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Post-Disaster C&D Waste Management: The Case of COWAM Project in Sri Lanka

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Abstract

Waste management is considered to be the weakest phase in responding to a disaster. This became apparent when Sri Lanka suffered enormously from the Indian Ocean tsunami of 2004. The City of Galle located on the south coast was severely affected by this event, causing some 4000 deaths and destroying over 15000 houses. The Construction Waste Management (COWAM) project funded by the European Union from 2005-2009 looked at the most sustainable ways of dealing with Construction & Demolition (C&D) waste after a disaster and devised a pilot C&D recycling plant (COWAM Centre) in Galle. This paper reflects on the C&D waste management practices followed by the city authorities during the recovery and reconstruction phase right up to the operation of the COWAM Centre with the intention of seeking best practices for the future. As part of the COWAM case study, semi-structured interviews were conducted with municipal authorities and voluntary organizations to identify the C&D waste management process followed during recovery and reconstruction. Empirical data was collected from actual demolition sites located in Galle to establish the quantity of C&D waste, composition, hazardous substances found, and collection efficiency. Findings revealed that waste was disposed initially into temporary dumping sites and later re-cycled through the COWAM Centre. However, this study found many issues that could have been avoided if Galle Municipal Council had planned and implemented a quick C&D waste management strategy. Key issues which arose were lack of heavy vehicles, lack of manpower, inability to forecast the amount and composition of waste, and inability to identify suitable temporary dumping sites. The characteristics of C&D waste gave a baseline for the design of COWAM Centre. The paper presents a viable approach to overcome issues pertaining to C&D waste management during the aftermath of a disaster through the lessons learned from the COWAM project.

Keywords: Disaster waste, C&D waste, recycling, recovery, reconstruction, Sri Lanka, COWAM Project

Introduction

Disasters create enormous amounts of Construction & Demolition (C&D) waste through destruction of buildings and infrastructure (EPA, 2008; FEMA, 2007). For example the Great East Japan earthquake and tsunami of 2011, Haiti earthquake of 2010, hurricane Katrina of 2005 and Indian Ocean tsunami of 2004 are events that generated large volumes of waste and overwhelmed the existing solid waste management capacities of the local authorities concerned (Basnayake et al., 2005; Luther, 2008; Brown et al., 2010; Shibata et al., 2012). Brown et al. (2011) assert that disaster debris impacts not only on the environment but also rescue and emergency services, provision of lifeline support and socio-economic recovery of the affected areas. Thus, management of wastes created by disasters has become an increasingly important issue that needs to be addressed when responding to a disaster (Thummarukudy, 2012).

Sri Lanka, an Indian Ocean island with 20 million people, experienced a waste management crisis at the aftermath of the Indian Ocean tsunami of 2004. Approximately US$ 5-6 million has been spent in managing tsunami debris in Sri Lanka (Basnayake et al, 2005; UNEP, 2005). Costs to public health and the environment due to prolonged exposure to waste could increase the above estimate significantly (Srinivas and Nakagawa, 2008). Environmentally sensitive coastal dumping sites, waste burning, insufficient landfill capacity, impact on ground water, and lack of coordination were some of the problems encountered by local authorities in the affected areas (Basnayake et al., 2005; Selvendran and Mulvey 2005; Pilapitiya et al., 2006; Srinivas and Nakagawa, 2008).

Galle, the third largest Sri Lankan city and located on the south coast was severely affected by the tsunami with some 4000 deaths and destruction of more than 15000 houses. The Construction Waste Management (COWAM) project funded by the European Union from 2005-2009 examined at the most sustainable way of dealing with the C&D waste generated during the disaster in Galle. It devised a C&D recycling plant called the 'COWAM Centre' to recycle most of these waste residues. This paper reflects on the C&D waste management practices followed by the Galle Municipal Council during the recovery and reconstruction phase right up to the operation of the COWAM Centre with the intention of seeking best practices for the future.

Post-Disaster Waste Management

Management of disaster waste is much harder than ordinary C&D waste as the former are very often mixed and contaminated (Rafee et al., 2008; Kobayashi, 1995). According to the United States' Environment Protection Agency, disaster waste comprises soil and sediments, building rubble, vegetation, personal effects, hazardous materials, mixed domestic and clinical wastes and, human and animal remains (EPA, 2008). It presents a risk to human health from biological, chemical and physical sources (EPA, 2008). The composition of waste differs from disaster to disaster. However, C&D waste is a common type found in every disaster along with automobiles, furniture, vegetative debris, mixed metals, ash and charred wood (EPA, 1995). Baycan and Patterson (2002) classified C&D wastes arising out of a disaster as: recyclable materials (concrete, masonry, wood, metal, and soil), non-recyclable materials (household inventory, organic materials, and other inert materials) and hazardous waste (asbestos, chemicals). According to Kourmpanis et al. (2008), C&D waste is considered to be a priority waste stream and appropriate actions must be taken to make its management effective.

Past disaster experiences show various methodologies have been employed in different contexts. Table 1 illustrates four such situations and the way disaster waste had been managed. It clearly illustrates that the most preferred methodology is recycling even though there are issues with mixed waste, contamination etc. Recycling is the collection and separation of materials from waste and subsequent processing to produce marketable products (Tam and Tam, 2006). Recycling prevents useful material resources being wasted, reduces the consumption of raw materials and reduces energy usage. Numerous materials can be recycled, with the most common being wood, concrete, brick, metals (Ortiz, et al., 2010). Recycling is widely assumed to be environmentally beneficial, although the collection, sorting and processing of materials into new products also entails significant environmental impacts (Klang, et al, 2003). Nonetheless, recycling supplies valuable raw materials to the reconstruction process (Rameezdeen, 2009). In order for a material to be successfully recycled, three major areas need to be taken in to account, namely, the cost-benefit of recycling, compatibility with other materials, and properties of the recycled material (Tam and Tam, 2006).

Baycan (2004) introduced a model for disaster waste management based on the experience of Marmara earthquake of Turkey in 1999. Rubble constituted a major portion of C&D waste. Accordingly, rubble was collected first and transported to temporary dump sites during the recovery period. These materials were transported to recycling plants or landfill sites later depending on the recycling potential. The methodology was criticized as double handling which resulted in high transportation costs. The key principles of this model are;

a. reduction of quantities of waste for final disposal,

b. conservation of natural resources, and

c. minimization of prolonged exposure and resulting problematic environmental impacts.

Similarly, Eerland’s (1995) waste management model of the Kobe earthquake gives a clear picture of how segregation was carried out. Initially the waste was segregated using separation plants of the capacity of 50 tonnes per hour. Screening, wind sifting, hand picking and belt separators were some of the technologies used. Finally, the separated materials were sent to recycling and reuse (Eerland, 1995).

Table 2 illustrates the waste management strategies used during recent natural disasters in Sri Lanka. As in many developing countries, the most commonly used strategy was either open dumping or land filling. Uncontrolled dumping of disaster waste can have a significant negative impact on public health and the environment.

Table 1: Disaster waste management examples

Disaster	Amount of waste	Strategies used for management	Issues encountered
Marmara Earthquake Turkey	13 million tons	▪ Recycling plant ▪ 17 dump sites	▪ Large quantities of reinforcement bars cause operational problems in the recycling plants ▪ illegal dumping at coastal areas
Kobe Earthquake Japan	15 million tons	▪ A small proportion recycled ▪ Majority ended up in land reclamation	▪ Segregation is time-consuming and costly
Beirut, Lebanon	4 million tons	▪ A stationary recycling plant	▪ Problems arising due to the unclean nature of disaster debris
Kosovo	10 million tons	▪ A mobile recycling plant ▪ Decentralized depots for collection and storage	▪ Spread of the damage over a large rural area

Source: Baycan and Petersen, 2002; Earland, 1995; Pasche and Kelly, 2005

Table 2: Disaster waste management strategies used locally

Disaster	Strategies used for management	Issues encountered
Tsunami, 2004	▪ Local authorities, volunteers and land owners removed debris ▪ Recycling plants were used in Galle and Batticaloa ▪ Incineration ▪ Land filling	▪ Lack of awareness of waste management techniques ▪ Unplanned landfill sites in environmentally sensitive areas ▪ Illegal landfill sites ▪ Lack of capacity to handle large quantities of waste ▪ Inadequate funds for waste management ▪ Lack of coordination
Floods (frequent)	▪ Open burning ▪ Open dumping ▪ Land filling	▪ Illegal dumping on roadsides, vacant land or river banks
Landslides (frequent)	▪ Recycling ▪ Open dumping ▪ Land filling	▪ Poor collection methods ▪ Lack of capacity to handle large quantities of waste

Source: Pilapitiya et al., 2006

Methodology

The aim of this study was to investigate the C&D waste management practices that followed the relief, recovery, rehabilitation and reconstruction phases of a disaster in order to learn lessons for the future. Case study method proved to be the most appropriate, as it provides access to the real-life context of disaster waste generation, collection and handling (Yin, 2003). It provides a rich data set based on experiences and explanations of the people and organizations involved. As it begins with a theoretical framework described above, it has the ability to test the existing theories or concepts. However, the major limitation of the present study is that it cannot be based on multiple cases as disaster situations are very rare. The study is based on a single disaster, the 2004 Indian Ocean tsunami. The City of Galle was selected as the case study site due to the accessibility of information and the fact that a Construction Waste Management (COWAM) project was implemented during 2005-2009. COWAM was funded through the EU-Asia Pro Eco II B – Post Tsunami Programme and was led by the TuTech Innovations GmbH of Hamburg, Germany. The project partners in Sri Lanka were the Galle Municipal Council (GMC) and the University of Moratuwa. As part of the case study, interviews and C&D data collection on actual demolition sites were carried out using a retrospective study design described below (Robson, 2011).

First, interviews were conducted among GMC officials and volunteer organizations who elicited information on the waste management strategies and the challenges they encountered during the post-disaster phase. The interviewees were the Lordship of Mayor of Galle, Deputy Mayor, 4 elected members, Municipal Commissioner, Municipal Engineer, Medical Officer, 3 technical officers belonging to the waste management division, 2 Public Health Inspectors, and one officer from each of the 5 volunteer (non-government) organizations involved in relief and recovery operations. The duration of these 19 interviews varied from 30 minutes to one hour, conducted in the Sinhalase language, and recorded with the permission of the interviewee. The sample is a reasonably good representation of the persons involved in waste management operations having both officials and volunteers. The limitation of the interviews is that the opinion of the general public could not be obtained due to the very large sample frame and the resource constraints of the study. Interviewees were asked to describe each phase of the waste management process based on a semi-structured guideline that reflected the theoretical base of the study. Any personal bias was removed through triangulation as a result of more than one representation from different groups (as an example, the politicians' version was not only that of the ruling party but also from the opposition; 3 out of the 4 elected members were from the opposition). Key themes emerging from the interviews were identified and cross-checked among different groups (politicians, officials, volunteers). Code-based content analysis technique was used to analyze the data using NVivo (Version 7) software. Coding structure was prepared focusing mainly on two themes as given in Figure 1.

Second, waste benchmarking was carried out in order to establish a baseline for design of the COWAM Centre and as a valuable database for future use. Twelve demolition projects operated by local demolition companies were selected to obtain data to develop a 'waste index' and to assess the composition of C&D waste pertaining to local conditions. This is a quasi prospective-retrospective study design to obtain data from a current situation that could be related to a similar past event (Robson, 2011). Direct observations coupled with actual data from these companies enabled a 'controlled' evaluation of the amount of waste generated in a demolition operation. Direct observation as a data collection technique has been successfully used in similar studies by various researchers (Lu et al., 2011; Gavilan and Bernold, 1994; Poon et al., 2004). A researcher was stationed during the whole demolition operation to record the number of truck loads of waste handled and the volume of each truck in order to obtain the 'waste index' of a building as follows.

$$\text{Waste Index (C)} = \frac{\text{Volume of waste generated in a building (W)}}{\text{Gross Floor area (GFA)}}$$

Where,

W = Volume per truck load (V) x Number of truck loads (N)

45 random waste samples were obtained from these demolition operations into timber boxes measuring 1 m^3 to ascertain its composition and the proportion of hazardous materials present. The quantification of waste in these samples was carried out using source evaluation methodology. The use of source evaluation for waste quantification is very popular among researchers (Lu et al., 2011; Ekanayake and Ofori, 2000; Bossink and Brouwers, 1996). A comparison of the waste collection techniques among these demolition companies was made possible due to some using 'source separation' and others 'commingled collection'. Out of the 12 projects, 8 used source separation and 4 commingled collection. Cost, revenue and profit of each demolition operation were employed to gauge the efficiency of the two methodologies. The cost and revenue of a recycling operation consisted of the following components.

Cost = Cost of demolition + Cost of separation + Cost of recycling + Cost of disposal of the residue

Revenue = Payment from client + Revenue from selling recycled products

Findings from the case study are discussed in the following section.

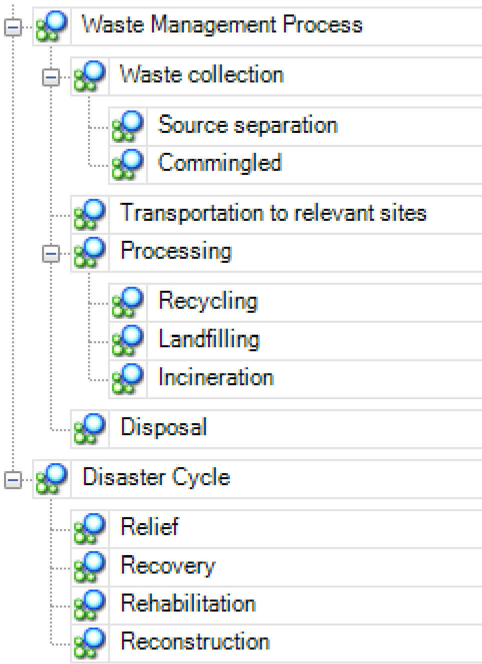

Figure 1: Coding structure used

Picture 1. Sampling Tool

Findings

Waste generation and collection

Post-disaster recovery at Galle was mainly handled by the GMC. Soon after the disaster, due to its unmanageable volume, the municipality decided to dump all waste wherever space was available. There were no records of types and amounts of waste deposited in these temporary sites. Neither was there a mechanism to forecast the amount of waste generated by the destruction. In order to overcome this issue should future disasters occur, the waste benchmarking exercise described in the methodologies section was carried out as a part of the COWAM project. According to Poon et al. (2004, p.677), a 'waste index' could be used to estimate the quantities of waste generated due to a demolition operation. Using the formula given in methodologies section, waste indices were calculated for the twelve demolition projects; 10 single storey and 2 two-storey residential buildings. Mean waste indices for these two types were found to be 0.34 m^3/m^2 and 0.73 m^3/m^2. Using these values, the volume of C&D waste generated as a result of 15000 houses being destroyed in Galle could be estimated.

Municipal workers and volunteers initially cleared the access routes by dumping waste at the curbside. Subsequently, using municipality trucks these wastes were transported to temporary dumping sites in a very ad hoc manner. The main issues encountered at this stage were: firstly, the identification of dumping sites close to Galle; and secondly, lack of trucks and workmen to collect and transport waste to these identified sites. There was also the technical issue of demolishing partially destroyed buildings as they posed a severe risk to the public. The municipality did not possess equipment to carry out such an operation. Volunteers and builders helped to clear these partially destroyed buildings. During collection, it was not sure whether ‘source separation’ or ‘commingled collection’ would be used considering a host of uncertainties surrounding a disaster event. Though some districts like Batticaloa had segregated C&D waste prior to dumping, Galle municipality dumped it without segregation. Financial data collected through the 12 case studies revealed that profits are higher in source separation compared to commingled collection as given in Table 3. However, in a disaster, it is rarely economic efficiency that becomes the deciding factor. Interviews revealed that commingled collection was the most practical strategy to use.

Table 3: Comparison of waste handling methodologies (n=12)

Type of handling	**Mean revenue per GFA (in SL Rupees)**	**Mean cost per GFA (in SL Rupees)**	**Mean profit per GFA (in SL Rupees)**
Source Separation	3132	1087	2045
Commingled Collection	1883	970	913

In order to implement a waste management strategy, it is very important to know the composition of waste being generated. Table 4 illustrates the composition based on the 45 samples of 1m^3 timber boxes used in this study. More than 50% of the waste consists of bricks, cabok (a Laterite brick) and normal clay brick. This poses some challenges to recycling which is described in the next section. It is also important to understand the proportion of hazardous waste in the total waste stream in addition to its composition and the potential impact on human and environmental health. The study found that approximately 14.2% of C&D waste could contain different hazardous materials. As this is very substantial, suitable measures have to be taken in dealing with these wastes. Table 5 gives the composition of these materials that could contain hazardous substances. Asbestos contributed about 19% of hazardous C&D waste. Time and effort was spent on removing hazardous substances at the recycling stage which dramatically reduced the financial viability of recycling operation.

Processing

Waste from the temporary dumping sites was transported to the COWAM Centre for processing during the rehabilitation and reconstruction stages of the disaster. Had the waste been separated, it would have been of much higher quality. In order to sustain the local recycling market, readily re-usable products were sent to the market directly without being taken to the COWAM centre. The study found that there is a small but thriving recycled product market in Galle. Thus, COWAM Centre received mostly the mixed waste that did not have a market value. This measure helped the local recycling market to be revived as a result of the disaster.

Hazardous substances were removed prior to separation and crushing. The COWAM Centre crushed these mix wastes to produce aggregates for use in local roads. The low quality of local roads in Galle requires high levels of maintenance, imposing high costs on the municipal budget (5.3% of annual budget). This is particularly problematic after monsoon seasons when many potholes must be repaired. Apart from the associated labour and monetary costs, regular road maintenance also causes traffic jams. Road construction and maintenance also uses a significant share of natural material resources that can be partially replaced by recycled C&D products. The aim of this measure is to simultaneously reduce the environmental impact of road construction and maintenance while improving road and maintenance quality, reducing maintenance requirements and municipal costs. The residue needs to be sent to permanent landfills after recycling was estimated to be only 4-7% of the waste bought to the COWAM Centre.

Table 4: Composition of C&D waste in Galle (n=45)

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

Table 5: C&D waste that could contain hazardous substances (n=45)

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

Capacity constraints of GMC

The case study revealed a few issues with regard to capacity constraints of the GMC which prevented an effective waste management during the post-disaster stage. These observations could be generalized across other local authorities as some of them are due to lack of a national strategy and a framework for C&D waste management in Sri Lanka. These constraints are:

- Lack of a framework or statutory guidelines that could be enforced during a disaster,
- Lack of technical knowhow on C&D waste management,
- Lack of funds, resources, and equipment, and
- Coordination issues.

An in-depth review of the national disaster management policy shows that there is no provision, model, or a framework for disaster waste management (Disaster Management Act No. 13 of 2005). Solid waste is handled by the National Environmental Act of 1981 and C&D waste is considered 'inert'. Its management is not given a high priority compared to the municipal solid waste (Rameezdeen, 2009). The organizational structure of the GMC is arranged in such a way and the priority of top management is placed solely in dealing with the day to day municipal waste. Technical training programs, both foreign and local, which are used to train and maintain an effective labor force, were not sought in the area of C&D waste management. The Technical Officers and the Public Health Inspectors were not interested in C&D waste; they do not envisage a career in C&D waste management; and as a result do not feel training is required in that area. Lack of funds, resources and equipment have prevented GMC in going beyond the basic obligations of the municipal council. Even the municipal waste is collected with great difficulty and the interviewees see no reason why they should go beyond their mandate. Coordination issues were highlighted as a major constraint particularly during disasters. While many NGOs had the manpower and were willing to become involved in tsunami waste disposal, GMC never approached them.

Discussion

Even though a national level agency was established after the tsunami disaster as the peak body for disaster management in Sri Lanka, it is the local authority that has to attend to most of the initial relief and recovery operations. Thus, the capacity of the local authority to deal with disaster waste becomes crucial. Therefore, this study particularly concentrated on local authority level waste management process that followed the tsunami disaster of 2004. The case study on Galle Municipal Council (GMC) found several issues pertaining to the capacity of dealing with C&D waste. The main concern was the neglect of C&D waste in the day-to-day operations of the GMC; lack of interest, knowhow, funds, resources and equipment to deal with it; and serious coordination problems during a disaster.

This case study demonstrated the use of waste benchmarking for planning. The 'waste index' could become a very useful tool in rapid need assessments undertaken immediately after a disaster. According to the International Federation of Red Cross Societies, rapid need assessments are undertaken typically within the first week of a disaster to establish the immediate survival needs of the affected people, which includes waste disposal among a host of other needs such as food, shelter, medical care, safe drinking water, and psychosocial support. If national level disaster organizations such as Disaster Management Centre can provide standard 'waste indices' in their guidelines for different types of buildings and infrastructure, local authorities can easily estimate the amount of C&D waste generated during a disaster. Composition of C&D waste and the extent of hazardous substances present are useful information for planning. As more than 50% of C&D waste emanated from bricks, source separation became very difficult and the recycled output of mix waste was of low quality.

Based on the case study, a process model is suggested for disaster C&D waste management as given in Figure 2. Accordingly, waste collection needs to be handled in two stages; first, a preliminary curb-side collection in order for emergency operations to resume, and second, a planned operation of either source separation or commingled collection. FEMA (2007) supports this observation and recommends the creation of on-site temporary collection centres. Galle's experience shows that source separation, though ideal, is very difficult to organize and handle. In disaster situations, source separation was found to be inefficient and impractical as clean-up and recovery is the priorities rather than recycling (Peterson, 2004). If waste can be source separated, it could then be deposited in temporary mono landfills until the local authority is ready for processing. Commingled collection will lead to mixed waste and the subsequent plant based separation will be costly. The COWAM project increasingly sought the collaboration of local recycling companies to benefit from the operation and therefore only handled mixed waste that was not considered valuable. These mixed wastes were crushed to form aggregates for use in local roads.

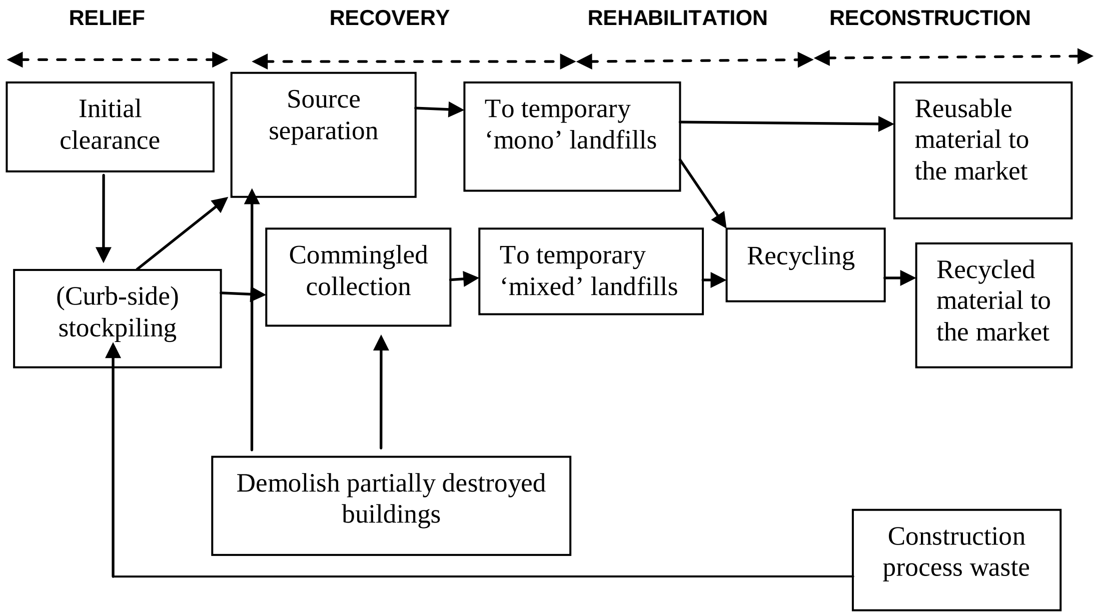

Figure 2: Proposed C&D waste management model

Conclusions

The COWAM case study provides some lessons for future disaster C&D waste management at the local authority level. The main issues encountered were the lack of capacity to handle an enormous quantity of waste, difficulty in estimating the quantity and composition of waste, difficulty in identifying temporary dumping sites and coordination among different parties involved. In order to overcome these issues, waste benchmarking and publication of those results was suggested. Collection and processing of waste should be done in two stages, with temporary landfills serving as an intermediate solution. Source separation coupled with mono-landfills will provide a high quality output when the final recycling is carried out.

However, limited resources may force a local authority to carry out commingled collection with mixed landfills. Encouraging the participation of local recycling companies will boost the local recycling market. A process model encompassing the above stages summarized the major findings.

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