (Brown, Milke, & Seville, 2011). Yet, in both case studies, the case of a natural disaster and the case of man-made disaster, developing countries were not prepared for handling the situation after the disasters (Amanullah & Furedy, 1994; UNEP, 2005; UNEP & UNCHS, 1999). The waste management system was facing serious problems and the work was not efficient already before the disasters happened (Vidanaarachchi, Yuen, & Pilapitiya, 2006; KEPA, 2009; Amanullah & Furedy, 1994; Knowles, 2009). Before the disaster in Sri Lanka, the solid waste management system collected less than 60% of the waste in the cities and 2% of the waste in the countryside (Vidanaarachchi, Yuen, & Pilapitiya, 2006). Where, in Afghanistan for example, waste was collected once a month in the best cases in the cities, and the countryside did not receive any collecting services at all (Amanullah & Furedy, 1994). The solid waste management infrastructure was not properly equipped in both man-made and natural disasters cases, and the limited recycling approach was done by individuals' efforts mainly (Vidanaarachchi, Yuen, & Pilapitiya, 2006; Amanullah & Furedy, 1994).

The primary waste collection in the emergency phase in Sri Lanka was accomplished by military, volunteers, NGOs, and regular waste management workers (Pilapitiya, Vidanaarachchib, & Yuenb, 2006; Karunasena, Rameezdeen, & Amaratunga, 2012). On the other hand, the waste in different phases was collected by different actors in the man-made conflicts such as waste sellers in Afghanistan (Amanullah & Furedy, 1994), Military in some special cases in Iraq (Kharrufa, 2007), and NGOs in Kosovo (Martel, 2003). However, although the general waste management problems were similar in both cases natural and man-made disasters, but in the case of man-made disasters the situation was different during and after the conflicts. During and right after the conflicts, the countries faced loss in information (UNEP & UNCHS, 1999) and equipment (EC & WB, 1999), where in some cases the waste services stopped entirely, and even the NGOs efforts had to stop at some point (Amanullah & Furedy, 1994). In the Iraqi case, there was not even an authority to control the system, and as a result the waste management system was in a total mess (Kharrufa, 2007). Obviously, garbage and debris remained under streets with no collection of any sort during the emergency phase in the man-made case (Amanullah & Furedy, 1994). These problems were not presented in the natural disaster case, as the military force helped removing debris and opening roads in the emergency phase after the disaster (Yamada, Gunatilake, Roytman, Gunatilake, Fernando, & Fernando, 2006). In fact, there were some cases in the man-made disaster where military helped removing debris, like the case of Iraq where the U.S. army removed piles of debris, and in some cases turned the area into gardens. However, it is important to note that this was not at the emergency phase after the conflict. In fact, the removal focused only on the piles that presented a potential danger to soldiers (Kharrufa, 2007).

Informal waste collection that is usually done by waste pickers is a common phenomenon in the developing countries in the regular times. The poor solid waste management in these countries provided living opportunity for many people. Those people are usually specialized in their work and divided according to their way of getting the waste and the places they get it from (Wilson, Velis, & Cheeseman, 2006). Clearly, disasters occurring in developing countries generated more wastes than usual. As a result, the importance of waste pickers work in helping the poor solid-waste management in these countries at the time of crisis increased. Actually, their work was able to provide a primary waste sorting that the authority cannot provide usually (Pilapitiya, Vidanaarachchib, & Yuenb, 2006; Karunasena, Rameezdeen, & Amaratunga, 2012). Although waste pickers work provides a good primary separation opportunity, it is important to know that screening the waste in the case of man-made conflicts can be dangerous. These waste piles could contain military hazard waste (Amanullah & Furedy, 1994), and in some cases there might be exploding materials in them, which puts the waste pickers in a serious danger (Martel, 2003).

In the peaceful days, NGOs tend to work in the field of waste management and help improving people and communities' wellbeing by providing waste management projects and educating locals. However, as mentioned in the theory, their work in the disasters areas becomes more challenging on many levels, especially funding (Ahmeda & Ali, 2004). These problems were clearly present in the case of Sri Lanka. The competition between NGOs and INGOs, the lack of resources and information, and also the big amount of money flowing into the country caused problems for Local and international organizations, and to the government as well. Different observers, especially donors, expected to see good achievement in the work, but the lack of information, knowledge, and resources made that difficult. Where, at the same time, NGOs had to spend the money fast (Karunasena, Amaratunga, & Haigh, 2010). Actually, in the man-made case the situation could be even more complicated. For example, KEED worked in Afghanistan before the war supporting the local solid waste management system in Kabul, and it was supported by 22 different organizations. However, when the war started all the organizations stopped supporting KEED, and the available infrastructure was able to support their work for another two years. After that, they needed to stop working entirely (Amanullah & Furedy, 1994).

The generated waste and debris after these disasters included the familiar generated debris after catastrophes, like the debris of destroyed buildings. Additionally, the generated waste in Sri Lanka case included minerals and vegetation resulting from the tsunami (IUCN, 2005). Furthermore, the man-made conflicts generated more dangerous wastes like exploding materials and hazardous chemicals (Martel, 2003; UNEP & UNCHS, 1999). It was also noticed that the random humanitarian aids formed a significant source of waste, especially the expired medications (KEPA, 2009). However, in the natural disaster case in Sri Lanka (Pilapitiya, Vidanaarachchib, & Yuenb, 2006) and in the man-mad disaster in Iraq (Kharrufa, 2007) individuals and house owners separated the usable debris and waste of demolished and damaged buildings to reuse them for rebuild their homes. As a result, these materials did not reach the solid waste system as they were not considered to be wastes, except in the cases where the materials were entirely damaged (Kharrufa, 2007).

Nevertheless, landfills were not appropriate for waste dumping. In Sri Lanka, there were no engineering landfills (UNEP, 2005). Also in Kosovo, landfills were open surface-dumping areas that did not follow any restrictions at all in the emergency phase. They were also placed nearby the residential areas (KEPA, 2009). Generally, developed countries tend dump their wastes and debris in landfills and as the space in landfills is usually not enough, they have to incinerate their wastes to save the space (Karunasena, Amaratunga, Haigh, & Lill, 2009). In fact, this situation was noticed in Sri Lanka. After the tsunami, the landfills were not able cover the entire need of waste dumping. Therefore, the waste was burned, and in some cases the destroyed buildings materials were crashed to save space in landfills (Srinivas & Nakagawab, 2008). Furthermore, limited composting activities were applied to some materials in Kosovo like plastics and organics (Karak, Bhagat, & Bhattacharyya, 2012). Where, the American military over there practiced incineration to minimize the volume of their wastes, but they did not follow proper waste handling restrictions (Martel, 2003).

In the beginning of the emergency phase, the responsible authority in Sri Lanka took about three days to fulfill the needed requirements in order to face the catastrophic situation (Yamada, Gunatilake, Roytman, Gunatilake, Fernando, & Fernando, 2006). In fact, the waste was supposed to be collected in the temporary areas for some time until it is possible to remove it (Karunasena, Rameezdeen, & Amaratunga, 2012). However, the acceptable temporary sites were spotted within two months after the tsunami, but the waste remained in the random areas for long time. In some cases, the waste was just left in the first place it was placed in and as it was not in the way it was simply ignored. As a result, it was noticed that most of the environmental impacts of this disaster came from the negligence practices and not from the disaster itself (Pilapitiya, Vidanaarachchib, & Yuenb, 2006). On the other hand, although fixing the mess after the conflict in Kosovo started right after the war stopped (EC & WB, 1999), but the information about where wastes and debris were placed in the emergency phase was not available (KEPA, 2009). Nevertheless, there was a small scale waste storing in the military camps like the case of Bondsteel where the waste was stored in dumpsters (Martel, 2003). However, for the waste and debris storing part, it was noticed that in both cases there was no proper temporary storages and sites. Clearly, the waste was stored in any available space regardless to the environmental impacts (KEPA, 2009; UNEP, 2005).

Nevertheless, the estimated time for the recovery phase was up to five years after the conflict in Kosovo (EC & WB, 1999), but even ten years after the war the situation was not good enough (KEPA, 2009). In the case of Iraq, there was no authority to face the emergency phase after the war, also there was not any studies held to determine the problems and find solutions for them (Kharrufa, 2007). In the case of Afghanistan, the situation continued to be worse after the war (Rahimi, 2011). The lack of finances and the "know how" were the main problems facing Afghanistan after the war in addition to the country sides ignorance that resulted the spread of diseases (Amanullah & Furedy, 1994; UNEP & UNCHS, 1999). Finally, in the case of Sri Lanka, it was noticed that the authority was not working hard enough to solve the problems, and sometimes they took some decisions that made the situation even more difficult. Actually, in some areas the decisions they took left the NGOs and the volunteers to face the emergency cleaning alone (Pilapitiya, Vidanaarachchib, & Yuenb, 2006).

6 CONCLUSION

In this thesis, the aim was to explore the main stages of disaster solid waste management in order to find the most important steps that should be accomplished to bring the affected area back to its normal situation, and to prevent different the environmental impacts. From the theory and the case studies, it is clear that the key to success in facing disasters is to be prepared with a proper plan before the disaster. This plan should include responsibilities division, and clarify the general work process. In the emergency phase right after the disaster, the responsible authority has to traverse the shock stage quickly and fulfil its responsibilities. Although the solid waste is not the first priority after the catastrophe but it is important to remove the piles of debris blocking the roads for the rescuers. In many cases, the military force took a place in removing debris in the emergency phase, especially when there was not enough manpower. Also, NGOs and volunteers were supporting the process in the emergency phase and in the later phases. After the emergency phase the recovery phase will start. In this phase the debris should be already removed from the most important areas, and the removal of the rest of debris and waste will start. Also, demolishing building activities will start, which will generate more debris to remove. Nevertheless, it was noticed that the emergency phase in the case of man-made disaster was not handled like the natural disasters, and in some cases there was no presence of any solid waste management activities during the emergency phase.

Debris removal can be handled manually or by machinery depending on the situation. It was noticed in developed countries that more machinery was used for removing debris, where developing countries counted a lot on the manual removal. In addition, privet sector was able to support the waste management system in the case of disasters by providing the needed tools to the authority, and by conducting the work as contractors or subcontractors. Moreover, many people in the developing countries tend to take the usable materials from the generated debris after the disaster and reuse them for rebuilding their homes. Also, there were the waste collectors who took the recyclable materials from debris and wastes piles, or they bought them from people door to door. These practices were able to remove some burden from the solid waste management system in the developing countries.

After the removal of waste and debris from the affected areas the collected materials must be transferred to temporary storages or temporary sites where solid waste is gathered and sorted before being introduced to the normal waste management system, where they will be sent to landfills or recycled. Sorting different types of waste was partly handled before reaching temporary storages in the developed countries. Where, authorities in the developing countries did not apply waste sorting before reaching the temporary sites. In fact, in many cases there were no temporary storages especially in the case of man-made disasters. Instead, the waste was placed in any available place regardless to the environmental impacts. However, developed countries gathered all the debris and waste in the temporary storages, then classified them and sent them to the proper ending point. In fact, it was noticed that the debris resulting from destroyed and demolished buildings, and the property contained in these buildings formed the largest amount of debris after disasters. Nevertheless, there's also the debris generated depending on the unique type of the disaster, such as mud in the case of the tsunami and explosive materials in case of war. Therefore, we can see that the generated debris depends on the type of disaster hitting the area and the nature of the affected area. Furthermore, in the cases were debris was recycled, the buildings materials were crashed to be reused later, and other materials like white goods were recycled as well. Other materials were incinerated then sent to landfills, or just sent to landfills. Therefore, it was noticed that after the disasters there was more need for spaces in landfills, and sometimes there was a need to construct new landfills to meet the growing needs for waste and debris disposal. Actually, developing countries in many cases did not use proper landfilling restrictions, or they just left the wastes and debris in the temporary places where they were gathered in the beginning. That was one reason for delaying the end of the recovery phase in developing countries. The time to recover from the disaster effects relied on the work seriousness of the responsible authorities. Therefore, Developed countries tend to schedule there work process and assess their achievements. As a result, there was an estimated time for the area to return to the normal situation. On the other hand, in developing countries there was no time estimation for the recovery phase to end, and in many cases the problems remained unsolved for long time.

6.1 Research limitations

This research was conducted based on secondary data collected from the available researches, studies and reports. However, it is important to know that the data collected about Sri Lanka case study and the man-made case study were mainly from non-governmental researches. Therefore, the performance evaluation was done by a third party, and there was not enough official information available to be compared with the independent studies. Where in case Japan, most of the information was taken from governmental sources like the Ministry of Environment annual reports, and there were not enough independent studies about the case. Also in the case of Hurricane Katrina many data resources were from the responsible authority that conducted the work. As a result, the work was conducted and assessed by the same party.

6.2 Recommendation

The most important issue in facing disaster solid waste management in any country is to have a ready plan in the peaceful time. All the problems that can face the authority after the disasters like having enough space in landfills, ways of collecting debris, finding places to establish the temporary storages, and handling debris etc. should be decided before the disaster. Developing countries need to be encouraged and helped to solve their problems in the peaceful time. Also, they need to have at least a general idea about handling extreme cases to avoid randomness and improve the efficiency. Moreover, NGOs have to be prepared with the needed guidelines to support the solid waste system after the disaster. However, the plan prepared for any country should be realistic and able to overcome the specific problems of that country, as it is not enough to use the general rules and regulations used in other countries. Therefore, the planner should consider previous experiences and the country unique situation, and then prepare the plan based on this information.

Generally, people should be encouraged to recycle the materials they can use and that can be done by paying them to do that or by removing some cost from the payments they have. Waste collectors can present a good example of individuals recycling that should be encouraged, supported, and protected from the risky materials in the debris. Training is also an important factor to avoid unnecessary difficulties with the workers, volunteers, and even NGOs as there will be an urgent need for more workers with enough knowledge about the work process. Also, educating people about how to react in the case of disaster and what they should do in the emergency phase like collecting important personal belongs, helping removing the debris to open the roads for rescuers, and reusing the materials with consideration of the health and safety rules will help locals to help their selves after the disaster. Moreover, the available studies and researches gave the impression that the man-made disaster embodying the state of war was not considered as disaster situations in the sector of solid waste management. Instead, it was dealt with as a high load of work testing the ability of the existing solid waste management of handling the problem of the solid waste after the disaster. In fact, it was not mentioned in the form of post-disaster solid waste management. Therefore, the war cases should be handled by post-disaster solid waste management plans that regard the circumstances of the war and the special wastes and debris generated from it.

6.3 Future researches

This research had analyzed the main idea of disaster solid waste management in general. In this way it was possible to make a simple analysis for different countries and different disasters and conduct a comparison between different practices. However, future researches can make a deeper analysis regarding each stage and phase in different countries to provide a wider vision about the work achieved in each country after different disasters. Moreover, surveys and interviews can support the information about each case to avoid using self-assessment researches. On the other hand, they can provide better understanding of the real practices to avoid the secondary data resources that base their information about the regulations and expected practices more than the real practices.

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