The Government of the People’s Republic of Bangladesh

National Debris Management Guidelines

Ministry of Disaster Management and Relief

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1 **Objective of the National Debris Management Guidelines**

These National Debris Management Guidelines (Guidelines) have been prepared for the Government of Bangladesh (GoB) to be adopted nationally with the aim of strengthening the capacity of the Bangladesh disaster management system in improving debris response and recovery management at all levels.

The development of the Guidelines has been supported by the Department of Disaster Management (DDM) which will provide the key national and local Governmental departments with clear, pragmatic guidance on how to handle large volumes of debris following disasters. The Guidelines are applicable throughout the geographical areas of Bangladesh.

The Guidelines detail an approach from the initial assessments of debris arisings through design of debris management programmes to actual implementation and end use of the debris recycled materials. There is a strong focus within the Guidelines to mobilise communities and provide sustainable livelihoods through the debris management works.

At the City level, Debris Management Plans (DMP) have been developed for the cities of Dhaka, Chittagong and Sylhet. These DMPs identify potential quantities of debris per Ward of the respective City, potential hazards and constraints affecting the management of the debris, possible debris processing sites and City specific proposed preparedness actions.

These National Debris Guidelines have been prepared by the UNDP Early Recovery Facility through integrated collaboration and full cooperation of the Department of Disaster Management without who’s support the Guidelines would not have been possible.
2 Introduction

A natural disaster in Bangladesh will create varying quantities and types of waste and debris, dependent on the disaster type, intensity, location of impact, resilience and preparedness of the affected community as well as the building types in the affected community.

Where the handling and management of the quantity, type and location of disaster resulting debris overrides the ability of the local, regional and national capacity to deal with the debris, supportive debris management guidelines and procedures are required. **The purpose of these National Debris Management Guidelines: to provide guidance and proposed procedures on how to handle and manage debris which is beyond the capacity of the affected community.**

Successful handling and management of debris requires safe removal and transportation of debris to allocated spaces for storage and processing of the debris into recyclables. Measures are required to ensure that workers are protected whilst handing debris, the property rights of building owners are respected and that the social capital (community based skills, programmes and networks) that has been developed through disaster risk reduction measures are enacted.

Ensuring timely and effective removal of debris allows for more effective relief operations to access damaged areas. In addition, optimal reuse and recycling of the debris provides livelihood opportunities as well as cost savings for the ensuing reconstruction works since the use of recycled debris is often cheaper than natural raw materials from quarries.

These Guidelines have been developed as part of a UNDP Early Recovery Facility project implemented by UNDP Bangladesh with full collaboration and support of the DDM. The DDM manages a Bangladesh Incident Management System (BIMS) where these Debris Guidelines will supplement this initiative to facilitate robust national debris management in the event of a disaster.

*Photo 1: Typical Bangladesh debris from damaged urban buildings demonstrating the challenges with clearing, sorting and ultimately recycling debris.*
3 Bangladesh Institutional Framework

3.1 Institutional Mechanism of Disaster Management Scenarios of Bangladesh

For Bangladesh, the Government of the People’s Republic of Bangladesh has developed and implemented a disaster management approach focussed on the following three key documents determining the process for post-disaster management, wherein debris management is included:

a. *Disaster Management Act of 2012*;

b. *Standing Orders on Disaster*, as issued by the Ministry of Food and Disaster Management, Disaster Management & Relief Division and Disaster Management Bureau (dated 06 April 2010); and,


Within these three documents, Disaster Management for Bangladesh are centred around 4 situations:

- Normal time;
- Alert and Early Warning time;
- Emergency Response; and,
- Recovery Stage.

Within these situations, Debris Management is currently not explicitly addressed, however the Bangladesh Incident Management Systems (BIMS) has drafted an organogram to address emergency debris issues for saving lives in post-disaster events. Given the draft nature of this BIMS initiative, debris management actors are yet to be finalised over the coming period.

In addition, various city level contingency plans and national earthquake preparedness plans have been developed, which have provided input to the City Debris Action Plans.

3.2 Disaster Response Mechanism of Bangladesh and linkage to Debris Management issues

Key Disaster Management actors are mainly detailed in the Standing Orders on Disasters (SOD) and the Disaster Management Act. In the event of a high magnitude disaster, the Government can use statutory powers to nominate the relevant departments and organisations for deployment within the disaster management response.

Disaster Response coordination is allocated to the Disaster Management Committees at both National and Local level, which mainly deal with the emergency response during disaster. The National Response Coordination Group
(NDRCG) and the Local Disaster Coordination Response Group (LDRCG) are responsible for managing the response approach with the application of the incident Command System (ICS) at both the National and Local level. NDRCG is also responsible for maintaining the ICS.

These Debris Management Guidelines are envisaged to come under the preview of the NDRCG. In addition, the Bangladesh Disaster Response Coordination Framework is envisaged to be the most applicable regulatory framework for response coordination including debris management.

Diagram 1: Statutory Disaster Emergency Response Coordination Mechanism of Bangladesh

Note that the NDRCG (National Disaster Response Coordination Group) is the main central government focal point for disaster response and will be responsible for the overall debris management coordination in the event of a disaster in Bangladesh

A narrative overview of the above Statutory Disaster Emergency Response Coordination Mechanism as follows:

- **Field 1:** This is the Central Government Ministerial level under the direction of the Prime Minister’s office for coordination and planning at a national level for the whole of Bangladesh;
- **Field 2:** This is the City Corporation level to include for debris management and implementation activities based on support from the NDRCG and
under the direction of the City management with support as required from the Deputy Commissioner and others;

Field 3: Should the disaster be of national extent or of significant magnitude, the NDRCG can request the central Government to support and direct the various governmental departments and organisations, including especially the Armed Forces, to provide planning and implementation support as required;

Field 4: For City and District specific disasters (that are not nationally impacting), the Deputy Commissioner can be requested by the City authorities to support and direct the various governmental departments and organisations, including especially the Armed Forces, to provide planning and implementation support as required;

Field 5: Where required and requested by either the NDRCG or City authorities, the Deputy Commissioner can direct the Law & Order Enforcement agencies to respond and support the disaster response; and,

Field 6: Enacting the various sections of the Disaster Management Act 2012, the Government can direct and engage with a range of supporting organisations such as NGOs, UN agencies, private sector, International NGOs etc to support the disaster response.

3.3 Regulatory Framework for Debris

To ensure and facilitate that the debris works are regulatory compliant to the national and regional laws and legislations, a review of the regulatory framework concerning debris and its management is required. Thus the collation of applicable regulations that govern debris is required, which can include Waste Management Legislations, EIA legislations as well as land property rights as regards ownership of the debris from damaged buildings. These are to be collated and included in the City Disaster Management Plans.

For Bangladesh, this assessment is also to include the Standing Orders on Disasters, Disaster Management Plans and related legal disaster preparedness planning procedures. More on this is included in below section 6 for Actors in Debris Management.

From the planning of the debris management, answers to the following issues are required and integrated into the ensuing debris management plan(s):

a. Who owns the debris?

b. When do they own the debris?

c. Who has the liability for the debris removal and treatment?

d. Are there any disaster exemptions governing debris ownership and management?
4 Debris Objectives and Early Recovery

4.1 What is Debris

These National Guidelines address the ‘Debris’ that arises i.e. damaged buildings, building materials, furnishings etc., and not the ‘waste’ that arises from the daily lives of households, markets, offices, industrial and commercial premises and public sector offices.

Typical debris in Bangladesh from damaged buildings and infrastructure comprises concrete, masonry bricks, building stones, tiles, reinforcement bars, corrugated iron sheets, timber, doors and window frames, pipes and tanks, electrical wires and cables, glass as well as furniture and fixtures.

In addition, and taking into account that 32% of the Bangladesh landmass is within a coastal zone wherein 28% of the population live, then there will also be a high proportion of vegetation following certain disasters such as cyclones. This vegetation debris typically comprises fallen trees, garden waste, soils and earth as well as agricultural crops.

It is acknowledged that a high proportion of disaster debris is reusable and recyclable where local reuse of building materials by building owners is common following a disaster and should be supported. Recycling and composting of the debris requires more mechanical processes and thus additional organisation and management is required to enable this.

Caution also needs to be taken with the handling of debris since it can pose a health risk to debris workers and general public if it is mixed with hazardous wastes such as asbestos, oils and chemicals.

Note that these guidelines do not cover the demolition of buildings damaged by the disaster event but rather the Guidelines focus on the handling and management of the debris from collapsed buildings.

4.2 Debris Management and Early Recovery

There are numerous ways in which effective debris management can support Early Recovery approaches since the removal of debris is a precursor to recovery activities being implemented – a damaged building will need to be removed before reconstruction can commence.

Livelihoods, both temporary and sustainable, are a strong objective with Early Recovery measures and the handling, management, reuse and recycling of debris provides numerous opportunities to support livelihoods. Examples include cash-for-work debris removal as a temporary livelihood opportunity as well as reusing timber from debris to make furniture as support towards a more sustainable livelihood. In Bangladesh, Cash-for-Work programmes are to be compliant with the Ministry of Disaster Management and Relief (MoDMR) rules for selection and implementation of such projects with a focus on marginalised people.
Since the quantities of debris arising from disasters can be significant, debris programmes often last several years wherein longer term sustainable livelihoods can be realised, i.e. establishment of small scale debris crushing and screening teams which can subsequently serve the construction industry with building waste recycling services.

One of the biggest costs in debris management is transportation of the debris from source to its disposal or treatment site. By locating debris reuse and recycling centres close to the debris source, transport costs can be significantly reduced which in turn reduces the overall cost of recovery. In addition, the cost of raw materials following disasters often increases significantly as reconstruction demands on the local quarries outstrips their supply. By use of recycled debris (often cheaper than quarry materials when transport taken into account) cost savings are also realised in the reconstruction phase. Thus effective debris management can support key Early Recovery focusses for the post-disaster phase.

4.3 **Key Objectives with Debris Management in Disaster Response**

The key success criteria for effective debris management in a disaster response situation, as aligned with the two main phases identified in the BIMS, include:

*For the Immediate/Response Phase (0 – 72hrs):*

- Immediate removal of debris from streets and access points which hinder the approach of Search and Rescue (SAR) teams as well as routes for the emergency vehicles;
- Removal of debris from critical and essential facilities such as hospitals, fire stations, police stations and key government departments to enable their access and egress to carry out their immediate duties;
- Removal of debris which may pose a public health threat if containing hazardous materials and substances, for example heavily contaminated debris from industrial oils or fuels; and,
- Removal of damaged building and structural elements (i.e. unstable walls) and debris piles which pose an immediate threat to SAR teams, emergency response units as well as the public.
For the Removal Phase (Short Term) (0 – 6 months)

- Facilitate improved access to damaged homes and buildings by clearing debris thus enabling the return of residents and business owners;
- Maximise local employment within the debris management works through Cash-for-Work projects and debris recycling activities;
- Respecting the rights of building owners to both recover articles of personal value as well as determine whether they want for their debris to be removed;
- Value recovery through recycling the debris for use as construction materials in the local rehabilitation and reconstruction works;
- Reduce the burden on raw materials (i.e. quarries) by substituting raw construction materials with recycled debris;
- Reduce the quantity of debris being disposed of at often already overburdened dumpsites and landfills, thus extending the life time of disposal facilities in the region; and,
- Ensure that the debris recycling works are based on a sound consultative and participatory mechanism for the local stakeholders.

All of these objectives are both achievable and have been realised in past debris management programmes following natural disasters.
5 Typical Types of Debris

Debris from disasters has numerous similarities the world over with the main fractions constituting typically of concrete, bricks, timber, vegetation and soils regardless of location. The main variations lie in the composition of these fractions within the overall debris quantity, i.e. how much percentage wise of each material, as well as the additional materials within the debris. Furthermore, the debris may contain materials and substances hazardous to humans as well as the environment.

5.1 Typical Debris composition

The composition and location of debris from a disaster will vary depending on the nature of the disaster¹.

Photo 2: Typical urban debris with a high proportion of reinforced concrete and bricks.

Photo 3: Post cyclone debris will most often have the debris spread out over an area of impact. Source: Concern Worldwide.

The type and composition of the debris arising will depend on numerous factors such as type of disaster, location in Bangladesh, whether urban or rural, as well as typical construction materials used in the disaster affected location. Disaster specific debris is detailed in below section 5.2.

For all types of debris though, there will be a proportion of the following composition to varying ratios:

- **Concrete**, both as cast concrete, reinforced concrete as well as concrete blocks and elements;
- **Bricks** largely as masonry bricks from buildings as well as roofing tiles of same materials;
- **Rocks/Stones** typically as rough cut stones used in the walls of buildings;
- **Vegetation** from damaged and uprooted trees, agricultural crops, bushes and other green waste;
- **Wood** from structural timbers as well as internal paneling and furnishings, hereunder also straw from roofing;
- **Asphalt** from hardstanding areas within the plot of the building or structure as well as roads;
- **Soils, mud and sands** from landslides, soil erosions and movements as well as excavations in connection with the clean-up and demolition works. Included in this category are also building materials such as mudbricks and adobe;
- **Plaster** from coating of the walls and often mainly of gypsum;
- **Metals** such as reinforcement bars, structural steel and metallic structures such as tanks and industrial plant;
- **White goods** such as fridges, freezers, cooking ovens etc.
- **Electronic wastes** such as TVs, stereos, computers;
- **Furnishings**, internal general wastes which includes paper, cardboard plastics, glass etc;
- **Personal belongings** from homes, offices and industrial sites;
- **Cars, boats and other mobile items** where disasters such as flooding can move these items and deposit nearby on top of structures etc.;
- **Industrial wastes** such as fuel, chemicals, solvents and other hazardous materials, substances and wastes from damaged industrial and commercial plant; and,
- **Human and animal corpses**.

The actual composition of the debris with the above materials is very much dependent on the location of the debris arising, for example urban areas will have more structural concrete from buildings of 2 or more floors whereas rural areas will have more bricks and timber within the debris. Also, the specific location of the debris within a disaster area will dictate the composition of the debris with industrial and commercial zones of an urban area generating more metals and potentially hazardous wastes as compared to residential areas.
5.1.1 Hazardous materials

Within the typical materials listed above for debris content, there is likely to be materials and substances that are hazardous to humans as well as the surrounding environment.

Types of Hazardous Materials

The following types of hazardous materials would be expected in Bangladesh within the debris:

- *Paints, adhesives and other chemicals* typically found in homes (often under the sink) and used for cleaning or domestic refurbishments;

- *Clinical and health care wastes* where healthcare centres, hospitals and clinics might have been included in those buildings damaged; and,

- *Heavy metals* within the building fabric and structural components, i.e. lead in piping and paints as well as mercury in thermostats etc.

Asbestos is not a common material used in Bangladesh except potentially in areas near ship breaking works (i.e. in Chittagong) where the asbestos has been stripped from ships and used locally in buildings. Where asbestos is a potential threat it will often be found in cement roofing sheets, insulation lagging for water and heating systems, as well as numerous other uses where the heat resistant material proved useful.

Within industrial zones there will be a higher occurrence of heavy metals within the building fabric and structural components, i.e. lead in piping and paints as well as mercury in thermostats etc. Furthermore, in commercial and industrial areas there may be a higher occurrence of contaminated soil within the plot of land where the contamination can be from oils leaking out of damaged tanks and pipes or from underground tanks. In addition, hazardous materials can be brought to the location by the disaster event, i.e. flood waters containing oils from nearby damaged industrial facilities.

Occurrence of Hazardous Materials

It is important to note that just a small quantity of these types of hazardous materials and substances can contaminate the whole debris quantities and in order to recycle and reuse the debris, these would typically need to be removed before processing and cleaning.

Furthermore, after the disaster event, there is a risk of hazardous materials (such as Hospital Waste) being tipped onto debris piles thus contaminating the debris.

With each hazardous material having its own risk characteristics, each of these materials requires special attention in order to mitigate against possible harm and damage. Thus, the attention paid to these materials will vary according to resources available, time, local knowledge and skills and finances. For example, asbestos is considered a “must” to remove since the risk to human health is significant from even just a small exposure risk. On the other hand, small quantities
of paints and oils can be accepted within the debris stream if the final disposal of the debris is at an environmentally sound engineered site and the handling of the debris is not manual.

5.1.2 Recyclability of Debris

An important factor when deciding upon how to deal with the debris is whether it is viable to recycle the debris or it should be disposed of without sorting. Where the debris is readily sorted and the debris removal works allow for manual and mechanical sorting, then it may be viable to recycle (crushing, screen or shred) the debris into a recycled material.

A key component in this decision is the "cleanliness" of the debris, i.e. how much contamination is present from both non-recyclable and non-reusable waste materials as well as hazardous materials.

A high proportion of such contamination limits the options available for the debris, since pre-sorting of these contaminants from the debris would be required before any reuse or recycling can be effected. This pre-sorting is both time consuming as well as potentially costly, which is to be compared with the benefits gained from the pre-sorting.

It should be noted that pre-sorting can have other benefits than solely to separate out the recyclable and reusable debris materials, namely that pre-sorting can be manually intensive and thus provide a good opportunity for employment as well as reduce the quantities of debris which require disposal at dumpsites or landfills (which in themselves are expensive and thus should be preserved for more difficult wastes such as industrial and household wastes).

Examples of both clean and mixed wastes are illustrated in the following photos.

*Photo 4: Clean debris ready for recycling from damaged buildings in Lebanon. Source DWR.*
5.2 Debris by Disaster Type

Appreciating that different types of disasters generate different compositions and locations of debris, this sub-section presents the typical debris types per disaster type to which Bangladesh is vulnerable.

5.2.1 Flood Debris

The risk of flood in Bangladesh is high as evidenced in past many years of flooding from riverbank overflow. Flooding is a key disaster risk for Bangladesh with 80% of the landmass being at risk from flooding and nearly 80 million people vulnerable to flooding. The below map provides an overview of the flood risk in Bangladesh.
Map 1. Flood risk for Bangladesh including normal and flash floods.

Building damage from floods depends largely on the building construction materials and length of time during which the building was flood affected.

The structural integrity of a building can often be salvaged if allowed to dry out following short periods of flood, however the building contents (i.e. furnishings, carpets, inventory, personal belongings and household goods such as fridges and washing machines, are normally damaged extensively. Thus after floods it is typical for the homeowners to clear out their homes and place the damaged items on the street for collection. Attention should be taken with this waste since it can be mixed with hazardous materials such as household cleaning products and electronic goods.

Within the building fabric, mould may be present and timber may have begun to rot. Should a building be considered damaged beyond repair, then the demolition of the building can be carried out with due sorting of the demolition waste into recyclables and non-recyclables.

Where cars and other large mobile items, such as boats, are present, these will often be moved by the waters and deposited nearby, sometimes on top of buildings and fencings. The subsequent handling of this type of debris requires heavy plant to move what can be more than 1 tonne of material.
Flooding may also bring mud, clay and gravel into affected areas, making access difficult once the floodwater recedes. Removal of this materials may be required for relief and recovery operations, where the mud, clay and gravel may be mixed with hazardous materials, requiring further assessment before dumping.

The more hilly parts of Bangladesh are prone flash flooding which affects communities with a higher velocity of flood waters than river flooding. These higher velocities of water can lead to more direct structural damage and thus also more building debris being included in the overall disaster debris. In addition, flash flooding contains more vegetative debris as well as sands and mud from soil erosion during the flood.

5.2.2 Cyclone Debris

Coastal parts of Bangladesh are at high risk of cyclones as presented in the below map with resulting storm surges creating large quantities of debris.

Map 2. Cyclone risk for Bangladesh.

Cyclones often tear the roof off buildings, whereafter the structural integrity of the remaining building can lead to the collapse of walls. Where the buildings are poorly constructed, houses and huts can ‘fold’ under roof tops, encapsulating the debris of the building.
Photo 6: Post Bangladesh Cyclone 1991 damage showing collapse of buildings and issues of mixed debris needing sorting before reuse/recycling. Source: AP Images.

Typically, debris will be spread out over open land, streets, and marketplaces, where this includes roofing materials, small household items and dust carried by the wind. This may cause serious problems where asbestos is present since the asbestos can become spread out within the debris making safe decontamination difficult.

Ships and boats are often thrown ashore and destroyed, requiring specialized waste management as well as heavy plant to move these items. This was very much the case in 2007 when Cyclone Sidr hit Bangladesh with significant quantities of debris resulting. Vessels that sink in harbours need also to be removed.
Electrical and telephone grids and poles will often be severely damaged as well as sub-stations and transformers potentially containing oil and PCBs, both of which are hazardous to humans and the environment.

One key impact from Cyclones (as well as below Tornados) is the felling of trees and electrical poles across roads thus hindering access for the emergency services, where the use of chainsaws and lifting equipment is important for immediate use.

5.2.3 **Tornado Debris**

Tornados are becoming increasingly relevant in Bangladesh with coastal areas similar to cyclones being affected. The debris is also similar to Cyclones albeit more local on impact and with less storm surges leading to less boats and light craft being included in the debris.

The debris from Tornados is spread over a large area as the debris cloud passes through and across the impacted land.
5.2.4 *Earthquake Debris*

For Bangladesh, a major natural disaster risk is Earthquake where Bangladesh is located on three different fault lines as below map illustrates.

![Earthquake Zones Map](image)

*Map 3. Earthquake risk for Bangladesh.*

Following an earthquake, buildings and infrastructure can collapse ‘in-situ’, i.e. floor slabs collapse on top of each other, trapping debris within damaged buildings and structures. This can lead to challenges in removing heavy slabs, dealing with reinforced concrete and sorting out hazardous waste (e.g. asbestos) from non-hazardous debris. Since the effects of an earthquake are widespread, large areas of industrial zones can also be impacted which can lead to significant potential...
negative impacts on human health and the surrounding environment. Examples of this in Bangladesh are the industrial zones of Dhaka and Chittagong where large oil and fuel containers, chemical storage and industrial plants are present and prone to damage.

In addition, collapsed buildings may overlap across streets, making access difficult for the search and rescue as well as the ensuing relief and recovery operations.

Handling debris following earthquakes often requires heavy machinery, which communities may not be able to afford or have difficulty to access.

Quantities of debris can often be higher than from other natural disasters since all building contents are typically rendered as debris since they become damaged by collapsed structures and mixed with the general waste.

5.2.5 Tsunami Debris

Being a low lying coastal country, Bangladesh is potentially at significant risk to tsunamis, especially as the Bangladesh coast is very near to the Burma, Andaman and Sunda Trenches.

Debris from tsunamis are often spread over large areas with a large proportion of the debris being taken back out to sea by the returning tsunami waters. With the impact of a tsunami on structural buildings and infrastructure being significant, the types and content of debris is all construction waste as well as vegetative waste, being mixed to a high degree.

5.2.6 Landslide Debris

In areas where landslides have occurred and buildings directly impacted, i.e. engulfed by the landslide, the options for debris removal are limited. This is due to the often huge volumes of material forming part of the landslide requiring significant heavy plant and machinery to excavate.

In addition, in areas of landslides, many slopes remain unstable and subsequent heavy rains can increase the risk of further landslides.

5.3 Typical Debris quantities

The quantities of debris from a natural disaster is dependent on numerous factors such as the scale of the actual event, whether the event occurred in an urban, peri-urban or rural area, the vulnerability of the built environment and communities to the effects of a disaster or conflict and the composition of the typical buildings and structures.

Quantities can therefore vary from several hundred thousands of tonnes to millions of tonnes of debris. It can thus be appreciated that the quantities of debris from disasters and conflicts can be significantly large and require considerable programmes to deal with these quantities.
The time and resources required to handle, recycle and transport the debris from large scale events such as Earthquakes should not be underestimated, often requiring several years and numerous crushers, shredders and other heavy plant.

With specific reference to the main disaster vulnerable cities in Bangladesh, the below data has been derived by the Comprehensive Disaster Management Programme (CDMP) office in Dhaka using the US Government’s HAZUS modelling tool for Sylhet and Chittagong in the event of an earthquake. These debris quantity estimates provide an indication of the possible quantities arising from various earthquake scenarios and are used at the City level to develop the Disaster Management Plans.

<table>
<thead>
<tr>
<th>Case</th>
<th>$M_w$</th>
<th>Depth to Top of Fault (km)</th>
<th>Dip Angle</th>
<th>Debris Estimate [t]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.5</td>
<td>17.5</td>
<td>30°</td>
<td>17,160,000</td>
<td>Plate Boundary Fault -1</td>
</tr>
<tr>
<td>2</td>
<td>8.0</td>
<td>3</td>
<td>20°</td>
<td>3,177,000</td>
<td>Plate Boundary Fault -2</td>
</tr>
<tr>
<td>3</td>
<td>6.0</td>
<td>6</td>
<td>90°</td>
<td>8,536,000</td>
<td>Mw6.0 beneath city</td>
</tr>
<tr>
<td>4</td>
<td>6.0</td>
<td>22</td>
<td>45°</td>
<td>5,095,000</td>
<td>Mw6.0 beneath city</td>
</tr>
</tbody>
</table>

Table 1. Earthquake Scenario Parameters for Chittagong City Corporation Area

<table>
<thead>
<tr>
<th>Case</th>
<th>$M_w$</th>
<th>Depth to Top of Fault (km)</th>
<th>Dip Angle</th>
<th>Debris Estimate [t]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.0</td>
<td>3</td>
<td>60°</td>
<td>2,767,000</td>
<td>Dauki Fault</td>
</tr>
<tr>
<td>2</td>
<td>8.3</td>
<td>3</td>
<td>30°</td>
<td>422,000</td>
<td>Plate Boundary Fault -3</td>
</tr>
<tr>
<td>3</td>
<td>6.0</td>
<td>7</td>
<td>90°</td>
<td>1,711,000</td>
<td>Mw6.0 beneath city</td>
</tr>
<tr>
<td>4</td>
<td>8.0</td>
<td>3</td>
<td>60°</td>
<td>3,576,000</td>
<td>Dauki Fault</td>
</tr>
<tr>
<td>5</td>
<td>8.5</td>
<td>3</td>
<td>60°</td>
<td>5,257,000</td>
<td>Dauki Fault</td>
</tr>
</tbody>
</table>

Table 2. Earthquake Scenario Parameters for Sylhet City Corporation Area

As a comparison of the above then following the 2010 Haiti Earthquake, debris management in Port-au-Prince was estimated to require more than 4 years to remove and dispose/recycle the debris in a responsible manner. This included for significant funds to be spent on moving the approximately 10 million m$^3$ of debris resulting from the earthquake.
6 Debris Assessment

The first step to planning and implementing debris management works is to carry out an assessment of the debris resulting from the natural disaster. The more robust and reflective of the debris situation on the ground the assessment is, the better a plan can be developed for the handling, transport, reuse, recycling and disposal of the debris.

However, caution should also be taken to not spend too many resources and too much time on trying to gain exact details as to the quantities of debris since a variance on +/- 100,000m$^3$ of debris is not going to make a significant difference on a debris plan for several million m$^3$ of debris.

Note should also be taken throughout the assessment process of the regulatory framework within which the assessment is being carried out. Such aspects as legal definitions of waste and debris, debris ownership and debris removal authorisations are to be adhered to, as well as reporting to the correct Bangladesh Governmental department responsible for the debris management in a post-disaster situation. Please refer to section 3 of these Guidelines.

An overview of the main steps in carrying out a debris assessment are included in the below flowchart.

![Diagram 2: Debris Assessment and Action Planning flowchart](image)
6.1 **Urban Debris**

Where a disaster has impacted an urban city of Bangladesh, the quantities of debris across the city can be significant and seem difficult to measure. It is therefore often required to zone the disaster affected area to enable effective logistics, division of tasks and support management.

For cities and urban areas of Bangladesh, these zones can be Ward boundaries, especially since each Ward has its own administration and disaster preparedness exercises and training occur at the Ward level with urban volunteers and civil society organisations.

Furthermore, each Ward may also have different building types and construction materials depending on the demographics of the city, where zoning enables for different debris reuse and recycling opportunities dependent on the Ward specific construction materials.

For logistics, once the debris in a Ward has been assessed, it will enable logistical planning including the selection of laydown areas for debris processing where several Wards could share a debris depot if centrally located.

6.2 **Rural Debris**

Debris arising from natural disasters in rural areas is often handled in a different manner to urban debris since logistics are different. Where villages and rural lands are impacted and debris arises from damaged houses and vegetation, local solutions are often provided with the reuse of salvageable items and dumping locally of the remaining wastes. This contrasts to the urban approach where the larger quantities in more local areas can lead to increased collection and reuse/recycling through systemised works.

A key challenge to rural debris arisings is the dissemination of information relating to debris handling, risks from debris and safe demolition where it is difficult for the local government agencies to cover the large rural areas. Thus past experiences, i.e. Nepal April 2015 Earthquakes, have seen local debris and demolition information centres established which disseminate best practice in safe debris handling and demolition works. Such guidance is also included in the City Disaster Management Plans for dissemination to the rural areas associated with the individual cities.

6.3 **Debris Assessment**

Based on the selected zones for the urban area affected by the disaster, the location, type and quantity of debris can be assessed in the post-disaster phase as follows:
6.3.1 **Debris Location**

The location of the debris following the natural disaster is to be recorded with indication of whether the debris is hindering access or close to public and environmental receptors that could be at risk from the debris should it be contaminated.

The source of the debris is also to be determined since this can give indication of type, recyclability and content of debris.

6.3.2 **Debris quantities**

Debris quantities at each location is to be estimated with indication of whether additional debris is arriving and from which source.

For the estimation of debris quantities, a volume based approach is most applicable whereby the approximate volume of a debris stockpile in the street or on a plot can be estimated. A ration of between 1.2 to 1.6 tonnes/m$^3$ of debris can be used to convert into tonnes, depending on type of building from which the debris came.

Where damaged buildings are still standing, a general ratio of between 0.5t to 1t per floor square meter can be applied depending on the type and purpose of the building.

6.3.3 **Debris composition**

The debris composition is to be assessed which will give an indication of which debris management and recycling options exist for that debris. Debris composition has three levels as follows:

1. Are there any potentially hazardous materials within the debris (see above sub-section 5.1.1. Hazardous Materials) and if so, the debris may need sampling to confirm presence (i.e. for asbestos) or disposal at the allocated disposal site;
2. If the debris relatively clean of non-recyclables and thus could be brought to a debris depot for sorting and subsequent recycling. Non-recyclables in this case include plastics, paper and household waste (often dumped onto the debris piles) which can be difficult to extract prior to recycling; and,
3. If the debris contains too much non-recyclables then it may be optimal to transport directly to a landfill for disposal.

Within the Debris Management Plan there will be allocated routes for each of the above debris compositions.
6.4 Debris Mapping

Once all the relevant debris data has been collated, and to provide a planning tool for managing the debris, it is advantageous to develop a debris map identifying:

- Location of the debris sources/piles with indication of quantity, type and quality;
- Location of landfills to which the debris can be taken if not recycled;
- Location of actual (or potential) debris processing sites to which the debris can be taken for sorting and processing; and,
- Location of main (re)construction sites which can use the recycled debris once processed.

Using the map, it is then possible to determine the optimal logistics routes for the specific debris sources/piles taking into account that transportation of the debris is a major cost and burden on the road traffic, and that there are significant cost savings in recycling the debris into the new (re)construction works.
7 Actors in Debris Management

Following a natural disaster there are numerous actors involved in the planning, management and handling of debris.

7.1 Actor Identification

For Bangladesh, debris actors are identified dependent on the type and location of the actual disaster, for example for a cyclone striking the coastal area of Bangladesh usually the District Disaster Management Committee and District Disaster Response Coordination Groups will be responsible for Cyclone management issues. In this case, the relevant Deputy Commissioner will take the lead for Cyclone Disaster Management and other departments will work in a supporting agency role.

For earthquakes then there is currently no explicit lead agency for handling the debris management challenges however there is an arrangement similar to the City Disaster Management Committees in urban area. Usually these committees will take the lead for earthquake disaster event management with support as required from the Armed Forces, Law & Order enforcing agencies & NGOs as per section 25, 30 & 31 of Disaster Management Act 2012. It has been noted within the DDM that these sections of the Disaster Management Act will need to include for debris management in future amendments to the Act.

The remaining sub-sections of this section on Debris Actors detail where debris management has specifically been included in the Bangladesh disaster management system.

7.1.1 Standing Orders on Disasters

In accordance with the “Standing Orders on Disaster”, as well as the Disaster Management Act 2012 where indicated below, the following actors are identified as having specific roles relating to debris management.

Bangladesh Armed Forces

The Armed Forces are instructed under the Standing Orders to “support the local administration in the removal of debris”. This is further strengthened by Section 30 of the Disaster Management Act 2012 which states that the National Disaster Response Coordination Group may request the Government for the support of the Armed Forces. The Government approval for such requests will depend on the magnitude of the disaster and location.

Bangladesh Police

The Bangladesh Police are instructed under the Standing Orders to “ensure acquisition of vehicles for debris disposal etc. immediately after a disaster”. This is further strengthened by Section 31 of the Disaster Management Act 2012 which states that the Deputy Commissioner may request the Police forces for support in post-disaster management. As per the Disaster Management Act 2012, then the
definition of the Police forces includes the Bangladesh Police including Rapid Action Battalion (RAB), Coast Guard, Border Guard of Bangladesh and Ansar and VDP including other similar para-military and non-military forces.

**Ansar and Village Defence Party (VDP)**

Due to their presence throughout the country, the Ansar and Village Defence Party (VDP) plays an important role in post-disaster response. This includes a role in accordance with the Standing Orders to “form the following groups for earthquake emergency management: 2) Committee for Debris cleaning”.

**Bangladesh Road Transport Corporation**

The Bangladesh Road Transport Corporation is instructed to carry out the following operations in accordance with the Standing Orders (section 4.2.21.5): “(c) Provide truck fleet, on receipt of government orders, for transportation of relief materials, house building materials and debris clearance equipment to the affected areas.”

### 7.1.2 Debris Actors

In addition to those organisations identified with key roles in the Standing Orders, the following actors are also typically involved:

**City Corporations**

The City Corporation is ultimately responsible for planning and managing the debris resulting from natural disasters, including directing where the debris should be taken to for disposal and allocating engineering resources to support/lead in the debris removal works. This can be instructed to the City’s solid waste department (or conservancy department) who have the trucks and manpower to handle debris. It is however doubtful that the City department will have enough resources to deal with all the debris arising and as such more actors are often required.

Furthermore, it is the role of the City Corporations to also handle Hospital Waste within a post-disaster response situation where a key focus is to ensure that this waste is not mixed with normal municipal solid waste (i.e. from households).

**UN Agencies and International NGOs**

Reference to Section 53 of the Disaster Management Act whereby the Government can receive cooperation from any foreign country, government and international and regional organization.

Typically the lead UN agency for debris removal is UNDP with resources to contract debris removal services as well as potential for debris recycling initiatives. This is based on UNDP’s past experiences from natural disaster responses dealing with debris. Other UN agencies can support this initiative through the UN Early Recovery cluster.

International NGOs have experience in debris management from past natural disaster responses, especially on emergency employment through cash-for-work for debris removal and in some cases debris recycling projects. These include Oxfam, Islamic Relief amongst others.
National Non-Governmental Organisations

Reference to Section 25 of the Disaster Management Act whereby the Government can involve any non-governmental institution and persons in activities related to affected area management.

Numerous national NGOs and Community Based Organisations (CBO) in Bangladesh are implementing disaster preparedness planning programmes in disaster vulnerable areas, often in urban areas and at the Ward level. These programmes focus on training Ward Officers and Urban Volunteers in disaster response including debris management.

Urban Volunteer groups

Urban Volunteer groups provide a valuable resource in being able to mobilise large groups of people to support the debris removal works with manual labour, often through cash-for-work or similar schemes. The management of these groups is key to ensuring most effective use and their participation is key in the development of the city level disaster debris preparedness plans.

Private Sector

The private sector can provide machinery and resources for debris removal, either through pre-events contracts (see below), as a donation or on a paid contract basis. The private sector has valuable skills for this debris management which are key to enabling debris removal, often since there is a lack of trucks and heavy machinery to handle the debris.

The involvement of private persons in disaster relief is governed by Section 25 of the Disaster Management Act 2012.

Informal Sector

The informal sector for waste management will often be engaged either through direct payment by building owners looking to retrieve valuables and scrap from their damaged homes/buildings or at a later stage in the debris cycle where informal sector sorts the debris at disposal sites.

This sector is often difficult to engage into a formal debris management contract but should be borne in mind within the debris plans to ensure optimal benefit is gained from their work.
8 Debris Removal and Management Options

There are numerous options for the removal and subsequent management of debris from using the debris as an unsorted fill material (i.e. for land reclamation) to recycling it into a concrete aggregate for new concrete. Disposal of debris is also an option however typically the least favoured option since represents an opportunity cost relating to lost livelihoods and (re)construction materials.

This section provides an overview of these options with the subsequent section providing specifications as to end use possibilities for reused and recycled debris.

8.1 Priorities in dealing with Debris

Immediately following a disaster, the main concern is on lifesaving measures such as Search and Rescue, as well as opening up routes to critical and essential facilities. During this phase of disaster response, the handling of debris is often connected with either:

- Search and rescue operations where removing the debris and damaged buildings is required for access to the survivors;
- Removal of debris from key access routes (roads and highways) for emergency vehicles such as ambulances, fire engines and the police;
- Removal of debris from critical and essential facilities such as fire stations, hospitals, police stations etc.;
- Removal of unstable structures which are at risk of further collapse;
- General access for returning public and humanitarian assistance; and,
- Removal of debris to minimise public health risks from the piles of debris becoming magnets for general waste disposal which in turn create a health risk through vermin, disease and odours.

For priorities in dealing with these debris quantities, the below table presents some typical scenarios.
<table>
<thead>
<tr>
<th>Priority</th>
<th>Description of Priority</th>
<th>Debris Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To remove the debris which is impeding Search and Rescue operations as well as the immediate, emergency relief operations (i.e. the provision of first aid, food, shelter and water.)</td>
<td>Immediate removal of debris from areas of local SAR operations as well as debris piles/unstable structural elements that pose a threat to the SAR teams. The site for dumping of the debris should be selected with consideration to future use of the land on which dumped (i.e. not to dump debris on someone’s agricultural land)</td>
</tr>
<tr>
<td>2</td>
<td>Removal of debris from critical facilities and services such as hospitals, fire stations etc. to enable access.</td>
<td>Handling requires attention to Health and Safety for the workers. Site for dumping of the debris as for Priority 1.</td>
</tr>
<tr>
<td>3</td>
<td>The removal of damaged buildings and infrastructure which could cause an immediate threat to public safety such as unstable structures and large piles of unstable debris in urban, residential areas</td>
<td>Handling requires attention to Health and Safety for the workers. Site for dumping of the debris as for Priority 1.</td>
</tr>
<tr>
<td>4</td>
<td>To remove uncontrolled dumped debris from urban areas since if left to lie will often attract dumping of general wastes (which will reduce opportunity to recycle the building waste), which in turn can lead to public health and environmental risks.</td>
<td>Handling requires attention to Health and Safety for the workers. Site for dumping of the building waste as for Priority 1.</td>
</tr>
<tr>
<td>5</td>
<td>Remove debris from streets, roads and public rights of way to enable return of affected communities to their damaged properties.</td>
<td>Handling requires attention to Health and Safety for the workers and there may be an opportunity to sort the wastes into recyclables before transport.</td>
</tr>
<tr>
<td>6</td>
<td>To remove debris of damaged buildings from private and public plots of land to enable reconstruction.</td>
<td>Handling requires attention to Health and Safety for the workers and there may be an opportunity to sort the wastes into recyclables before transport.</td>
</tr>
</tbody>
</table>

Table 3: Typical priorities for building waste in the post-disaster phases with handling comments (Adapted from: “A Brief Guide to the management of Building Waste Materials in disaster response operations”, a booklet developed in collaboration between ProAct Network, Shelter Centre and Disaster Waste Recovery (DWR)).
The actual selection of priority is dependent on the specifics of the relief situation and will need to take into consideration aspects such as reducing public health risks, access requirements, availability of plant and equipment, time and resource constraints as well as knowledge of relief efforts in debris handling.

8.2 Debris Management Options

The actual options for how to deal with the debris once it has been generated are varied and largely dependent on the “quality”, quantity and location of the debris, as well as the potential end use applications, i.e. is there a market for the possible reusable and recycled materials. Often the debris management option selected will be largely local specific dependent where the disaster affected community will initiate preliminary debris management within days of the disaster applicable to their own needs and requirements for building materials. Where debris management plans and projects are thus brought in, these local initiatives are to be respected and integrated to ensure community benefits and focus.

In general, a focus should be placed on optimising the benefits which can be gained from debris through reducing public health risks by removing the debris from populated areas, employment generation, reusing and recycling the debris, substituting quarry materials and minimising waste quantities requiring disposal at a landfill.

It is important to note that the initial handling of the debris can have a significant impact on the options available for the debris management. For example, if the debris is mixed with general waste then the opportunities to recycle are considerably reduced since pre-sorting of the debris/waste is required to enable reuse and recycling. The mixing of debris with general waste can easily happen if the debris is allowed to remain dumped in urban areas where the public will view the debris pile as a “waste” pile and add their own wastes to the pile. Also, if the debris is removed from a localised disaster zone and dumped with other wastes at a “dumpsite”, then it can become too mixed to reuse/recycle and the potential opportunities are lost.

For an indication of the main options for debris management, the following can apply.

8.2.1 Mixed Debris

For debris which is mixed with non-reusable and non-recyclables (see section Error! Reference source not found. for further details on cleanliness of debris), then the cost and effort in sorting the waste into reusable and recyclable materials can be excessive as compared to the benefits. For example, it may be better application of limited resources to use the manual labour on repairing water supply to an affected community rather than sorting debris.

Assuming that there are no hazardous materials and substances in the debris, mixed debris can thus remain mixed and be readily used as a general fill material for low-tech options such as recreational parks, land reclamation or other. If this
option is selected, then it should be ensured that the debris does not contain extensive quantities of degradable materials (such as timber, cardboard, plastering etc.), since these quantities will degrade over time and leave void spaces, which in turn affect the stability of the fill.

An assessment of the structural integrity of the resulting compacted fill material will be required to ensure that the risk of subsidence is minimised, this being a risk due to the gradual decomposition of the degradable materials that may be present in the mixed debris.

Where the mixed debris does contain hazardous materials such as heavy metals, oils, and chemical residues, these hazardous materials will either need to be sorted from the debris for separate controlled disposal, or the whole debris quantity can be classified as hazardous and disposed of accordingly. The degree of contamination from hazardous materials would need to be assessed by sampling and analysis of the debris, with characterisation of the debris based on the results of the laboratory analyses.

8.2.2 Relatively Clean Debris

Where debris is relatively clean, i.e. only minor quantities of inorganic materials such as paper, plastics and soils, then this material can typically be crushed and used as engineering fill in non-structural applications. Such uses include as fill material for embankments, backfill for trenches, fill material for gabions and possibly as a sub-base and base material for road construction.

Where the non-recyclable (organic) component of the debris is less than 1 – 2 % of the total quantity, then this material can readily be crushed and separated into the required fractions for roadbase material; a useful material in most reconstruction programmes where the rehabilitation of roads is often required.

Photo 8: Debris recovered as part of clean-up operations in Muzaffarabad (Pakistan) has been used as engineering fill material in this river gully, where a drainage system was put in place to allow the river to continue flowing uninterrupted. Source: DWR.
Should the economics be viable, then it may be justifiable to separate the non-recyclables from the debris before crushing in order to improve the quality of the debris to meet the roadbase specifications. This would be the case where the total cost of handling the relatively clean debris (i.e. separation and crushing) is lower than the total cost of importing equivalent quantities and types of natural raw crushed materials; this concept also being applicable to mixed debris.

8.2.3 Clean Debris

Where the debris is clean, it can readily be crushed and screened for most applications typically associated with crushed stone from quarries, with the only technical limit being compliance with the relevant specifications.

Clean debris may arise where the originating structure has been soft stripped (i.e. all non-recyclables removed prior to demolition) or where source separation of the non-recyclables is carried out during the demolition, often by a manual process.

The value of applications for the crushed and screened clean debris are often higher since the ‘quality’ of the recycled material will be similar to natural gravel and can thus be used in road construction or in low strength concrete foundations and pavements.

8.2.4 Asbestos

These guidelines do not include for the handling and management of asbestos for which it is recommended national legal requirements are enforced. General guidance can be received from “Safe handling of Asbestos in Disaster Response Operations”, a booklet developed in collaboration between ProAct Network, Shelter Centre and Disaster Waste Recovery (DWR), see [www.shelterlibrary.org](http://www.shelterlibrary.org).

8.3 Debris Monitoring

Monitoring and evaluation of the debris works can provide lessons learnt and opportunities to improve the ongoing debris works. Monitoring also provides a mechanism for ensuring correct payments to the implementing agencies and contractors are being made.

8.3.1 Debris removal monitoring

Establishing a monitoring mechanism for the removal of debris by wheel loaders and trucks is key to ensuring that the debris is being removed and disposed of appropriately and that payments for services are correct.

The monitoring can either be manual with roaming inspectors and use of debris transfer notes, or more computerised with the use of GPS devices placed on debris trucks to monitor their routes and ensure they are disposing of the debris at the correct locations.
Payments can be linked to documented debris removed (often by visual inspection by a debris inspector confirming that the truck has been filled with debris) as well as debris receipt documentation at the depot receiving the debris. This documentation can be cross referenced and provide the basis upon which payments are made.

8.3.2 Health & Safety

Working with debris is a potentially dangerous employment and as such the implementing agencies are responsible for ensuring their labourers and contractors are applying the correct and contractually required Personal Protection Equipment (PPE) as well as working safely.

H&S inspectors can 'roam' the debris works and check on use of PPE as well as approved methods of work, reporting back to debris management should there be any concerns.

8.3.3 Environmental monitoring

Where debris is being either processed at a debris recycling yard or being disposed of, potential negative environmental impacts are possible. These include dust, noise, traffic and vibrations. Monitoring of these processing activities can be provided to ensure that the operations are not having a detrimental impact on the surrounding neighbours and environment, with proposed mitigation should the environmental impacts become unacceptable.

Where debris is being disposed of into a landfill, sea for reclamation or as a landraise, monitoring of the debris being disposed of is required. This to ensure that only permitable debris is disposed of and no putrescible or decomposable solid waste is mixed in with the debris. Such solid wastes should be disposed of at the appropriate, authorised landfill.

8.3.4 Reuse and Recycling rates

A further benefit to monitoring debris activities is to record the level of reuse and recycling which in turn can provide data to document how much natural raw materials have been substituted with recycled debris. Such substitution has the following benefits:

- Cost savings since recycled debris is often cheaper that natural raw materials from quarries as the debris is often already located at the site of end use as a (re)construction material;
- Reduced truck movements where trucking can be a major burden on already heavily trafficked roadways in post-disaster recovery;
- Natural resource conservation since reduced extraction of raw construction materials from the quarries; and,
- Reduced burden on the landfills and dumpsites that would otherwise have received the debris and in turn can then receive more solid waste.
9 End Use Applications and Specifications

Reusing and recycling debris is only applicable where there is an end-use market ready to incorporate the reused and recycled material. Cleaning debris and recycling for purely environmental purposes is not considered sustainable, where the associated resources could be more valuably applied to other activities benefiting the disaster/conflict affected communities.

It is acknowledged that there is currently an end-use market for construction and demolition (C&D) waste in cities of Bangladesh whereby the C&D waste is manually sorted and ‘processed’ by manual labour. The resulting recycled waste is then often sold to slum areas for their use as fill or road material. Since C&D waste is very similar to debris then this market process would be valuable to support and expand in times of post-disaster and provide good opportunities for labour employment.

A typical driver which often stimulates the use of reusable and recycled materials in post disaster reconstruction programmes is the hugely increased demand for gravel and aggregates in reconstruction and rehabilitation works, often pushing the quarry prices significantly upwards. This in turn supports the economics for reusing and recycling debris.

Should the economics of recycling be favourable, the next step on deciding which application to aim for is the availability of established quality standards and specifications for the application. Thus if recycling of the debris is shown to be a locally viable option, local standards and specifications will need to be evaluated to ensure that the reusable and recycled debris can meet these. Alternatively, where there is a lack of such standards and specifications, reference can be made to relevant national or international standards, assuming these are approved by the relevant authorities.

In the majority of cases, the specifications and standards will refer to materials derived from natural materials, i.e. quarries, and no mention is made to use of recycled / secondary materials. In these cases, it may be required to run demonstrations on the use of recycled materials to show how these materials can just as easily be used as natural raw materials, assuming that the recycled materials meet the specifications. A dispensation can then be included in the current specifications allowing materials to be derived from either primary (natural) or secondary (recycled) sources. Furthermore, it can be applicable to ‘blend’ the recycled materials with natural raw materials, which reduces initial perceptions of risk from using recycled materials.

Generally, the level of crushing and screening with subsequent testing required to establish compliance with appropriate construction material and highways specifications increases in-line with the value of the product (from backfill through to use in concrete).
Some of the typical reusable and recycled debris applications which have been adopted in post-disaster and conflict reconstruction programmes, and which have associated standards/specifications, are listed as follows.

Further information on specifications and opportunities for the use of recycled materials from debris can be found at the UK’s Aggregain website (www.aggregain.co.uk).

9.1 Recycling of Debris
Parts of the debris can often be directly reused without any mechanical processing, typically only requiring sorting and possibly some cleaning. Debris materials such as bricks, stones and building blocks can often be reused if sorted from the general debris and incorporated into the reconstruction works.

Relevant specifications would be those applicable to the end-use, i.e. reused bricks to comply with specifications and standards for the manufacture of masonry bricks for example ASTM C62 - 08 Standard Specification for Building Brick (Solid Masonry Units Made From Clay or Shale).

9.1.1 Engineering Fill
Where the debris is either mixed or there is no real market for a higher value recycled product, the debris can be used as fill material for a variety of fill purposes, i.e. ground stabilisation work, in the construction of recreational facilities, as cover material and drainage media at landfills, road embankments, backfilling for trenches and general landscaping.
Debris can also be used for land reclamation, however it must be ensured that any potentially hazardous materials are removed from the debris before disposition since negative environmental impacts on the marine environment can be long term and harmful.

Generally, the size of the debris should not exceed 300 mm, and the reinforcement bars from concrete should be cut off. Furthermore, the organic content of the crushed materials should be limited to 1 - 3 %.

Alternatively, specifications do exist in certain countries depending on application, i.e. in the UK, the Manual of Contract Documents for Highway Works: Volume 1 (MCHW1), Specification for Highway Works, Series 600 are used.

9.1.2 Gabions

Crushed and screened debris can be used in the fabrication of gabions (typically mesh cages filled with crushed rocks) which can be used for a variety of purposes including the construction of embankments and artificial reefs in marine projects.

For the latter, a project in Sri Lanka following the Tsunami utilised reinforcement bars (abundant in the debris from damaged reinforced concrete) to create large steel cages, which were then filled with debris to create building blocks. These were then anchored to the sea bed and to one another to form a sea wall encompassing a new fish farm facility.

The recycled material for gabions will need to meet the required specifications such as “Class 6G Selected granular material” of the UK’s Manual of Contract Documents for Highway Works: Volume 1 (MCHW1), Specification for Highway Works, Series 600.
9.1.3 Building Blocks

Clean debris can be crushed and screened to a small fraction called fines and used in the manufacture of building blocks which in turn are used for the (re)construction of buildings. This process often only utilises a small part of the overall debris quantity crushed and screened since the fraction size required is relatively small as compared to the total quantity crushed, with the larger sizes of crushed material being used for applications such as gabions.

![Building blocks for reconstruction purposes which can be produced from recycled debris, Balakot, Pakistan. (Source: DWR).]

There are numerous specifications for building blocks including:

- BS EN 771-3:Aggregate concrete masonry units (Dense and lightweight aggregates); and,
- Concrete masonry blocks based on the aggregate requirements under ASTM C55-06e1 Standard Specification for Concrete Building Brick.

9.1.4 Sub-base for road construction

The use of recycled debris in road construction is a typical application in many countries with an established track record and associated specifications / standards. The clean debris is crushed and screened into several fractions typically which can then be blended with natural raw materials from quarries.

Specifications for road-base materials where recycled debris can be used include:

- Sub-base for road foundations based on ASTM D2940-03 Standard Specification for Graded Aggregate Material for Bases or Sub-bases for Highways or Airports; and
- Sub-base for road foundations based on the UK Specification for Highway Works (SHW) Series 800 and BS EN 14227-1 “
The debris will need to be cleaned of non-recyclables such as organics (paper, cardboard, furnishings), plastics and other non-inert materials leaving only the concrete, bricks and stones for crushing and screening.

*Photo 13: Recycled aggregate from crushing of building waste in Kosovo, as used for road construction or low strength concrete foundations. (Source: Golder Associates)*.

### 9.1.5 Concrete aggregate

The rules relating to the use of recycled materials for concrete are not as straightforward as for other applications due to the structural bearing element being of concern to the engineers utilising the aggregate. The cleanliness and quality of the debris for recycling to concrete aggregate will need to be very good, where only clean concrete with some masonry brick would typically be acceptable for crushing and screening.

It is generally acknowledged that recycled concrete can potentially be used as the coarse aggregate in grades of concrete up to Grade 20. In addition, recycled concrete can often be blended with natural raw concrete aggregate replacing up to 20% of the coarse aggregate in concrete grades up to Grade 50.

The recycled material to be used in the production of concrete would need to meet a specification such as *Concrete Block Specification: ASTM C90-06b Standard Specification for Loadbearing Concrete Masonry Units* or the European *BS EN 12620: 2002+A1: 2008 Aggregates for Concrete*.

### 9.1.6 Scrap Metal

The metals arising from the debris, mainly either structural steel from frameworks or the reinforcement bars from reinforced concrete, are readily recyclable and often removed from the debris in the early days of the post-disaster scenario. This removal being due to the ease of selling the scrap metal to merchants for cash,
thus providing an incentive for the affected communities to generate some cash from their debris.

The remaining scrap metals, i.e. corrugated roof sheets, can be collected by the contractors working on the demolition works and debris management contracts, and sold onto the scrap metals market, an established market anywhere in the world.

9.1.7 Quality Control and Assurance

For the purpose of ensuring that the recycled materials have been produced to a certain quality system, a specific set of quality management guidelines have been developed by WRAP (UK’s Waste and Resources Action Programme) called The Quality Protocol – for the production of aggregates from inert waste.

These guidelines provide a “uniform control process for producers, from which they can reasonably state and demonstrate that their product has been fully recovered and is no longer a waste. It also provides purchasers with a quality-managed product to common aggregate standards, which increases confidence in performance. Also, the framework created by the Protocol provides a clear audit trail for those responsible for ensuring compliance with Waste Management Legislation” (reference www.aggregain.co.uk).

The Protocol contains sections defining the acceptable wastes, production control requirements, acceptance criteria for incoming wastes, inspection and testing regimes, record keeping, as well as example flow charts for the acceptance and processing of inert waste.

9.2 Reuse of Debris

The definition of reuse is when the debris is not treated or processed but reused in its original form.

The reuse of debris is many times carried out by the building owners at the site of the damaged building, for example the sorting out of bricks to reuse, segregation of timber and wood for burning as heating element, etc.

If the reusable debris has not been sorted out at the site, then it can be segregated at the debris processing (recycling) site in a more centralised manner.
9.2.1 Wood and Timber

Wood and timber are often a significant proportion of the debris once the bricks and concrete have been removed. This wood and timber can be readily used for heating and cooking or can be set aside for use by local carpenters or furniture makers.

Photo 14: Separation of wood and timber from post-Tsunami debris in Banda Aceh. The reused timber was used by local furniture makers. (Source: UNDP).

9.2.2 Bricks

Whole and undamaged bricks are often separated out for use in rehabilitation and reconstruction works. These can be stacked by the side of the damaged building for use by the owner or collected centrally for distribution into the local community.

Photo 15: Separation of bricks from the debris whilst removing debris in Kathmandu following the April 2015 Earthquake. (Source: Disaster Waste Recovery).
10 Debris Processing Equipment Specifications

For each of the debris options this section provides the typical tools, equipment, plant and machinery required, as well as human resources. Included in Appendix A is a typical list of equipment and machinery used in debris management which can be referred to for the development of the City Disaster Management Plans.

The following section presents the typical forms of handling and processing the debris from its location at source to final end-use or disposal.

The main emphasis of recycling the inert debris is to remove the non-recyclables (i.e. plastics, timber, furnishings etc.) from the inert materials before processing. This results in a quality product which can be used in road construction and for low strength concrete.

10.1 Sorting of debris

The debris will often be mixed, i.e. the recyclable concrete and bricks mixed with furnishings and other non-recyclables. In order to realise the maximum value from the debris in terms of items for reuse and recycling, it is typically necessary to sort through the waste to extract the non-recyclables.

This can be done in a variety of ways from the most basic manual sorting to mechanical means more appropriate for the larger volumes. The following subsections present some of the typical methods adopted in post-disaster.

10.1.1 Manual Sorting

The debris can be strewn out on the ground, and manual labour used to pickout the non-recyclables and other items. The remaining material, i.e. inert materials such as concrete and bricks, can then be collected for processing.

Photo 16: Debris sorting in Kathmandu, Nepal following the April 2015 earthquake. Note the stack of reusable bricks to the right of the photo. (Source: Disaster Waste Recovery).
10.1.2 Primary mechanical sorting

Alternatively, basic plant can be constructed locally for the mechanical sorting of the debris, which provides a higher throughput with less personnel.

Photo 17: A mechanical “grizzly” to the left in the photo sorts the finer materials from the oversize concrete and bricks, whereafter the oversize can be placed on a picking station to the right in the photo for manual separation of non-recyclables. (Source: DWR)

The above example is from Kosovo where the plant was all constructed locally and this mobile setup was brought from site to site for source separation of the debris into recyclable concrete and bricks.

Such picking stations are useful since they can provide a slow moving conveyor belt from which wastes can be removed manually by labour standing by the conveyor belts. This can occur either at the work site with mobile picking stations or at a central location with a large stationary setup.

These belts enable up to 6 persons to safely work (three on either side), and the belt is normally positioned (raised) in order to allow the operators to work at waist height.
10.1.3 Primary Screening Unit

Should a larger throughput be required, then a more sophisticated primary screening unit can be used to remove the finer soil fractions from the debris. These units are highly mobile and only require a single-axle truck to move around site.

Photo 18: Typical conveyors with adjustable belt speed for use as a picking station. (Source: DWR)

Photo 19: A mechanical primary screening unit for separation of soil from debris enabling the larger bricks, stones and concrete to be separated out and subsequently crushed.
10.2 **Crushing of debris**

Depending on the location and context, a wide variety of crushers are available, each being particularly suitable for differing purposes and end-products. Crushers can generally crush glass, porcelain, granite, bricks, blocks, asphalt and reinforced concrete.

They can range from on-site mobile crushers, processing from 5 to 10 tonnes per day up to full scale plant that can handle up to 500 tonnes per hour.

The following sub-sections present the most common types of crushers used in post-disaster works. Note that for all options there is also a solid second-hand market for crushers and screeners which can be suitable used for post-disaster works, ensuring that the plant is delivered with adequate guarantees, warranties and service arrangements.

10.2.1 *Locally manufactured crushers*

There is extensive use of small scale mobile crushers in Bangladesh as below where these types of crushers are ideally suited to crushing debris in a post-disaster situation. With their small size, these crushers can enter into the streets of urban areas affected by disasters and provide a useful local service with the crushed material being left within the community for local reuse and recycling.

*Photo 20: Locally manufactured “mobile” crusher from Bangladesh quarries. (Source: M Bjerregaard).*

Discussions with the manufacturers of such crushers will need some design alterations to consider the handling reinforcement bars when crushing the concrete, which will often require a larger aperture for the outlet of the feed hopper.

10.2.2 *Small mobile crushers*

Should locally manufactured crushers not be available, there are several options for the purchase of small, mobile crushers which can be used in urban and rural areas.
These smaller crushers can be transported by typical 4x4 vehicles and are operated by remote control, thus allowing access to even the most rural areas of a disaster affected community. The output crushed material is not suitable for engineered roads or low strength concrete but can be used for access road rehabilitation or as general fill, i.e. for parks.

### 10.2.3 Medium mobile crushers

For larger quantities of debris, a medium sized mobile plant can be used, which would normally feed straight into a screening unit (for the separation of the crushed material into 2 or more size fractions. The final product size will depend on the required use for the recycled material.
Medium sized crushers for recycling debris will require an overband magnet for the separation of the reinforcement bars from the crushed material.

10.2.4 Large Stationary crushers

Although not typically utilised in post-disaster works since the spread of debris in a geographic area makes a mobile crushing solution more cost effective from a logistics view, a stationary crushing can be implemented if the quantities in an urban area are significant (i.e. more than 1 million tonnes of debris).

Stationary crushers and screening units have a higher throughput than any of the mobile solutions. They do require a larger facility infrastructure for the works, i.e. site for recycling and stockpiling, and are more costly.

10.3 Shredding of Timber and other wastes

For the timber and vegetative debris within the waste, grinders and shredders are used for reducing the volume of this waste stream. It can then, for example, be used as a mulch in landscaping or for composting. This type of plant is relatively simple yet not often found in many countries, and will thus typically be imported.

![Typical mobile shredder for wood and timber.](image)

Photo 23: Typical mobile shredder for wood and timber.

10.4 Other wastes

For the other waste streams not typically directly recyclable or reusable, the norm is for these materials to be disposed of at the authorised dumpsite or landfill. In some cases it may be prudent to allow the local communities access to this waste stream under working conditions, for the extract of any materials which they may find of use for reuse. An example is the plastic which can be used to make products for sale on the local market, i.e. bags and carriers.
10.5 **Pre-Event Contracts**

Development of pre-event contracts for debris haulage, processing and recycling are valuable mechanisms for rapid deployment of debris removal and processing resources.

For pre-event contracts relating to the removal and processing or disposing of debris there are several forms of contract as listed below. The actual form of contract selected will depend on the quantities, type of contractor selected and purpose of the contract:

- **Time and Materials (T&M)** whereby the contractor is paid per hour or day for the use of their plant and machinery, typically including operator and all fuel/oils and maintenance included;
- **Unit price contract** for payment of the contractor per m³, tonne or truckload removed / processed; and,
- **Lump Sum contract** whereby the contractor agrees to remove all debris from a certain neighbourhood or Ward within a certain period of time to a fixed agreed price. Lump Sum is usually used for smaller, measurable jobs such as the demolition and removal of a single building or specific debris removal.

Where possible, pre-event contracts can be put in place with local contractors and NGO / CBO entities for the following types of activities:

**Volunteer Agreements**

Agreements can be made pre-disaster with the local Urban Volunteers and local NGOs to provide people for the removal of debris and subsequent sorting or recycling. These contracts or agreements can specify deployment procedures, minimum requirements to health & safety and coordination mechanisms.

**Loading and Trucking**

The loading of debris onto trucks for transport to the debris destination is a key element of debris management and can be included in pre-event contracts with local contractors. Specified in the pre-event contracts can be daily rates, agreements on supply of fuel, mechanisms for coordinating where the debris is to be taken and share of risks and liabilities.

**Storage space for the debris**

The debris for processing (sorting and treatment) will require space, land which can be agreed upon in the pre-disaster preparedness plan. Contracts for this land can be agreed upon in the pre-events contract specifying land rates, responsibility for security and site welfare facilities and handback conditions once the debris works have been completed.
**Processing plant and equipment**

Once the debris has been brought to a debris processing yard, plant and machinery will be required to treat the debris with screening, crushing, shredding and sorting being some of the key typical processes. Pre-events contract for the supply and operation of such plant and machinery can be put in place specifying types of plant and machinery required, operating costs and rates, supply of fuel and lubricants and minimum capacity requirements.

**Disposal facilities**

Where the debris is not to be processed or recycled, and for the solid waste elements of the debris which is non-recyclable, a final disposal site will be required. A pre-event contract can be made with the applicable disposal sites for the tipping fee, quantities and quality of debris acceptable at the disposal site are to be specified.
11 Debris Logistics

There are a multitude of ways in which the debris can be handled and transported from its current location to its final destination, be that as a reusable / recyclable material or for final disposal.

This section presents the main options for handling and transporting the debris.

11.1 Transport of Debris

There are two main mechanisms for bringing the debris from its source (i.e. location of damaged building) to the treatment site for recycling, reuse or disposal:

- **Push** which entails paying an organisation (i.e. contractor or through cash-for-work) to bring the debris to the treatment site; or,

- **Pull** which entails paying a sum of money for every load of debris brought to the treatment at a set rate, i.e. US$1 per wheel barrow of bricks.

The pull mechanism allows for the local community to participate in the debris clean up works and thus spreads the economic benefits of debris works deeper into the communities.

An example of this was the Oxfam GB reuse yard in Banda Aceh following the Tsunami where the yard paid a set rate per type of debris delivered to its yard, the debris being subsequently cleaned and reused / recycled in a variety of products.

*Photo 24 and 25:* The Oxfam GB ‘buy back’ scheme in Banda Aceh for debris where reused bricks are stacked in accordance with their size and colour and the photo to the right illustrates a price list for each type of debris brought by the local community to the ‘buy back’ yard. *(Source: Disaster Waste Recovery)*

The actual transport of the debris can be done by a range of different vehicles, from the simplest method of wooden carts pulled by animals to heavy duty excavators, trucks and skips.

This transport of debris is an important economical and logistical factor to be considered in the overall debris management plan, given the large volumes that need to be dealt with. Since there may be a lack of vehicles and the road
infrastructures may be damaged, then determining where the debris should be taken will have a considerable impact on the transport costs and traffic burden.

Knowing the location the debris and potential debris processing / disposal sites (see above Debris Mapping section) allows for the optimal logistics plan to be designed and implemented. Such decisions should also consider a cost-benefit analysis on transport costs, disposal costs and processing capacity requirements.

11.2 Temporary Debris Staging and Reduction Sites

The processing of the debris into a reusable or recyclable material can entail numerous different activities which can be carried out at various stages of the debris handling. For example, cleaning and stacking of bricks for reuse can be carried out at the actual site of the damaged building, and the crushing and screening of waste concrete and bricks can occur either at the damaged building site or at a debris recycling yard. Thus the term “recycling site” is flexible as to location but still has certain minimum requirements wherever it is located.

Preparing debris materials for reuse, i.e. cleaning bricks and stones, is typically a manual process and can thus be undertaken anywhere with enough space and level standing to carry out these tasks.

For more mechanical recycling, typically heavier / larger plant and equipment is required which subsequently leads to the following services and facilities being needed:

- Hard standing (i.e. a level, compacted area which can support truck movements as well as heavy plant and equipment) for the required plant and equipment where this area has adequate drainage and not flood;
- Protection of the neighbouring activities (i.e. housing) from the potential negative impacts of the recycling activities such as dust, noise and vibrations. Such protection can be either distance (i.e. locate the site far from residential areas), or earth bunds to minimise spread of impacts;
- Services such as electricity and water are often required however can be provided by generators and water bowser;
- Access to the site is important for both the plant and equipment but also the bringing and removal of the debris/recycled materials. Access should ideally be by a compacted road/track and where possible, the routing should not be a nuisance to neighbouring activities; and,
- Security and control of the site can be important for both the protection of the plant and equipment, as well as control of debris materials brought to the site to ensure that only recyclable debris is received (and not general waste).

Typically a total area of approximately 7,500 m² is required for a recycling yard in disaster relief work, with some of the more heavily damaged areas requiring more space to cater for the large quantities of debris.
It is normally recommended that the sites are located on publically owned land to avoid potential conflict of interests and minimise potential costs of using this land. However, it is appreciated that in Bangladesh the majority of available land would most likely be privately owned. In addition, it may be advantageous to involve a local gravel extraction/supply company in the preparation and management of the depot since integration of the recycling activities with the quarries can benefit the overall recycling initiative.

Once established, the following waste fractions would be accepted at the recycling yard:

- Concrete;
- Bricks;
- Rough cut buildings stones;
- Metal reinforcing bars;
- Scrap metal;
- Mixed debris with no contaminants;
- Clean timber and wood;
- Green waste for example from site clearance of fallen trees; and
- Plastics if plastic recycling is incorporated.

Photo 26: A typical recycling depot with crusher and screener at an industrial site on the outskirts of a city (Mitrovica, Kosovo), on hard standing and with recycled materials stockpiled ready for collection. (Source: Golder Associates).

Concrete blocks received at a crushing and screening site are normally required to be maximum 400mm by 400mm in size, with a maximum reinforcement bars protrusion of 100mm from the concrete blocks. This enables crushing of the concrete with minimised potential for plant blockages.
No other wastes are typically accepted at recycling yards, and thus the above waste fractions are to be clean of pollutants. This is especially true of hazardous wastes such as asbestos which should be strictly prohibited at the recycling yards, these being disposed of in a controlled manner at the local landfill/dump site.

11.3 Temporary Debris Staging and Reduction Site

Where debris quantities are spread throughout a geographical area or City, and the transportation of the debris to a single centralised recycling site is neither economically nor logistically feasible, then Temporary Debris Staging and Reduction Sites (TDRS) can be established. These are temporary depots to which local debris can be brought, and once enough debris has been collected (generally more than 1,500m³), a mobile recycling or shredding plant can be brought to site for processing the debris.

These sites are typically rudimentary in requirements with fencing, hardstanding and possible gatehouse. Limited services are required since mobile recycling and shredding plants will have their own power source (generators or the plant being fuel driven).

![Photo 27: A temporary recycling depot in a rural area of Kosovo with hardstanding, fencing and gatehouse, as well as the gradual build-up of debris for processing once quantities are sufficient. (Source: Golder Associates).](image)

Determining the location of these sites is to take into account the local area including access, land ownership and environment considerations. In Appendix B a briefing on the selection of sites for TDRS has been included as guidance.

11.4 Disposal of non-recyclables

For those debris materials which are generally non-recyclable, i.e. furnishings, personal belongings, packaging, mixed wastes and hazardous materials, these are to be disposed of at the locally authorised landfill or dumpsite, either under
controlled engineering for hazardous materials or general disposal for non-hazardous.

Control on the final disposal of these materials should be carried out to ensure that the wastes are not disposed of in an uncontrolled manner detrimental to the local environment, i.e. the wastes should be disposed of at authorised sites rather than dumped into river gullies or on the outskirts of towns and cities.
12 HEALTH & SAFETY

The Health and Safety (H&S) of the personnel working within the debris project is paramount to the success of any debris management initiative and should be an integral part of the project from day 1. This section highlights some of the minimum requirements for H&S in debris recycling operations.

Handling debris is a high risk activity due to the potential contents of the debris ranging from potentially asbestos, syringes and other healthcare wastes, sharp items such as reinforcement bars and concrete/brick blocks as well as the debris itself if in larger quantities (weight).

The handling and processing of the debris can thus lead to significant H&S incidents which are to be mitigated primarily through safe systems of work and secondly Personal Protective Equipment (PPE).

Photo 28: Access to damaged buildings and debris sites should be managed in a controlled manner to prevent unauthorised and unnecessary access. Above photo from Bangladesh exemplifies the issue of having too many people on potentially very unstable building at risk of collapse, especially following earthquakes where aftershocks are common.

The process of developing safe systems of work incorporates the identification of alternative means of work (i.e. lifting debris onto a truck) which encompass less risks, thus designing out the H&S risk from the start. If the activity is absolutely necessary and involves human interface, then PPE will be required. Generally, the more mechanised the work approach, the less risk to human health.

Typical PPE includes adapted footwear (hard boots to prevent spikes entering the sole and minimise the risk of harm from heavy materials dropping onto feet), gloves, overalls and masks.

The site layout of the recycling site is to take into account H&S aspects, for example one way traffic systems and limited cross over between vehicles and
humans at site. In addition, people working with the debris should have access to proper and clean changing and washing facilities for use during and after the debris handling and processing works.

During the processing works, adequate dust suppression mechanisms should be adopted (i.e. water spraying) to reduce dust. Furthermore, the plant and equipment used should be both fitted with noise, vibration and harmful emission reduction mechanisms, as well as suitable mounted machinery guards to prevent accidents from improper use.

Further guidance on H&S in waste management can be found in the World Bank Group’s “Environmental, Health and Safety Guidelines: Waste Management Facilities”.
13 **HANDOVER OPTIONS**

For the design of debris projects and programmes then an exit strategy is required when funding is completed. Options for further continuation of the debris teams and organisations, as well as the utilisation of the debris systems and machinery are presented.

It is recognised that all debris management works and projects are to be aligned with the lead Governmental agencies and departments to ensure that they support the affected communities as well as the local authorities. Where funds are donated by an international Donor or Funding agency then the legal context of such donation will have an impact on how the plant, machinery, equipment and project team can be handed over.

A key aspect of any debris management project in post-disaster and post-conflict scenarios is to ensure that whatever operations that are implemented also have an exit strategy which supports the local communities.

Such exit strategies incorporate a form of handover from the typically donor funded programmes to a sustainable, local operation which can continue the use of the plant and equipment to the benefit of both the local communities as well as the environment in general, hereunder debris and wastes.

Without an exit strategy, all of the efforts placed in planning and implementing the programme will be lost at the close of the programme, as the machinery is sold onto the second hand market and the trained, skilled personnel are made redundant.

Alternatives exist to disbanding the programme, some of these being covered briefly in this section.

13.1 **Public sector handover**

Where the Donor wishes to handover the debris management operations to a public sector organisation or department, such as a Ministry of Public Works which often has responsibilities for the maintenance of utilities and roads and can thus use the recycled materials directly in their works, the handover procedure can be simplified.

A direct transfer from the Donor to the public sector organisation can be effected once legal documentations are in place, where a focus should be placed on ensuring that the public sector organisation has the required skills and capacity to ensure continued operations. This can even be effected at the outset of the project whereby the Donor implementing agency supports the government agency in the use of the plant and machinery including provides training for the Government staff.

Supplementary training and support may be required for the public sector organisation to optimise their utilisation of the debris management system, this being in the form of expert advice available to the organisation and support on the integration of the new operations into the organisation’s own operations.
13.2 **Private sector handover**

Handover to a private sector company with the aim that the debris management operations are continued as a private company to the benefit of the affected communities through providing continued debris/waste related services and employing people, thus generating both salaries and tax revenues.

Potential mechanisms for handover to the private sector include:

- **In Trust**, i.e. the beneficiary has to comply with certain conditions on use of machinery. During period of trust, the Donor maintains overall ownership and right to re-take machinery if conditions broken. Upon end of trust period, full ownership passes to the beneficiary; or,

- **Bidding**, i.e. private companies bid for the machinery with conditions and minimum payment being equal to the cost of import duties.

Emphasis can be placed on a procedure which allows the Donor to maintain ownership of the equipment until the beneficiary has proved its professionalism and positive intent.

**Option 1 – In Trust with Management Contract**

The current (or new management) team of the debris project establish a separate private company which signs a management contract with the Donor for the operations and maintenance of the equipment. Thereby the Donor maintains ownership of the equipment, but the beneficiary (new company) operates the equipment.

The contract would typically stipulate that the beneficiary must comply with certain requirements, i.e.

- That the equipment must only be used for those purposes as described in the contract;

- The equipment is to be maintained in accordance with the manufacturer’s guidelines;

- The Donor has the right to regain operational control of the equipment at any time should any of the requirements not be met by the beneficiary;

- All income generated from the operations of the equipment is accrued to the beneficiary; and,

- The beneficiary is responsible for all operational costs, including maintenance, which may incur during the term of the management contract.

Should the beneficiary comply with the requirements of the management contract by a certain date (i.e. 2 years after handover), it is proposed that full ownership of the equipment is transferred to the beneficiary.

Note that the beneficiary can also be a community based organisation set up specifically for this purpose to continue operations as a non-for profit organisation,
thus effectively continuing the debris management options as an NGO (Non-Governmental Organisation).

Option 2 – Bidding

Under this option, the operations team with plant and equipment is intended for sale as a ‘going operation’ where private companies are invited to bid for the continued operations of the debris management system for a set number of years whereafter the ownership can revert to the company.

For any bidding procedure, the evaluation criteria can include such criteria as price willing to pay, demonstration of a good business plan and understanding of the market, as well as plans for the management of the company.

In the past, bid documents have included a requirement for the Bidder to include the following documentation for the continued operations:

- Marketing plan;
- Business plan;
- Operations plan;
- Maintenance plan; and
- Financing plan.

This option allows for a financial return to the Donor for the project implemented, where these funds can then be used to supervise and monitor the successful company in their continued operations of the debris management system, or the funds can be used for subsequent environmental programmes.

13.3 Public / Private hybrid handover

Another option for handover incorporates elements of both the private and public sector options, with the intention of assisting the public sector of the affected community in rehabilitating the public services as a result of the disaster/conflict, whilst also supporting economic development in that region.

Handover is performed to a private company, which is obliged to provide certain services to the public sector. Spare capacity after the fulfilment of such obligations can then be used by the recipient organisation for the performance of other (commercial) works for a profit. Note that a regular financial contribution is expected from the public sector department to cover monthly running costs, i.e. salaries and fuel/power consumption. In addition, the public sector department may be requested to provide a site for the storage and maintenance of the equipment.

Alternatively, a diminishing service contract starting at 100% service to the identified public body, and gradually decreasing to 0% over 12 to 18 months may be applicable, thus helping the public sector with the reconstruction and rehabilitation works and then, as the requirements for these works decline, moving more towards the commercial market.
Once obligations to the public sector department(s) have been concluded, and the recipient organisation demonstrated compliance and proficiency, then the Donor can make transfer of ownership to the private organisation.

Such a management contract is of relatively similar nature to that for private handover, with the addition of certain public sector obligations, either diminishing or static.

Note that with this option, the service contract is to be included in the tender documents for the selection of new organisation, thus making the public sector service contract open to public tendering.

13.4 Procedures for handover

The first step in most handover procedures is to develop an asset register for what plant and equipment is to be handed over, this being required to ensure that all parties are aware of what exactly is being handed over.

A valuation of the plant and equipment may be needed to place a value to the handover, especially if being tendered to the private sector. This valuation to take into account custom duties, excise tax or VAT as brought into the country by/for the Donor/.

A Memorandum of Understanding (MoU) between the Donor and the recipient country’s relevant Government Ministry/Department is often required, stipulating the decided modality for handover and spelling out each step of the handover process, be it to another public body or the private sector. This will be one of the more complicated actions required for the handover procedure since it will require lawyer approval from both parties.

Once the MoU has been agreed upon, the process for handover can be commenced.
14 **Economics of Debris Management**

The economics of debris management are dependent on numerous factors amongst others the value of the recycled material produced, the price for similar natural raw materials from quarries, the cost of transportation and processing and the cost of disposing of the debris at local landfills/dumpsites.

From a purely economical point of view, recycling of debris is only attractive when the recycled product is competitive with natural resources in relation to cost and quality. Recycled materials will normally be competitive where there is a shortage of both raw materials and suitable disposal sites.

This section presents the key factors affecting the economics of debris management and presents a simplified formulae for supporting decisions on what level of debris management is optimal.

14.1 **Cost-Benefit Assessment**

The cost-benefit assessment presents an economic model for the comparison of costs involved in recycling debris for reconstruction purposes and importing raw construction materials to be applied in the reconstruction work. The cost-benefit assessment compares two different scenarios:

*Diagram 3: Macro-economic model of integrated resource management and total costs of traditional waste disposal compared with recycling of wastes on site. (Source: Erik Lauritzen of ‘Lauritzen Advising’).*
The above figure illustrates the two main scenarios as regards handling debris within a reconstruction programme:

**Scenario I:** All of the debris generated by the demolished infrastructure and subsequent site clearance works is disposed of to landfill/dumpsite incurring costs in transportation and disposal. Subsequently all natural raw construction materials for the reconstruction work are imported from the quarries incurring costs on the import transportation as well as the cost of purchasing the quarry materials.

**Scenario II:** All recyclable materials from the debris are recycled within the local reconstruction work and substitute a proportion of the natural raw materials required for such applications as road construction, building blocks and engineering fill.

Scenario II encompasses cost reductions as compared to Scenario I since:

- The *transportation costs* are reduced as the debris is recycled locally within the reconstruction area with subsequent application in the local reconstruction works. This leads to reduced quantities of debris requiring transportation for disposal and subsequent reduction of quantities for import into the reconstruction area;
- The *cost of disposal* for the debris are reduced since less debris will be disposed of; and
- The *cost of purchasing* and importing natural raw materials from quarries will be reduced as recycled materials substitute some of the quarry materials (noting that the cost of gravel and aggregates from quarries often increases significantly in reconstruction scenarios as demand outstrips supply);

However, there are also potential cost increases in Scenario II as compared to Scenario I since:

- The non-recyclables within the debris may need to be separated for processing in scenario II whereas in scenario I, all debris would just be disposed of ‘as is’; and,
- The establishment of debris recycling operations will incur a cost, however this is often similar to the cost of processing the quarry material to the same specifications and can thus be neutral when compared to costs at the quarries, depending on the scale of operations in scenario II.

The cost-benefit assessment must thus take into account these aspects in determining the optimal design for the debris management project.
14.2 **Applicable Costs**

To provide cost input to the cost-benefit assessment, the following basic costs are applicable:

- Demolition costs for the removal of the damaged buildings and infrastructure;
- Transport costs for both the haulage of debris out of the demolition site as well as the import of natural raw materials;
- Natural raw material prices from the quarries to compare with the recycled materials produced through the debris recycling operations;
- Recycled material prices taking into account the cost of planning and implementing the debris management system; and
- Disposal costs for the debris and non-recyclables.

For the purpose of comparing the costs between Scenarios I and II, the following equation can be employed:

\[
T_c = (M_c + MT_c) + (D_c + R_c + RT_c + WT_c + W_c)
\]

where:

- \(T_c\) is total cost incurred from the scenario and is that borne by the organisation responsible for the overall implementation of the reconstruction works.
- \(M_c\) is the cost of natural raw materials for reconstruction works from the quarry taking into account any substitution of quarry materials with recycled materials
- \(MT_c\) is the cost of transporting the natural raw materials to the reconstruction site
- \(D_c\) is the cost of demolishing and site clearing the damaged areas taking into account that demolition costs for scenario II may be higher than for scenario I to allow for separation of non-recyclables during the site clearance works
$R_c$ is the cost of receiving and processing the debris into a recyclable material for reconstruction

$RT_c$ is the cost of transporting the recycled materials to the reconstruction site

$WT_c$ is the cost of transporting the wastes for disposal where in scenario I this includes all debris and in scenario II this includes just the non-recyclables

$W_c$ is the cost of disposing the wastes at the disposal site where in scenario I this includes all debris and in scenario II this includes just the non-recyclables

When employing this formula for the two scenarios, the result will provide an overview of the costs involved in both scenarios and provide the basis on which a decision can be made as to the feasibility of recycling the debris in the reconstruction works.

**Non-Financial Benefits**

The economic difference between the two scenarios presented above can often be minor. In these cases it can then also be advantageous to take into account additional benefits of recycling debris which are not directly financial, including:

- Employment opportunities for recycling personnel working at the debris management sites;
- Profit generation for recycling operator, through the sale of the recycled products to the reconstruction process;
- Production of construction materials for the reconstruction works, thereby alleviating the expected significant burden on the natural raw materials during the reconstruction work;
- Clean-up of the disposed debris, with the debris often being located on land which is either of development value to the community, in the way of urban development and/or has a negative impact on the local environment; and,
- Decreased pollution from the transportation of materials since a certain percentage of the construction materials can be taken from the debris, situated closer to the construction site than the raw materials quarries.

It is important to note that the revenue generated through sale of the scrap metal has not been included in the cost-benefit assessment and this can further support recycling operations.
15 **Disaster Debris Management Planning**

This section presents the planning requirements for both a preparedness Disaster Management Plan as well as, for locations with no Disaster Management Plan, an example of a planning model for debris management.

Note that in accordance with the National Plan for Debris Management 2010-2015, there are instructions for the development of sectoral and corporate level plans relating to disaster response. However, with specific regards to debris management, there are currently no directions to governmental agencies to develop Disaster Management Plans.

15.1 **Debris Management Plan**

Appreciating that debris will arise from any major natural disaster experienced in Bangladesh, the preparedness planning for these quantities is possible through a step-by-step approach as proposed in this section.

This is a simplified approach with the aim of demonstrating the process by which a plan can be prepared.

15.1.1 **Legal Issues**

One of the first steps is to gain an understanding of the regulatory requirements in Bangladesh as regards who would be legally responsible for the waste management following a disaster (i.e. does the government have the power to take control of a household debris and remove it without their consent?). This also links with who owns the debris at the various stages of the clean-up works.

Furthermore there is a need to have a legal definition of each of the waste streams to be dealt with along with waste acceptance criteria so procedures can be established for identification and handling the various wastes.

Any waivers of the current laws and regulations in a post-disaster event will need to be considered and be included in the Disaster Management Plan (see below).

For Bangladesh, numerous of these aspects are not directly covered in the Government issued Standing Orders on Disasters and Disaster Management Plan, wherefore in the City level Disaster Management Plans these issues are to be raised and solved.

15.1.2 **Projection of Debris Quantities and Types**

The initial phase of the preparedness plan involves the projection of possible debris generation for each of the waste streams, for a variety of possible disaster events. Within this needs to be included also the waste generated by the disaster, the waste generated by the disaster relief (i.e. packaging and from the disaster relief organisations) as well as the waste generated as a normal functioning of the city regardless of the disaster happened. This quantification could be made by type of waste, location and source.
For the Bangladesh cities, the HAZUS modelling has been done for the key vulnerable cities and this can be cross referenced with satellite or other maps for the debris (use of seismic hazard assessment to predict scale of damage) as well as looking at current debris generation and the population affected by the disaster event.

These can all be brought together in a database where scenarios can be run to help further planning.

15.1.3 Prioritisation of debris streams

Once each of the debris streams and their potential quantities/sources has been identified and projected, there is a requirement to make a prioritisation of which debris streams should be handled first, second etc. This not just by debris type (i.e. mixed, clean or buildings to be demolished), but also location since a ‘benign’ debris can be high priority if it is located somewhere that is hindering relief operations, i.e. on key access roads.

There is an important link here with both the disaster relief operations as well as linking in with the other disaster preparedness functions (transport, structural etc.).

15.1.4 Temporary Facilities

Now that the potential debris situation is better understood, one can start to plan for what machinery, storage areas, resources, technology etc. is required to handle each debris stream and location.

This will include such aspects as:

- Debris removal and transportation plant such as what type of dozers, chainsaws, trucks, special containers for hazardous and medical wastes etc.
- Storage areas for the debris should they require sorting/segregation etc. For example lay down areas and a consideration of transport routes.
- Recycling machinery such as crushers, screenings, shredders etc. for the debris etc.
- Skills and people required to manage all these aspects from labourers, foremen, recycling experts, waste disposal experts etc.; and,
- Disposal sites (landfills, dumpsites etc.).

The costing for each of these aspects is to be identified so when running the scenarios for the debris generation, one can link in the projected cost for handling these disaster debris. This will give input to the emergency management budget for the town/city/region.

Consideration is also required as to where locals can bring their (disaster) waste if they are going to clearing their own sites, linked with waste acceptance criteria for each storage site: some sites for recycling, some for debris, some for hazardous etc.
15.1.5  *End-uses*

Where there is an opportunity to recycle and reuse the various debris, there is a need to look at the specifications required for the recycled materials so that processes can be set up whereby the recycled materials are used directly into the reconstruction activities (i.e. crushed gravel in the road rehabilitation). This will prevent the wrangling that often follows using recycled materials between the supplier and the end user and which there is no time for in the disaster relief phase. One would envisage some specifications being developed which all buy into now (pre-disaster) and are ready to use immediately.

15.1.6  *Establishment of implementation organisation*

There needs to be established an implementation team for the disaster debris work which will implement the Debris Management Plan (as developed in below task). It would be best if this team (or at least parts of it) could be involved in the development of the Plan since then they have ownership of the plan and can more readily implement. Roles and responsibilities can be drawn from the Standing Orders on Disasters and Disaster Management Plan, where more specifically defined roles will be required for debris management than presently provided.

A proposed Debris Management Command System has been developed by DDM as included below which can form the basis for a command system in the event of a disaster.

*Diagram 4:  DDM Proposed Debris Management Command System.*

In addition, a crucial aspect is the development of pre-event contracts in pro-forma style, so pre-identified contractors can be immediately contracted in to remove and handle the wastes. These pre-event contracts should include an agreement on the legal issues, prices to be used, form of instructions to be used etc., so there is minimal procurement fuss in the immediate aftermath of the disaster.

For this work, local and regional contractors will need to be identified, liaised with and brought into the Debris Management Planning phase.
15.1.7 *Debris Action Plan*

This task brings all the above into a Debris Action Plan (DAP) with definition of roles and responsibilities for both maintenance of the DAP and then actual implementation should a disaster occur. This plan will need to dovetail with the other disaster preparedness plans developed for other lifelines, such as water, gas, electricity, roads and other wastes. In addition, the DAP is to have coordination functions for liaison with other ongoing and related disaster response mechanisms including SAR, restoration of services etc.

The plan should also include prepared checklists for the disaster debris assessment work so the teams can be deployed at short notice and there is consistency in the data collection. A crucial impact when dealing with prioritisation of waste work.

A DDM proposed team structure for the Debris Action Plan is included in below diagram.

![Diagram 5: DDM Proposed Debris Action Plan for Debris Manager/Team.](image)

Once a DAP has been agreed, the implementation of the DAP can be carried out by a Debris Management Team working in each respective zone or ward (depending on most effective zoning of the area impacted by the disaster). A proposed Debris Management Team has been developed by DDM and is included in the below diagram.
15.1.8 Communications plan

For the Disaster Management Plan to be effective there needs to be a comprehensive Communications Plan (as a part of the Disaster Management Plan) which spells out who does what, informs of which data/information and how the plan is actually affected as regards contracting in works.
The plan should also include advice on public and media relations since certain messages will need to be sent to support the disaster debris clean-up.

It would be advisable to have a GIS Information Management System to capture all the data and be a focal point for reference when seeking information about current status, work achieved and planned next steps.

15.2 Debris Planning Tool

Where there is no Disaster Management Plan, and a natural disaster has occurred which generates significant quantities of debris, the following holistic approach to disaster debris and waste management can be applied. This has been adapted from a United Nations Environment Programme (UNEP) disaster waste planning tool to help identify applicable debris and waste handling processes for reuse, recycling, incineration or disposal of each of the waste streams and/or landfill. This planning tool was developed in the aftermath of the Asian Tsunami in 2004 and has since been adopted in several post-disaster programmes.

It is proposed that the below model can support the development of the City level Disaster Management Plans as well as be aligned with the City specific disaster management plans as included in their Contingency Plans.

The below figure presents the overall approach of the planning tool and can provide a useful step-by-step guide to planning and implementing a debris management project since many of the issues are the same for wastes as for debris.
APPENDIX A

List of Typical Debris Management Plant, Equipment and Machinery
## List of Typical Debris Management Plant, Equipment and Machinery

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavator 20ton with following attachments:</td>
</tr>
<tr>
<td>Hydraulic Breaker</td>
</tr>
<tr>
<td>Hydraulic Grapple</td>
</tr>
<tr>
<td>Hydraulic Concrete Cutter</td>
</tr>
<tr>
<td>Auger</td>
</tr>
<tr>
<td>Excavator 12ton with following attachments:</td>
</tr>
<tr>
<td>Hydraulic Breaker</td>
</tr>
<tr>
<td>Hydraulic Concrete Cutter</td>
</tr>
<tr>
<td>Hydraulic Rod Cutter</td>
</tr>
<tr>
<td>Crane with following loading capacity:</td>
</tr>
<tr>
<td>100ton</td>
</tr>
<tr>
<td>50ton</td>
</tr>
<tr>
<td>30ton</td>
</tr>
<tr>
<td>Wheel Loader 15ton</td>
</tr>
<tr>
<td>Wheel Loader 15ton with tyre protection chain</td>
</tr>
<tr>
<td>Dozer with following types</td>
</tr>
<tr>
<td>Track</td>
</tr>
<tr>
<td>Wheel</td>
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<tr>
<td>Air Compressor with jack hammer</td>
</tr>
<tr>
<td>Dragline</td>
</tr>
<tr>
<td>Backhoe loader</td>
</tr>
<tr>
<td>Transporter 30ton</td>
</tr>
<tr>
<td>Tipper truck with following capacity:</td>
</tr>
<tr>
<td>5 cubic meter</td>
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<tr>
<td>3 cubic meter</td>
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<tr>
<td>Fork Lift</td>
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<tr>
<td>Roller of following category:</td>
</tr>
<tr>
<td>Combination</td>
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<tr>
<td>Vibratory</td>
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<tr>
<td>Pneumatic</td>
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<tr>
<td>Static</td>
</tr>
<tr>
<td>Hand</td>
</tr>
<tr>
<td>Water Tanker</td>
</tr>
<tr>
<td>Crane Mounted Truck 5ton</td>
</tr>
<tr>
<td>Mini Dumper 2ton</td>
</tr>
<tr>
<td>Tow Truck 5ton</td>
</tr>
<tr>
<td>Truck Mounted Access Equipments 20m</td>
</tr>
<tr>
<td>Truck Mounted Concrete Mixture</td>
</tr>
<tr>
<td>Motor Grader</td>
</tr>
<tr>
<td>17mm Chipping Hammer (Demolition Hammer)</td>
</tr>
<tr>
<td>Tool Description</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Chipping Hammer's 17mm Chisel Set (Bull point and flat bit)</td>
</tr>
<tr>
<td>Chipping Hammer's 17mm Chisel Set (Cold chisel)</td>
</tr>
<tr>
<td>400mm Petrol Chain Saw</td>
</tr>
<tr>
<td>400mm Electric Chain Saw</td>
</tr>
<tr>
<td>Hydraulic Jack (10 and 32ton)</td>
</tr>
<tr>
<td>400mm Petrol Rotary Rescue Saw (Power Cutter)</td>
</tr>
<tr>
<td>400mm Petrol Rotary Rescue Saw's Blade Set for Metal and Iron Cutter</td>
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<tr>
<td>Reciprocating Saw (Recipo Saw)</td>
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<tr>
<td>Reciprocating Saw (Recipo Saw) Iron and Wood Cutter Blade Set</td>
</tr>
<tr>
<td>235mm Circular Saw</td>
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<tr>
<td>20mm Electric Drill</td>
</tr>
<tr>
<td>20mm Electric Drill's Bit</td>
</tr>
<tr>
<td>52mm Electric Rotary Hammer Drill</td>
</tr>
<tr>
<td>52mm Electric Rotary Hammer Drill's Bit Set (Tungsten carbide-tipped bit)</td>
</tr>
<tr>
<td>Generator</td>
</tr>
<tr>
<td>Pliers</td>
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</tbody>
</table>
APPENDIX B

Temporary Debris Staging and Reduction Site Selection Criteria
Temporary Debris Staging and Reduction Site Selection Criteria

Based on the types of debris and waste that will be produced from the debris removal works, the following criteria should be considered when selecting a site for disposal of these materials.

1. Site should be controlled and contained with secure access points that can be monitored and identified for public use.

2. Site selection should take into account the natural watershed routes that are formed during rain or flooding and the materials deposited at the site should not cause flooding or drain off into natural water deposits.

3. Site should not alter the natural landscape of hillsides or ravines, so as to not create mudslides or washout during rains.

4. Site shall not be closer than 50 meters from a drinking water supply, streams, lake, ponds, wetlands or public water system for watershed control.

5. Sites shall not be situated on an unstable slope that has risk of landslides in events of inclement weather.

6. Sites shall have open ingress and egress points to prevent traffic and obstruction of external thru-traffic.

7. Materials disposed at site should follow a basic sorting/separating process to promote the recycling of reusable materials and the isolation of hazardous materials.

8. Materials at site shall not be burned for any reason unless properly carried out by debris/waste disposal specialists using methods of incineration and using the proper protective and handling materials.

9. Activity and deposits at site(s) should be recorded and documented, as well as the material that is being deposited. This can be reported to government entities and help to better address the needs of proper disposal in different areas.
This publication is a practical guide to assist decision makers in national and local government agencies in Bangladesh to understand the issue of disaster debris management. It outlines the development of a debris management mechanism that facilitates the development of local strategies on debris issues, bringing together knowledge and experience on existing and on-going work on debris clean-up.

It specifically looks at the issue of different types of debris and addresses the following issues:

- How debris can be collected and sorted for optimal reuse and recycling.
- What applications the debris can have in the reconstruction works.

This publication is part of the Early Recovery Facility, UNDP Bangladesh.