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MSB/UNDP
Debris Management Guidelines

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MSB

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1 Aim

These Debris Management Guidelines (Guidelines) have been prepared with the intention to support disaster recovery programmes with clear, pragmatic guidance on how to handle large volumes of debris following disasters and on cessation of conflicts (post-conflict).

The Guidelines detail the typical approaches from the design of the debris management schemes to actual implementation and end use of the recycled materials.

The Guidelines are envisaged to be a valuable resource to the United Nations Development Programme (UNDP), the Swedish Civils Contingency Agency (MSB), relevant governmental departments, implementing agencies concerned with debris, as well as a future resource for disaster preparedness planning in Lebanon and elsewhere.

2 Introduction

These Guidelines have been developed as part of a Sida (Swedish International Development Cooperation Agency) funded UNDP (United Nations Development Programme) Pilot Project on Rubble Recovery within the damaged areas of Southern Lebanon.

They provide a step-by-step guide to handling debris which can be a major hindrance to search and rescue operations, early recovery activities as well as rehabilitation and reconstruction works as a whole. In addition, debris can pose a public health risk if it is mixed with hazardous wastes such as asbestos, oils and chemicals.

Contra these challenges, there are also opportunities in the handling of debris, including reuse and recycling of the wastes into the reconstruction works as well as using the debris projects to foster livelihoods and income generating schemes.

These Guidelines have been developed by Martin Bjerregaard and draw on numerous other disaster waste management training programmes and guidelines as referenced.

3 Past Debris Management examples

This section presents three different examples of managing debris in two post-conflict (Southern Lebanon and Kosovo) and one post-disaster (post-tsunami Banda Aceh). These have been included to provide the reader with an indication of how debris can be managed in different humanitarian structures as well as different countries/cultures.

3.1 Rubble Recovery in Southern Lebanon

The 2006 hostilities in Southern Lebanon resulted in large scale damage to the built environment (infrastructure, buildings and structures), leading to a significant requirement for rehabilitation and reconstruction works.

Such rehabilitation and reconstruction works, including the preparatory clean-up works, generated large quantities of debris which was often dumped in an uncontrolled manner along roads and on empty plots. In addition, a large number of damaged buildings and structures were to be demolished and removed, further exacerbating the problems with access for the rehabilitation works (with debris preventing access).

Photo 1: The rubble recovery setup in Southern Lebanon as part of the UNDP Pilot Project. The photo shows (from the left) the manual sorting belt, the crusher and the screening unit with generators and one of the excavators employed. Source: MSB.

To support the affected Municipalities of Southern Lebanon with the handling of these large quantities of debris, UNDP established a Pilot Project for Rubble Recovery (with Sida funding), which focussed on demonstrating the environmental and financial benefits achievable through recycling the debris into a construction material.

For this project, UNDP procured a fully mobile rubble recycling plant comprising pre-sorting of the mixed debris, crushing and screening of the clean debris as well as the associated machinery required to load the plant. The operations were undertaken by a Lebanese contractor and a total of more than 50,000t rubble was recycled in two Municipalities of Southern Lebanon.

To deal with the geographic spread of the rubble, the project established several rubble depots in Southern Lebanon so that the recycling plant could travel from depot to depot, crushing and screening rubble for recycling. The end use application of the recycled materials include incorporation into the reconstruction of secondary roads and engineering fill.

On completion of the works, the recycling plant was tendered for sale with the purpose of continued recycling operations in Southern Lebanon, and a contractor was selected which committed to process a set quantity of rubble for the benefit of the Municipalities, i.e. for free. On completion of this quantity, the ownership of the recycling plant would pass to the contractor for continued operations as a private enterprise.

The Pilot Project successfully demonstrated the benefits of recycling the rubble in Southern Lebanon and several Municipalities have requested the recycling operations to be conducted in their areas. Furthermore, the project has left an organisation in place which can both provide this service now, as well as built capacity for any future requirements there may be for rubble recovery in Lebanon.

3.2 Debris Management in Kosovo

As a result of the 1999 conflict in Kosovo, significant numbers of buildings and infrastructure were damaged and required demolition with ensuing management of the rubble, as well as the municipal waste management services for cities and towns having been severely damaged. The Danish Ministry of Foreign Affairs (DANIDA) funded an environmental programme in Northern Kosovo, centred around Mitrovica, and the projects included rehabilitation of the municipal waste landfill as well as the waste collection services, capacity building in the waste management companies and a dedicated project for the demolition and recycling of the damaged buildings.

This dedicated project for demolition and recycling of the damaged buildings comprised the establishment of a Demolition/Recycling team, equipped with demolition excavators as well as a crusher and screening unit for processing the debris. In addition, the team was equipped and trained in the use of specialised asbestos equipment for dealing with those buildings which were contaminated with asbestos.

Photo2: Demolition of private homes in Kosovo with loading of the debris to be transported to the nearby recycling depot. Source: Golder Associates.

Photo 3: Crushing and screening of the debris for use as road based material in the rehabilitation of war damaged roads. Source: Golder Associates.

The project led to the demolition of more than 600 buildings and structures, including private homes, commercial and public buildings, bridges and roads. More than 90% of the demolition waste generated from these demolition works was then recycled into a road construction material which was either donated into the reconstruction works or sold to the UN and NATO, where the monies raised were invested back into the Demolition/Recycling team for expanded operations.

On cessation of the DANIDA funding, the Demolition/Recycling plant and equipment was tendered to the private sector for continued operations. The successful bidder, a local Kosovar construction based company, is continuing the operations of these machines to date.

3.3 Building Waste Management in Banda Aceh

As a result of the 2004 Tsunami, Banda Aceh experienced huge damage to infrastructure and buildings which in turn generated significant quantities of waste and debris. Initial assessments estimated in the region of 7 - 10 million m3 for Banda Aceh alone.

A large proportion of this mixed debris and waste was transported out of the urban areas and dumped in an uncontrolled manner on either vacant land or fish ponds, rice paddies, ditches, and land close to residential areas, further exacerbating the negative impact of the Tsunami since the owners of these lands could not then return and cultivate the land.

In order to support the debris clean up, several NGOs and UN Agencies commenced debris clean-up programmes, including the following:

Oxfam GB Recycling Centre

The Oxfam GB project included the establishment of a small scale recycling centre to which local people could be compensated financially for bringing debris to the centre, i.e. $x per wheelbarrow of bricks. This debris was then cleaned and reused in the rehabilitation works, i.e. bricks for new buildings, oil drums as waste bins for the roadsides, guttering for new housing etc.

Photo 4: The price list at OxfamGB's recycling centre in Banda Aceh detailing the money which Oxfam will pay locals for each type of debris they can bring to the centre. Source: DWR.

Photo 5: The received bricks are cleaned and stacked ready for reuse in the reconstruction works. Source: DWR.

This innovative method of small scale recycling centre allowed finances to flow directly into the local communities (i.e. bypassing the contractors with trucks who would normally collect the debris) as well as provide reusable construction materials for the reconstruction process.

UNDP's Tsunami Recovery Waste Management Programme

On a larger scale to the above Oxfam GB project, UNDP's programme was a multi-million dollar programme which included the clean-up of the rice paddies, fish ponds and private land onto which the debris had been dumped.

This entailed the subsequent sorting of the reusable and recyclable materials from the mixed wastes and supported the establishment of small scale enterprises such as a furniture making business using the reclaimed timber, as well as the reuse of the crushed concrete and bricks for use in road rehabilitation.

Photo 6: Concrete and bricks separated by the UNDP waste project in Banda Aceh from the mixed tsunami debris and ready for recycling into a road construction material. Source: DWR.

Photo 7: UNDP waste project separated timber in Banda Aceh and ready for use in the furniture making enterprise supported by the UNDP programme. Source: DWR.

4 Types of Debris

Debris from disasters or following conflicts has numerous similarities the world over with the main fractions constituting concrete, bricks, timber and soils regardless of location. The main variations lie in the composition of these main 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.

This section presents the main attributes of disaster and post-conflict debris.

4.1 Typical Debris composition

The composition of building waste from a disaster will also vary depending on the nature of the disaster1:

Photo 8: Post conflict (Jaffna, Sri Lanka) debris will often have reduced amounts of timber, furnishings and personal possessions since the buildings will often have been burnt during the conflict.

Source: DWR in Northern Sri Lanka

Photo 9: Post-tsunami (Banda Aceh, Indonesia) debris where the majority of the wastes will have been washed away by the waves, either being deposited towards the ebb of the wave or brought back into the sea.

Source: Golder for Oxfam in Banda Aceh

Photo 10: Post earthquake debris (Muzaffarabad, Pakistan) will most often have all the materials from the buildings still present at the footprint of the building.

Source: DWR for UNDP / UNEP in Pakistan.

[1] "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).

4.2 Debris arising

Debris from disasters or conflicts will typically arise from the following activities:

- *Debris clean-up* which normally comprises the removal of debris from the streets and roads as well as the heavily damaged buildings and structures. This type of debris is typically mixed with all forms of other wastes as well as potential for hazardous materials/substances;
- *Demolition of damaged buildings* which may not be readily cleared under the debris clean-up activities and require demolition plant to enact;
- *Repair of damaged buildings* where such repair involves partial demolition of damaged elements of the building and structure;
- *Demolition of bridges* which are often military targets in conflict as well as typical damage in earthquakes;
- *Rehabilitation of damaged roads* requiring the removal of the current roadbase materials which can be recycled into new roadbase material for the same road; and
- *(Re)Construction waste*, i.e. waste that is created from the construction and repair of buildings and comprises typically damaged bricks, packaging, surplus concrete etc.

These debris arise at different points of time during the relief and reconstruction phases with the immediate debris being often from the clean-up works as well as the demolition of damaged buildings. Then, as the reconstruction works start, the other sources of debris increase in quantity.

4.2.1 Main constituents

The main constituents of debris, regardless of their source, are as follows in the majority of cases:

- Concrete, both as cast 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;
- 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;
- Soils from excavations in connection with the clean-up and demolition works, as well as from such building materials as mudbricks and adobe;
- Plaster from coating of the walls and often mainly of gypsum;
- Metals such as reinforcement bars and structural steel;
- 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; and,
- Personal belongings from homes, offices and industrial sites

The actual composition of the debris with the above materials is very much dependent on the location of the debris arising, for example developing countries may have less structural concrete but 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 concrete and metals as compared to residential areas.

4.2.2 Hazardous materials

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

The following types of hazardous materials can often be found in the debris:

- *Asbestos* which can 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;
- *Heavy metals* within the building fabric and structural components, i.e. lead in piping and paints as well as mercury in thermostats etc.;
- *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
- *Contaminated soil* from the plot of land either under or near the damaged building and structure, where the contamination can be from oils leaking out of underground tanks or from the hazardous materials brought by the disaster event, i.e. flood waters containing oils from nearby damaged industrial facilities.

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.

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.

4.2.3 Cleanliness

An important factor when deciding upon how to deal with the debris is the ”cleanliness” of the debris, i.e. how much contamination is present from both hazardous materials as well as from non-recyclable and non-reusable waste 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 11: Clean debris ready for recycling.

Photo 12: Mixed debris following the Marmara Earthquake in Turkey, 1999.

4.3 UXO management

Specific for post-conflict debris management is the risk of unexploded ordnance (UXO) including mines. With consideration to personal safety and security, it is normally a pre-condition of any debris handling in post-conflict that the work area be swept for UXO, mines, booby-traps and other arms, and has been certified as clear by an authorised entity, i.e. a demining company or the military.

It is appreciated that such a sweep may not identify and remove all possible UXO, mines, booby-traps and arms since these may also be located within the actual rubble. As a precaution, a procedure should be developed for the event of finding such items within the rubble; i.e. stop works, remove personnel, call on a stand-by team to remove the item.

4.4 Typical Debris quantities

The quantities of debris from a natural disaster or conflict 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 thus vary from several hundred thousands of tonnes to millions of tonnes of debris. For example, following the Kobe Earthquake of January 1995 destroyed more than 192,000 buildings as well as roads and railways. The quantities of debris generated from the site clearing works was estimated at more than 15 million cubic meters.

Conflicts can also wreak large scale damage, for example during the Kosovo war in 1999, considerable damage was caused to buildings and structures across Kosovo. More than 120,000 housing units were damaged in Kosovo's 29 municipalities and it was roughly estimated that the waste from damaged buildings and structures at that time reached a magnitude of 10 million tonnes.

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.

5 Debris Management Options

There are numerous options for the management of debris from using the debris as an unsorted fill material to recycling it into a concrete aggregate for new concrete. This section provides an overview of these options with the subsequent section providing specifications as to end use possibilities.

5.1 Priorities in dealing with Debris

Immediately following a disaster or at the cessation of hostilities in a post-conflict scenario, the main concern is on lifesaving measures such as Search and Rescue, and providing water, shelter, food and healthcare. During these activities 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 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 rubble becoming magnets for general waste disposal which in turn create a health risk through vermin, disease and odours.

For priorities in dealing with debris, the below table presents some typical scenarios.

	Description of Priority	**Debris Comment**
Priority 1	To remove the building waste (debris) which is impeding search and rescue operations as well as the immediate, emergency relief operations (i.e. the providence of first aid, food, shelter and water.	The site for dumping of the debris should be selected with consideration to future use of the waste and future use of the land on which dumped (i.e. not to dump building waste on someone's agricultural land)
Priority 2	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 rubble in urban, residential areas	Handling requires attention to Health and Safety for the workers. Site for dumping of the building waste as for Priority 1.
Priority 3	To remove uncontrolled dumped building waste 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.	Handling requires attention to Health and Safety for the workers. Site for dumping of the building waste as for Priority 1.
Priority 4	To remove building waste of damaged buildings from private and public plots of land to enable reconstruction.	Handling requires attention to Health and Safety for the workers and there may be an opportunity to sort the wastes into recyclables before transport. Site for dumping of the building waste as for Priority 1.

Table 1: Typical priorities for building waste in the post-disaster phases with handling comments (Source: "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.

5.2 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.

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 rubble 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.

5.2.1 Mixed Debris

For debris which is mixed with non-reusable and non-recyclables (see section 4.2.3 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.

Photo 13: Rubble 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.

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.

5.2.2 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. 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.

5.2.3 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. Another example is in post-conflict where buildings and structures are often burnt with only the inert stone, brick, concrete and steel structural elements remaining.

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.

5.2.4 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.

6 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.

Should an end-use market be available for the uptake of the reusable and recycled materials, then the debris management systems should be designed to meet these requirements, i.e. if there is a market for sub-base material but not building blocks, the debris management system should be focussed on producing sub-base material from the initial phases of debris handling.

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).

6.1 Reuse 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).

Photo 14: The use of reused debris for the construction of retaining walls in Balakot, Pakistan. Source : DWR.

6.2 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.

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.

6.3 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 recent 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*.

6.4 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.

Photo 15: Building blocks for reconstruction purposes which can be produced from recycled building waste, 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.

6.5 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 16: Recycled aggregate from crushing of building waste in Kosovo, as used for road construction or low strength concrete foundations. (Source: Golder Associates).

6.6 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 upto 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*.

6.7 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.

6.8 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 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.

7 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.

7.1 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:

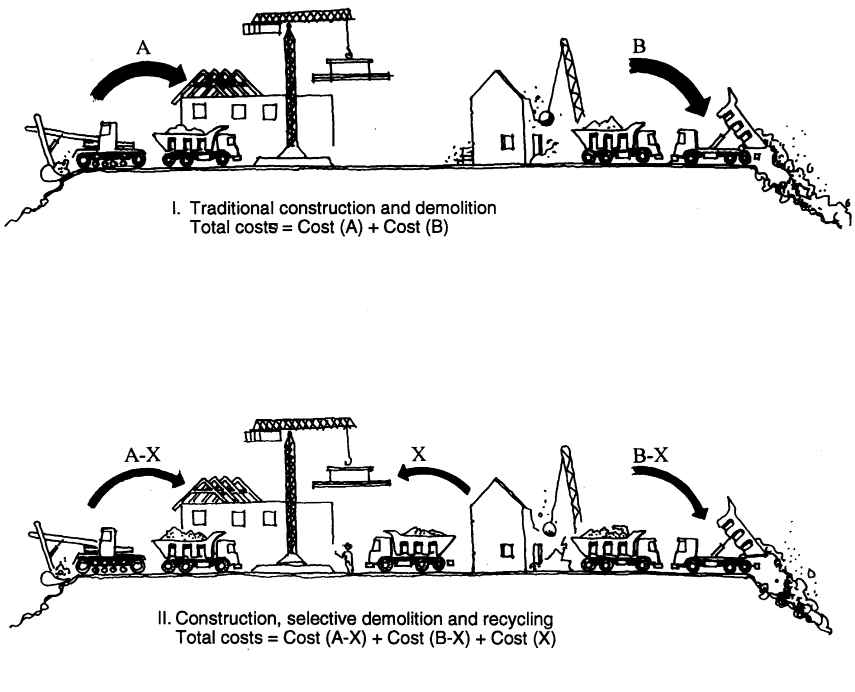


Figure 1: Macro-economic model of integrated resource management and total costs of traditional waste disposal compared with recycling of wastes on site. (Source: Erik Lauritzen of 'Lauritzen Advising').

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 transporyation 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.

7.2 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:

Total cost = Cost of raw materials + Cost of managing debris

shown as;

$$T_c = (M_c + MT_c) + (D_c + R_c + RT_c + WT_c + W_c)$$

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.

7.3 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;
- Cleanup of the disposed rubble, with the rubble 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.

8 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.

8.1 Transport of Rubble

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[2]:

- ***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 17: Payment list for a variety of building waste materials brought to the Oxfam GB reuse/recycling yard in Banda Aceh.

Photo 18: Stacked cleaned bricks ready for reuse at the Oxfam GB reuse/recycling yard in Banda Aceh.

The actual transport of the debris can be done by a range from 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. There may be a lack of vehicles and the road infrastructures may be damaged. This will have a considerable impact on the selection of temporary debris storage sites.

[2] "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 quantities and sources of the debris, with a cost-benefit analysis, will indicate which is the most environmentally and economically optimal transport solution.

8.2 Recycling Site

The processing of the debris into a reusable or recyclable material can entail numerous different activities (see section 11) 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 demolished building, and the crushing and screening of waste concrete and bricks can occur either at the demolition site or a 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 recycling, typically more mechanised 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 bowsers;
- 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 m^2 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, in certain situations, 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 19: 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 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 bloackages.

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.

8.3 Temporary Storage

Where debris quantities are spread throughout a geographical area and the transportation of the debris to a single centralised recycling yard is neither economically nor logistically feasible, then temporary storage sites can be established. These are temporary depots to which local debris can be brought, and once enough debris has been collected (generally more than 1,500m^3), a mobile recycling 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 plants will have their own power source (generators or the plant being fuel driven).

Photo 20: 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).

8.4 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 typically disposed of at the local 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 oncontrolled 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.

9 DEBRIS PREPAREDNESS PLANNING

Appreciating that debris will arise from the majority of natural disasters and conflicts, 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.

9.1 Legal Issues

One of the first steps is to gain an understanding of the legal situation in the country 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 disaster waste 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.

Consider any waivers of the current laws and regulations in a post-disaster event and have this included in the Emergency Plan (see below).

9.2 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.

This can be done by 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.

9.3 Prioritisation of debris streams

Once each of the debris streams and their potential quantities/sources has been identified, 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.

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.).

9.4 Temporary Facilities

Now that the 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.

9.5 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 process 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.

9.6 Establishment of implementation organisation

There needs to be established an implementation team for the disaster debris work which will implement the Emergency 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 emergency plan since then they have ownership of the plan and can more readily implement.

In addition, a crucial aspect is the development of pull-down contracts in pro-forma style, so pre-identified contractors can be immediately contracted in to remove and handle the wastes. These pull down 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 emergency planning phase.

9.7 Emergency Response Plan

This task brings all the above into an Emergency Plan (EP) with definition of roles and responsibilities for both maintenance of the EP and then actual implementation should a disaster occur. Of course this plan should dovetail into the other disaster preparedness plans developed for other lifelines, such as water, gas, electricity, roads and other wastes.

Included is also government coordination plans so one is hopefully not drowned in administrative bureaucracy!

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.

9.8 Communications plan

For the Emergency Plan to be effective there needs to be a comprehensive Communications Plan (as a part of the Emergency 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.

10 SKILLS REQUIREMENTS

Different personnel skills are required at the various stages of the planning and implementation of debris management schemes with the main ones being presented in this section.

10.1 Personnel

There are predominantly two types of personnel required for a debris management project split between the planning and implementation phases.

Note that Project Management skills are required throughout the project and it is proposed that the same management is maintained through from the planning phase to the implementation to provide consistency.

10.1.1 Planning

During the planning phase, the general requirement is for Technical, Legal and Waste Management expertise within debris and solid wastes, including for waste characterisation, logistics, optioneering on debris processing and engineering applications of the recycled materials.

In addition, Environmental Impact Assessors will be required to support the decision making for how to handle and manage the debris in comparison with the other waste streams.

10.1.2 Implementation

Once the plan and design for the debris management project have been defined, implementation will require more engineering and operative skills under a site manager(s). This includes the operations of the plant and equipment incorporated in the project as well as the general support functions such as mechanics, administration and ‘marketing’ for the purpose of promoting the use of the recycled materials in the reconstruction programmes.

There will be a need to maintain a waste management expertise within the team for the control of debris received at the recycling sites (i.e. waste characterisation for compliance with which debris materials will be accepted) as well as general management of the waste streams passing through the project.

11 Debris Processing Equipment Specifications

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.

11.1 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-recylables.

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 sub-sections present some of the typical methods adopted in post-disaster.

11.1.1 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 21: Islamic Relief project for the clearing and cleaning of debris (including rough cut stones) and subsequent reuse for new foundations (Source: Islamic Relief Pakistan)

11.1.2 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 22: 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: Golder Associates)

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.

Photo 23: Typical conveyors with adjustable belt speed for use as a picking station.

11.1.3 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 24: A primary screening feedstock for removal of soil fraction and possible contaminants (plastics, paper, non-recyclables) before crushing. (Source: Portafill)

11.2 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 45 to 400 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.

11.2.1 Locally manufactured crushers

Photo 25: Locally manufactured "mobile" crusher from Pakistan quarries. (Source UNDP Pakistan).

With there often being a quarry industry in many countries of the world, there is typically a service industry to these quarries. Thus it can often be possible to have locally manufactured small scale crushers produced "to specification" and used in the post-disaster clean-up and recycling works. Discussions with these manufacturers should include consideration for the handling reinforcement bars when crushing the concrete, which will often require a larger aperture for the outlet of the feed hopper.

11.2.2 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.

Photo 26: Crushing of debris in Pakistan following the 2005 Earthquake, using a small, mobile handfed crusher on tracks. (Source: Islamic Relief, Pakistan).

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.

11.2.3 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.

Photo 27: Crushing of debris in Kosovo using a medium sized mobile crusher (yellow machine to the left in photo) and a screening unit for separation of the crushed material into 3 size fractions (green plant to the right in the photo). (Source: Golder Associates).

Medium sized crushers for recycling debris will require an overband magnet for the separation of the reinforcement bars from the crushed material.

11.2.4 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.

11.3 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.

Photo 28: A typical mobile shredding plant for green wastes such as timber and wood. (Source: Vermeer)

11.4 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.

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).

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

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 Private sector handover

There are several options for the handover to private sector 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 own ership 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.

13.2 Public sector handover

Where the Donor wishes to handover the debris management operations to a public sector organisation or department, such as the Office 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.

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.

13.3 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 UNEP's Disaster Waste Management Planning Tool

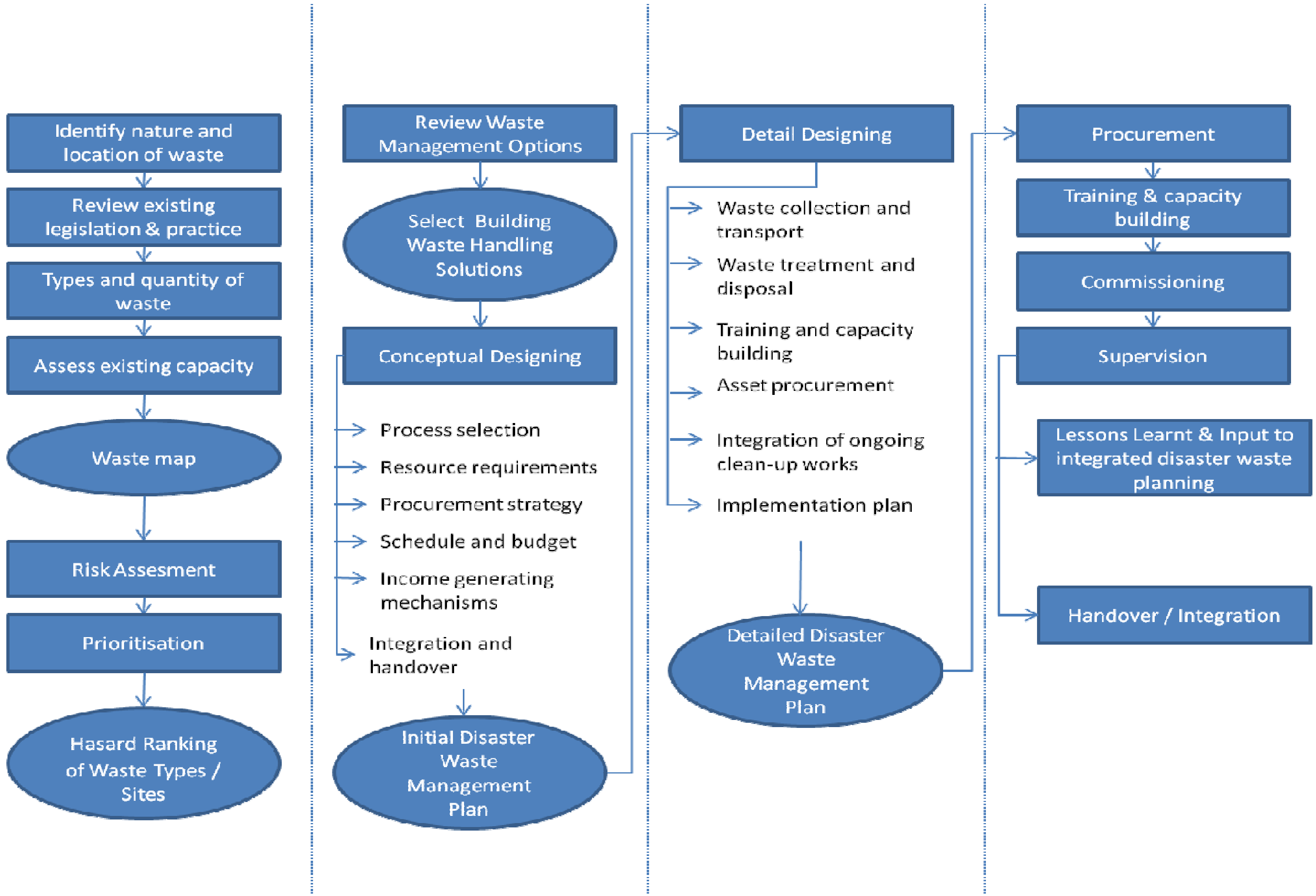
In order to provide a holistic approach to disaster waste management, hereunder debris, the United Nations Environment Programme (UNEP) have developed a planning tool to help identify applicable waste handling processes for reuse, recycling, incineration or disposal of each of the waste streams and / 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.

14.1 Planning a Waste Management project

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.

The following figure is an extract from the plan and the full Plan can be received by contacting Disaster Waste Recovery at info@disasterwaste.org.



SOURCE : UNEP Disaster Waste Management Plan (27 April 2007)