MOSUL DEBRIS MANAGEMENT ASSESSMENT

TECHNICAL REPORT

URP
URBAN RESILIENCE PLATFORM

Disaster Waste Recovery

UN HABITAT
FOR A BETTER URBAN FUTURE

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Cover Image: *Al-Nineveh Street, the commercial centre of Mosul's Old City, lies in complete ruin.* ©UN Environment Programme

Photos: All images in this report were taken by Hassan Partow/UNEP, except photo 9 which is from DWR.

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1.0 STUDY BACKGROUND

Based on an official request from the Iraqi Government for support in assessing the environmental impacts from the ISIL conflict, the United Nations Environment Program (UNEP) is providing technical assistance since July 2017 to national partners in two main areas: i) assessment and management of conflict debris; and ii) assessment and clean-up of contaminated sites. Specifically, UNEP and UN-Habitat initiated an assessment to quantify the volume and distribution of debris in the city of Mosul. Furthermore, UNEP commissioned and partnered with Disaster Waste Recovery (DWR) and Urban Resilience Platform (URP) - two organisations with extensive experience in conflict debris management - to model different operational approaches available to the city of Mosul for debris removal.

The results of this debris assessment and modelling are provided in this document, and were discussed at a workshop held in Mosul University on 19-20 March 2018 organized by UNEP and UN-Habitat in collaboration with national partners. Key stakeholders participating in the workshop include the Committee Responsible for the National Effort to Restore Services in Ninewa Governorate, Mosul Municipality, Ministry of Health and Environment, judiciary, Ninewa antiquities inspectorate, civil protection authorities, civil society and private sector representatives, academia and UN and international development agencies.

The workshop sought to provide a central forum on debris management and achieve four main objectives:

1. Agree on the need for a multi-stakeholder city-wide debris management master plan;
2. Deliberate on the key issues that need to be addressed in a debris plan;
3. Establish a mechanism and process for the creation of this plan; and;
4. Define the success criteria for the plan including identifying key ways to impact desired results.

2.0 CONTEXTUAL ANALYSIS: DEBRIS IN MOSUL

2.1 What is Debris?

This Mosul debris assessment addresses the "debris" generated by the conflict in the city of Mosul until its liberation on 10 July 2017. Debris in this context includes damaged buildings, building materials, furnishings and other miscellaneous products. It specifically does not include the household waste produced on a daily basis by homes, markets, offices, industrial and commercial premises and public-sector offices.

Typical debris in Mosul from damaged buildings and infrastructure comprises concrete, masonry bricks, building stones, gypsum used in traditional mortar and plastering, 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. Due to Nineveh governorate's semi-arid climate, it is expected that a large amount of dust and fines will also be present in the debris. This issue will need due consideration in decision-making on debris management options.

International best practice is to reuse and recycle a high proportion of debris generated by conflicts and disasters. Indeed, it is common that following a conflict of this scale building owners reuse building materials themselves. In fact, this is reportedly already taking place in Mosul where the local population is using the debris to level uneven ground. These efforts need guidance and support to maximize the potential for debris reuse and recycling.

Recycling of debris requires more mechanical processes. Therefore, additional organisation and management is required to enable this activity. In the case of the Old City of Mosul, a potential constraint on debris recycling stems from the relatively high proportion of gypsum and lime used in traditional housing construction which may limit end use applications. Further study is required to determine debris composition and potential end use applications. Nevertheless, this should not discourage recycling efforts as a substantial volume of debris in Mosul does not contain gypsum.

Serious caution needs to be taken concerning the presence of Unexploded Ordnance (UXO) in the debris. Modern industrially manufactured weaponry is known to have a failure rate of up to 10 percent; meaning that one tenth of all launched weapons will remain viable in the debris after battles. In Mosul, where artisanal weaponry was extensively used, the failure rate is expected to be higher. More importantly, the unprecedentedly widespread use of intentionally placed booby traps and improvised mines - especially in the Old City - adds a major complication to debris recovery efforts.

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

Photos 1 and 2: Decisions on the reconstruction of Old Mosul's many historical buildings will have important implications on debris reuse

2.1.1 Immediately Available Debris vs. Unreleased Debris

Throughout this report, debris is referred broadly to encompass both "immediately available" and "unreleased debris". In this context, immediately available debris is that which is easily and safely accessible. For example, fallen debris in roads and along public spaces. Whereas unreleased debris includes that from damaged buildings yet to be demolished and debris which is not easily accessible as within damaged buildings. This concept is critical as it underscores the importance of processes and actions which need to be carried out before the debris can be managed.

Photo 3: Extensive use of gypsum and lime in the construction of Old City buildings may limit the recycling value of the debris

Three key elements need to be addressed in a debris recovery operation of the nature and scale of Mosul:

i. The foremost problem in a post-conflict setting like Mosul is that of explosive ordnance disposal. UXO clearance of areas considered at risk by the armed forces, civil protection authorities and other agencies working in this specialised field (e.g. UN Mine Action Service) needs to be carried out as a pre-condition before handling any debris. A procedure should also be put in place on what should be done in the event that ordnance is found during debris removal operations.

ii. The second issue of importance is that of safe demolition of structurally unsound buildings. Many of the structures which suffered damage during the battle of Mosul are still standing but pose a serious risk of collapse. These buildings need to be demolished safely, which is a complex, dangerous and lengthy procedure, requiring specific skills and tools. This very process will delay the accessibility of debris throughout the clearing process.

iii. Another major question which is often underestimated or overlooked as to its implications on the overall debris recovery process is that of securing the necessary legal authority to undertake the work. Official approval of each individual property owner will be required before clearing the debris from their premises. Gaining this approval, which includes agreement on the responsibility of different materials within the debris, can be time consuming.

Photo 4: Example of easily accessible rubble on the streets, and 'unreleased' rubble from damaged buildings requiring complex demolition.

Photo 5: The demolition of these 10-storey buildings – visibly denting inwards after ISIL blew-up their foundation beams - will generate a considerable amount of rubble.

Photo 6: Artisanal weaponry is strewn in the debris

For the aforementioned reasons, it is important to recognize that debris clearing operations will be phased; with relatively fast progress as the initially accessible debris is removed, then a slowing and plateau as the operations continue into the more complex debris as illustrated in Fig.1.

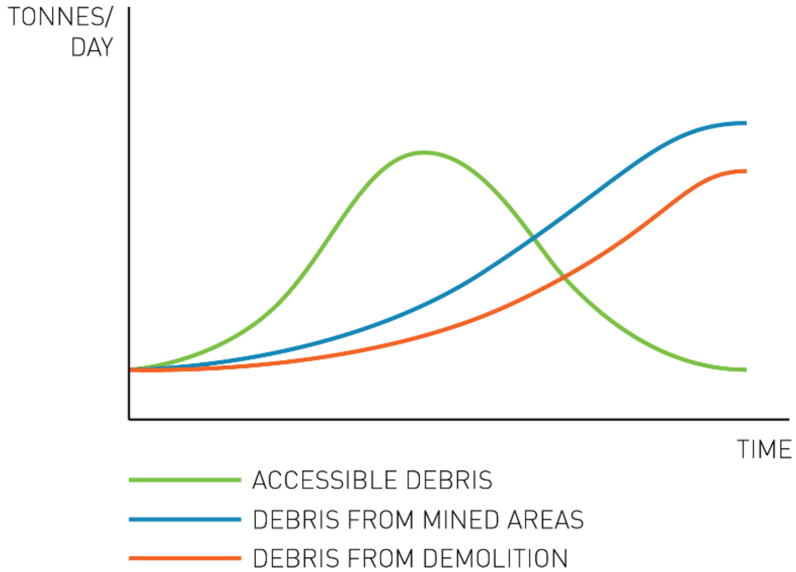


Figure 1: Typical Debris Generation Rates over Time

Photos 7 and 8: Small and versatile debris removal vehicles are needed to navigate through the maze-way of Old Mosul's narrow alleyways (typically 1-5 meters' wide)

3.0 RESULTS OF THE MOSUL MODELLING STUDY

3.1 Debris Quantities

The distribution of debris across the city of Mosul is displayed in Map 1, showing a strong concentration in West Mosul (approximately 75 per cent) and in particular in the Old City. The total quantity of debris is estimated by this study at 7,651,837 tonnes. From these calculations, and according to the methodology described in Section 7.2.1, the following operational scenarios were modelled with the aim of understanding the cost and timespan implications of different approaches to clearing the debris. The five scenarios developed are briefly described below.

Scenario 0: Current Operational Plan

The first scenario modelled is based on survey questionnaires, interviews, group discussions and site visits conducted with Mosul Municipality to understand their present approach using available human and technical resources.

Using this baseline scenario, the debris modelling team developed four theoretical scenarios to demonstrate the potential value of various changes in key management inputs, as identified below.

Scenario 1: Increased Trucking Capacity

Mosul's current transportation fleet was quadrupled, with all unit costs kept constant. All other inputs as per scenario 0.

Scenario 2: Mobile Debris Crushing

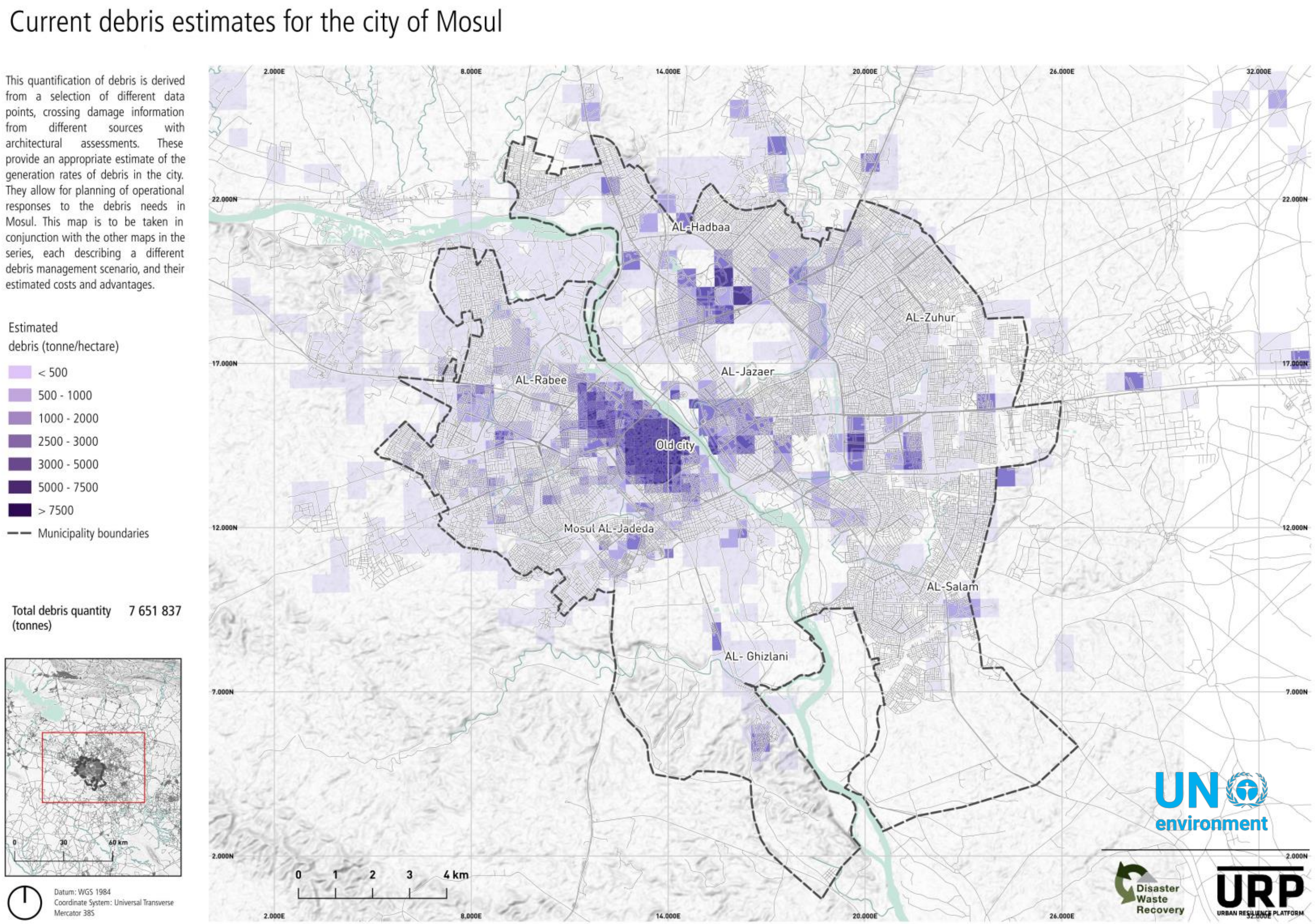
Eighteen small mobile crushers are deployed throughout the Old City, with five medium mobile crushers stationed at the existing transfer stations. All other inputs as per scenario 0.

Scenario 3: Fixed Debris Crushing

Three large fixed crushers were deployed on the outskirts of the city. All other inputs as per scenario 0.

Scenario 4: New Disposal Site

Change of final disposal sites on the Right Bank to site code 93: Ain Al Iraq Project. All other inputs as per scenario 0.



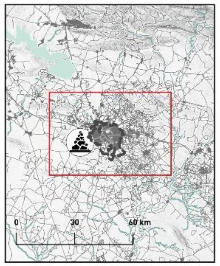
Map 1: Debris Estimates for the city of Mosul

Scenario 0: Current Operational Plan

This quantification of debris is derived from a selection of different data points, crossing damage information from different sources with architectural assessments. These provide an appropriate estimate of the generation rates of debris in the city. They allow for planning of operational responses to the debris needs in Mosul. This map is to be taken in conjunction with the other maps in the series, each describing a different debris management scenario, and their estimated costs and advantages.

Estimated
debris (tonne/hectare)

- < 500
- 500 - 1000
- 1000 - 2000
- 2500 - 3000
- 3000 - 5000
- 5000 - 7500
- > 7500
- Municipality boundaries
- Disposal sites
- Transfer stations



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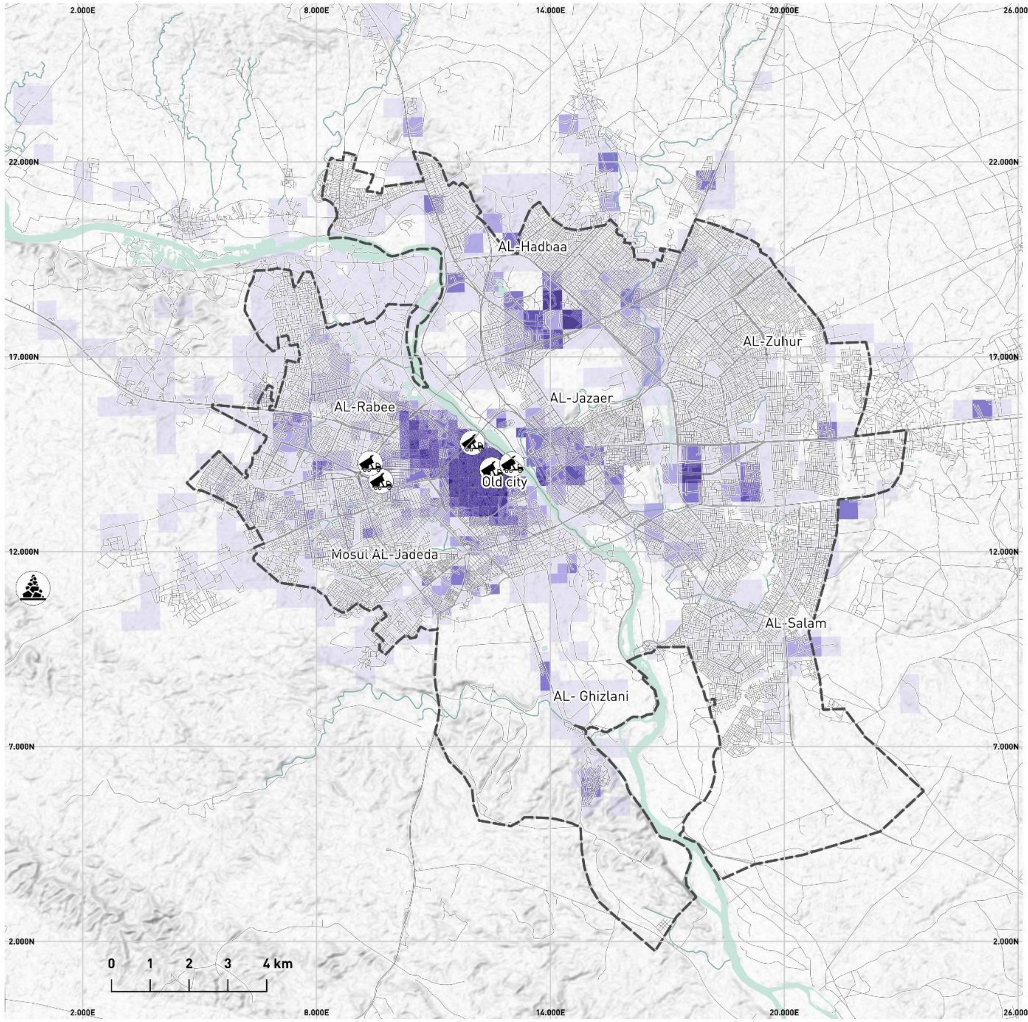


Debris management Model outputs

Total debris quantity (tonnes)	7 651 837

Rolling Stock Used in This Scenario

Truck Type	Big	Small
Capacity (tonnes)	42	14.7
Speed (km/day)	200	200
Cost (USD/day)	130	90
Units deployed	5	50

Total Working years	10.11
Total clearing cost	54 489 221
Reprocessing job creation (Full time equivalent)	-
Total fuel consumption	7 011 534
Trucking distance	26 492 817
	-

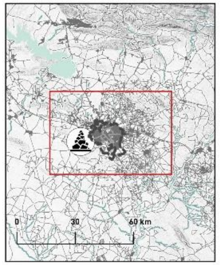
Map 2: Graphical Representation of Inputs and Outputs of Scenario 0

Scenario 1: Increased Trucking Capacity

This quantification of debris is derived from a selection of different data points, crossing damage information from different sources with architectural assessments. These provide an appropriate estimate of the generation rates of debris in the city. They allow for planning of operational responses to the debris needs in Mosul. This map is to be taken in conjunction with the other maps in the series, each describing a different debris management scenario, and their estimated costs and advantages.

Estimated debris (tonne/hectare)

- < 500
- 500 - 1000
- 1000 - 2000
- 2500 - 3000
- 3000 - 5000
- 5000 - 7500
- > 7500
- Municipality boundaries
- Disposal sites
- Transfer stations



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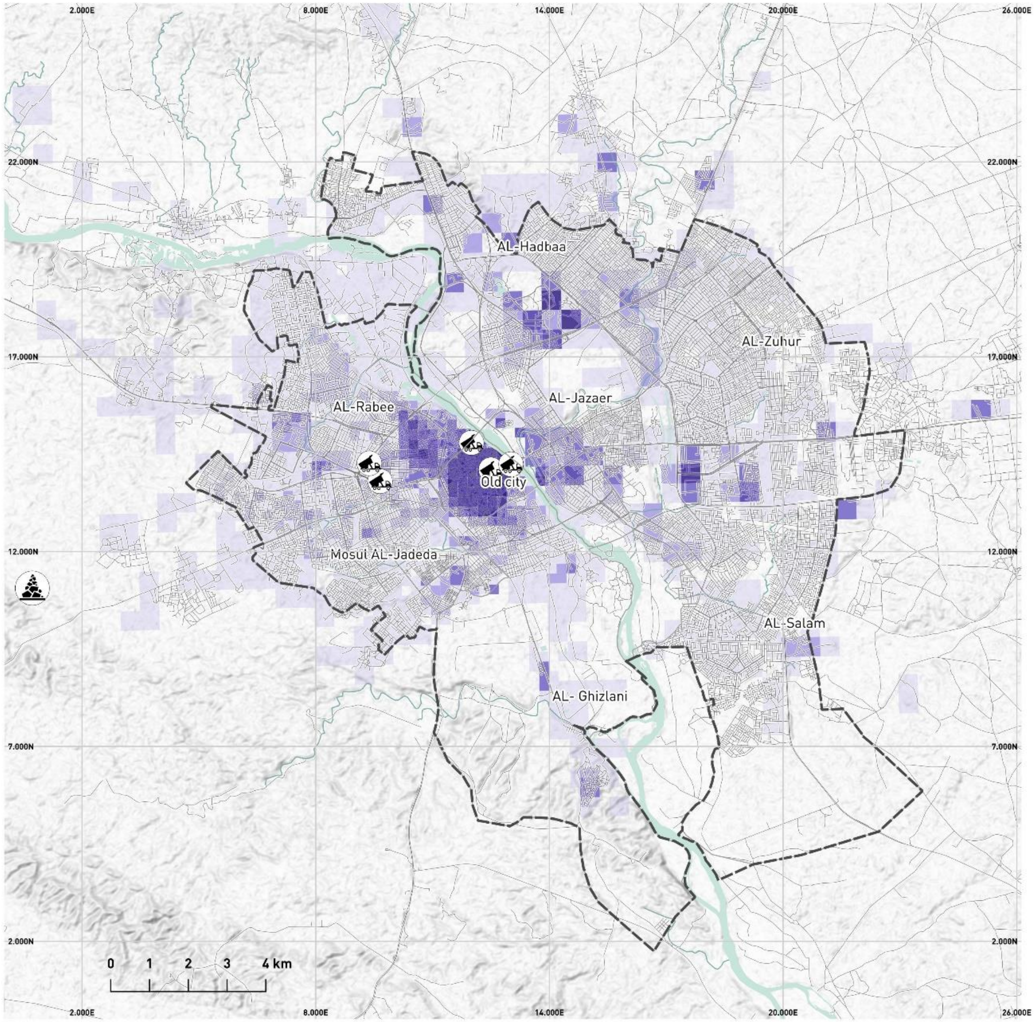

Debris management Model outputs

Total debris quantity (tonnes)	7 651 837

Rolling Stock Used in This Scenario

Truck Type	Big	Small
Capacity (tonnes)	42	14.7
Speed (km/day)	200	200
Cost (USD/day)	130	90
Units deployed	20	200

Total Working years	2.38
Total clearing cost	53 470 921
Reprocessing job creation (Full time equivalent)	-
Total fuel consumption	6 961 361
Trucking distance	26 303 239
Material recovered for (re)construction (T)	-

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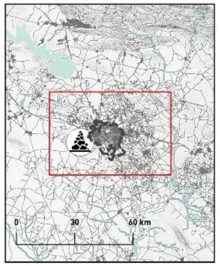
Map 3: Graphical Representation of Inputs and Outputs of Scenario 1

Scenario 2: Mobile Crushing

This quantification of debris is derived from a selection of different data points, crossing damage information from different sources with architectural assessments. These provide an appropriate estimate of the generation rates of debris in the city. They allow for planning of operational responses to the debris needs in Mosul. This map is to be taken in conjunction with the other maps in the series, each describing a different debris management scenario, and their estimated costs and advantages.

Estimated debris (tonne/hectare)

- < 500
- 500 - 1000
- 1000 - 2000
- 2500 - 3000
- 3000 - 5000
- 5000 - 7500
- > 7500
- Municipality boundaries
- Disposal sites
- Transfer stations
- Mobile crushers



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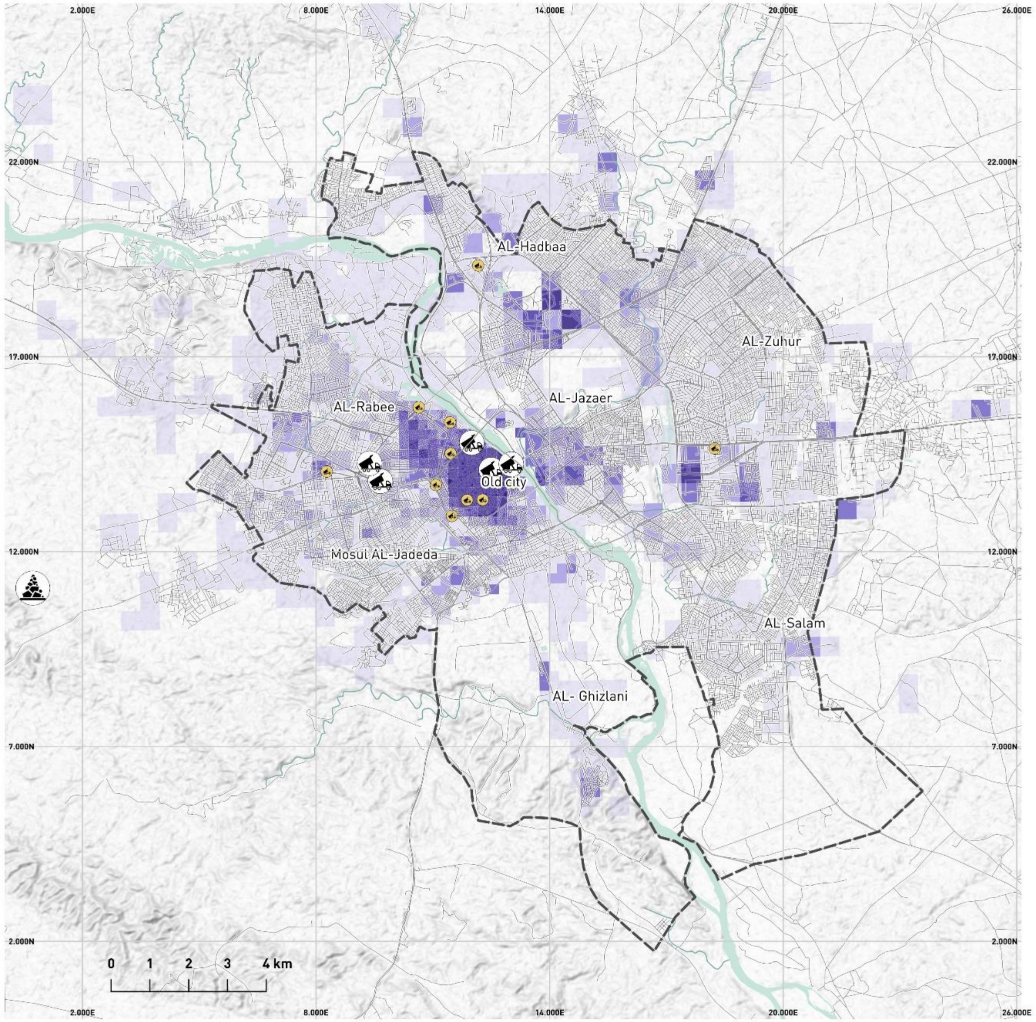

Debris management
Model outputs

Total debris quantity (tonnes)	7 651 837

Rolling Stock Used in This Scenario

Truck Type	Big	Small
Capacity (tonnes)	42	14.7
Speed (km/day)	200	200
Cost (USD/day)	130	90
Units deployed	5	50

Total Working years	7.20
Total clearing cost	49 914 999
Reprocessing job creation (Full time equivalent)	134 820
Total fuel consumption	7 101 175
Trucking distance	15 964 060
Material recovered for (re)construction (T)	3 973 757

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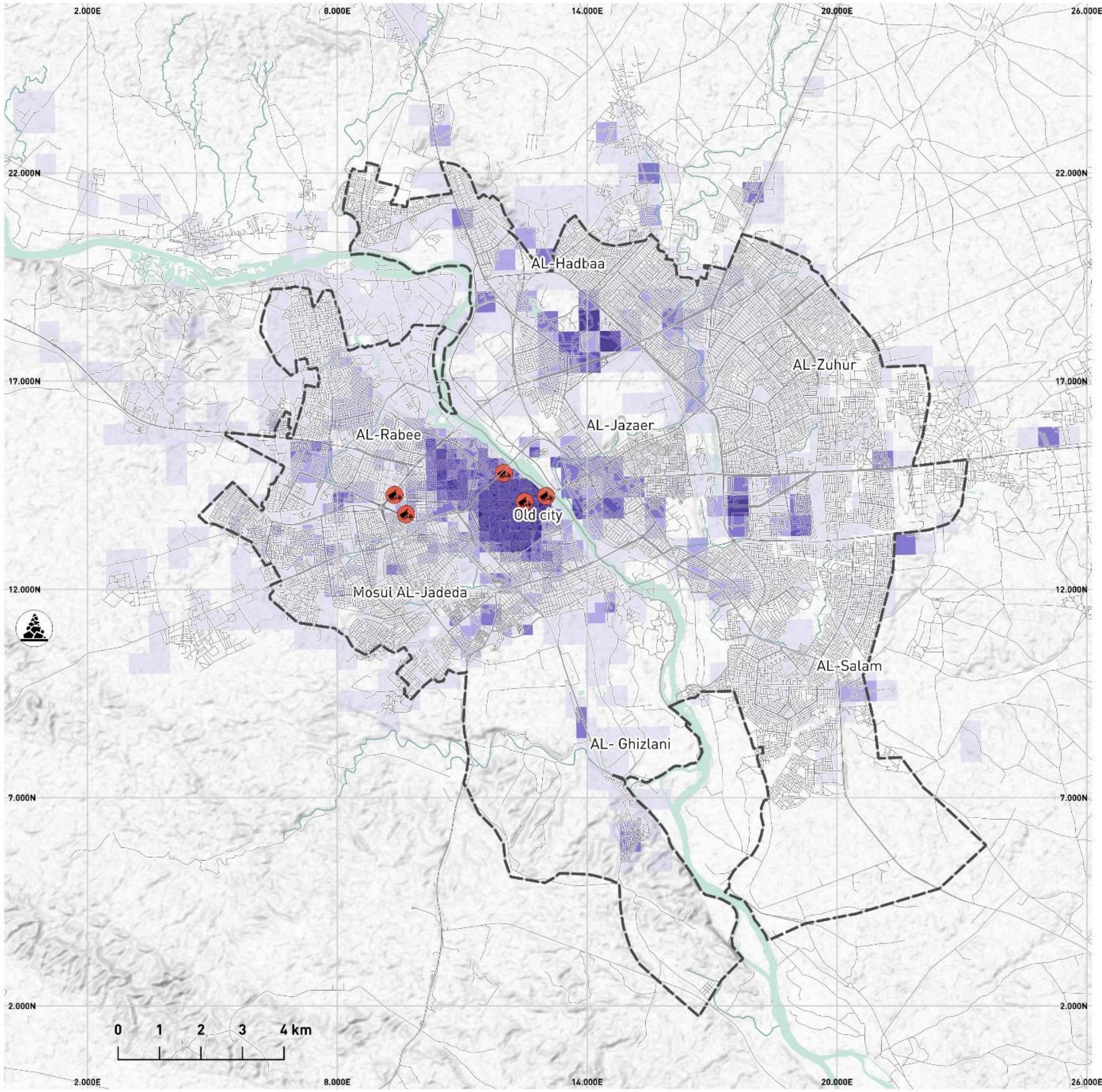
Map 4: Graphical Representation of Inputs and Outputs of Scenario 2

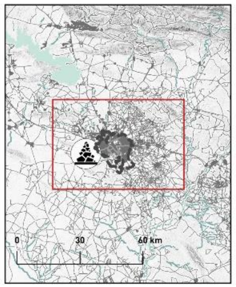
Scenario 3: Fixed Crushing

This quantification of debris is derived from a selection of different data points, crossing damage information from different sources with architectural assessments. These provide an appropriate estimate of the generation rates of debris in the city. They allow for planning of operational responses to the debris needs in Mosul. This map is to be taken in conjunction with the other maps in the series, each describing a different debris management scenario, and their estimated costs and advantages.

Estimated
debris (tonne/hectare)

- < 500
- 500 - 1000
- 1000 - 2000
- 2500 - 3000
- 3000 - 5000
- 5000 - 7500
- > 7500
- Municipality boundaries
- Disposal sites
- Fixed large crushers





Datum: WGS 1984
Coordinate System: Universal Transverse Mercator 38S

Debris management Model outputs

Total debris quantity (tonnes)		7 651 837
Rolling Stock Used in This Scenario		
Truck Type	Big	Small
Capacity (tonnes)	42	14.7
Speed (km/day)	200	200
Cost (USD/day)	130	90
Units deployed	5	50
Total Working years		6.20
Total clearing cost		34 030 504
Reprocessing job creation (Full time equivalent)		38 680
Total fuel consumption		5 077 742
Trucking distance		13 705 397
Material recovered for (re)construction (T)		4 770 201

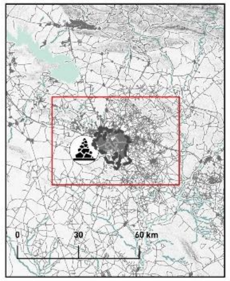
Map 5: Graphical representation of Inputs and Outputs of Scenario 3

Scenario 4: New Disposal Site

This quantification of debris is derived from a selection of different data points, crossing damage information from different sources with architectural assessments. These provide an appropriate estimate of the generation rates of debris in the city. They allow for planning of operational responses to the debris needs in Mosul. This map is to be taken in conjunction with the other maps in the series, each describing a different debris management scenario, and their estimated costs and advantages.

Estimated debris (tonne/hectare)

- < 500
- 500 - 1000
- 1000 - 2000
- 2500 - 3000
- 3000 - 5000
- 5000 - 7500
- > 7500
- Municipality boundaries
- Disposal sites
- Transfer stations



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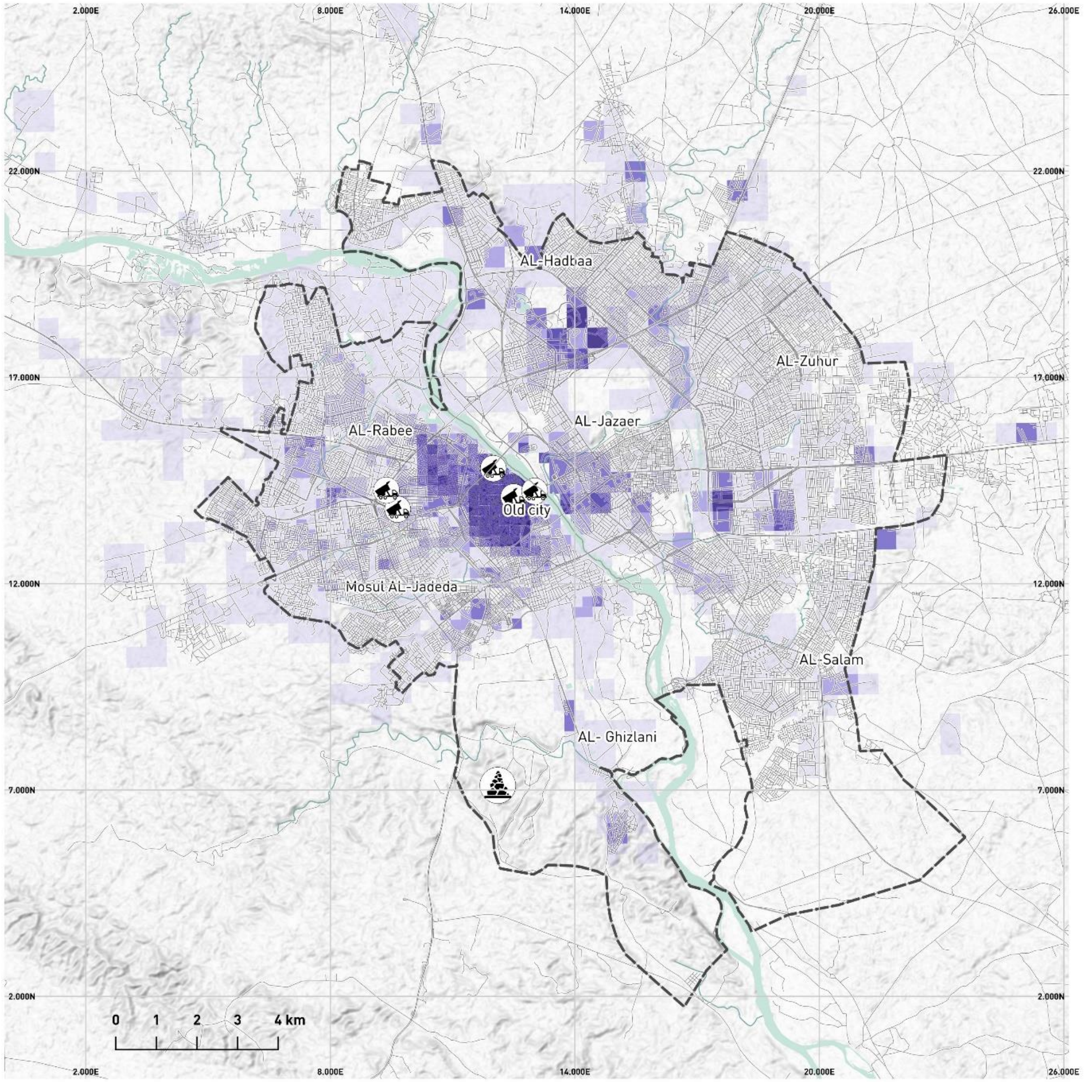

Debris management
Model outputs

Total debris quantity (tonnes)	7 651 837

Rolling Stock Used in This Scenario

Truck Type	Big	Small
Capacity (tonnes)	42	14.7
Speed (km/day)	200	200
Cost (USD/day)	130	90
Units deployed	5	50

Total Working years	6.47
Total clearing cost	33 352 555
Reprocessing job creation (Full time equivalent)	-
Total fuel consumption	4 445 679
Trucking distance	16 797 830
Material recovered for (re)construction (T)	-

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Map 6: Graphical Representation of Inputs and Outputs of Scenario 4

3.2 Breakdown of Results

The results of each scenario were normalised for five key criteria by indexing them against the maximum value under that category: **i)** time to clear; **ii)** total clearing cost; **iii)** total fuel consumption; **iv)** trucking distance; and **iv)** material disposed.

The indexed results are shown in the radar diagram below where the preferred outcome for each category is situated at the centre of the diagram. Scenario results are also compared in additional charts shown in Figures 3-5.

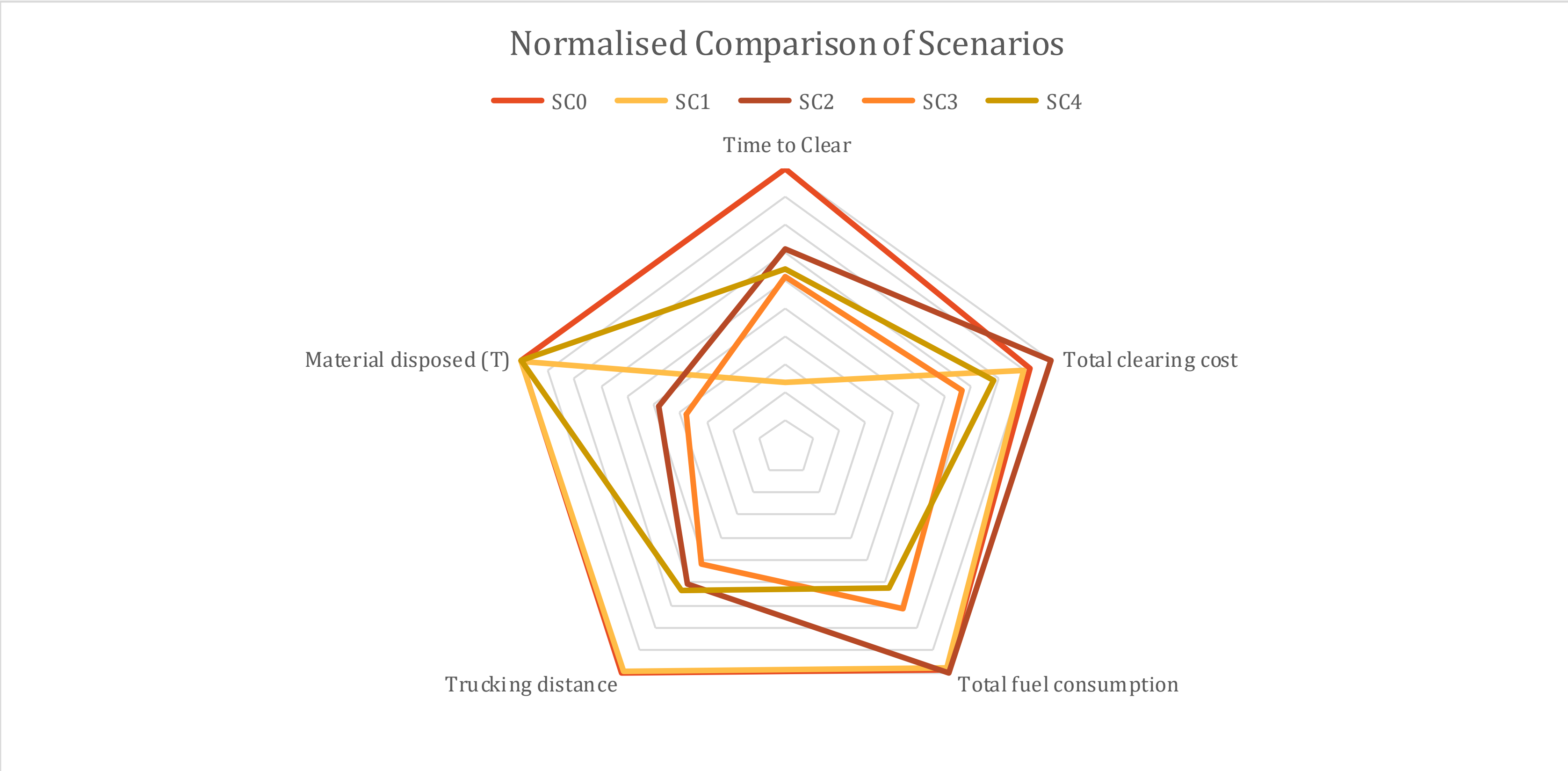

Figure 2: Normalised Comparative Results of the Scenarios

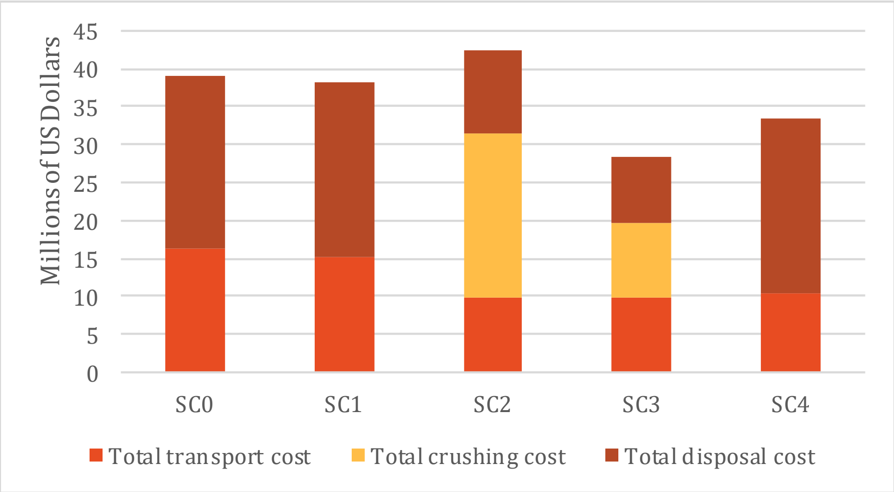

Figure 3: Total Fuel Consumption Breakdown

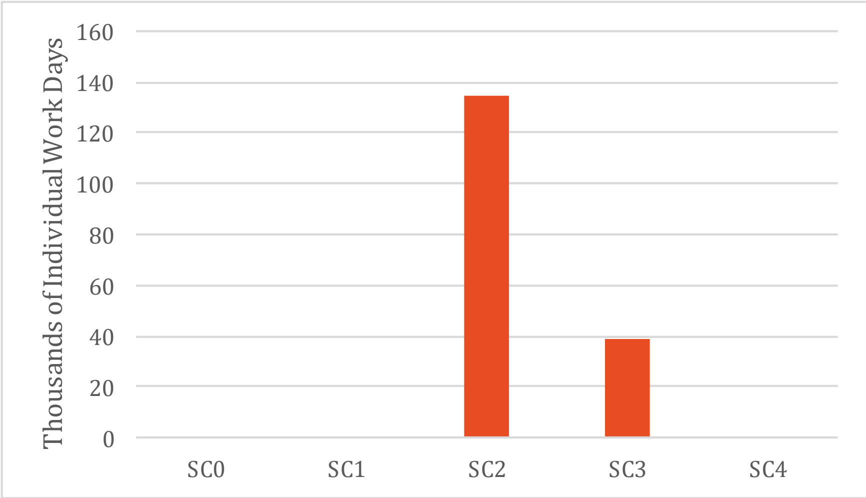

Figure 4: Workdays Created through Material Recovery

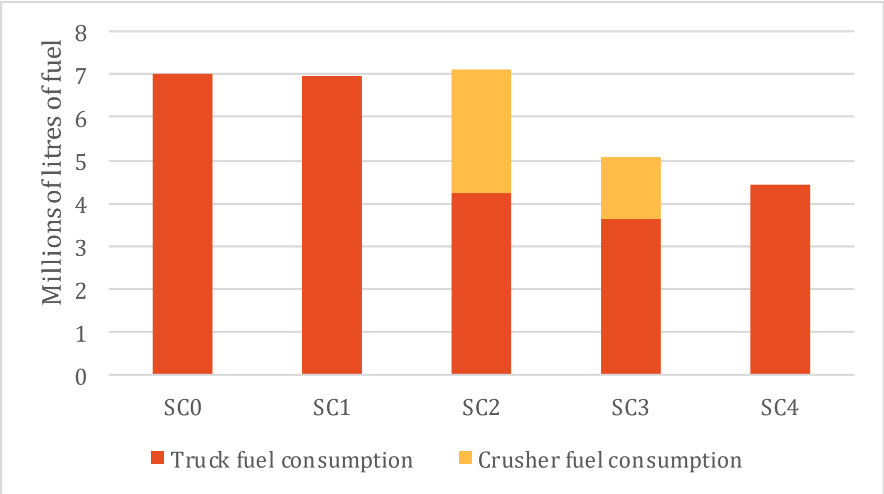

Figure 5: Total Cost Breakdown

4.0 METHODOLOGY

4.1 Quantitative Analysis of Debris in Mosul

Debris quantities in Mosul were estimated using multiple information sources and analysis methods. These methods are described below, as well as the ways in which they interact with each other to arrive at final city-wide estimates.

4.1.1 Damage Analysis through Satellite Imagery

Damage assessments based on satellite imagery analysis were conducted by both UN-Habitat and UNOSAT. The results of these studies were not identical and were therefore used in complementarity.

UN-Habitat data

This damage data was provided according to damaged parcels with an extra indication of whether the damaged parcel was:

- Housing
- Administration
- Factory
- Religious
- Commercial
- Road

The Debris Review Team conducted a rapid architectural assessment to arrive at debris quantities per municipal sector for these different types of constructions. These factors were then associated to the numbers of damaged buildings of each category, as well as their overall size based on image analysis.

Using this approach, the total debris distribution map for the city of Mosul was generated as shown in Map 1. The methodology for these calculations is detailed in the following section.

4.1.2 Methodology Details

Using an assessment template provided by the debris review team, UNEP and UN-Habitat compiled a debris specific architectural assessment of the city. First, six typical building types were defined according to their average size and occupancy. The table below shows the characteristics of these building types as defined for this assessment. The final column shows the results of the calculations based on the information provided from the field questionnaire.

Table 1: Definition of Basic Building Types in Mosul

Building Type Name	Average Number of Floors	Average Total Area (m2)	Typical Number of Occupants	Building Material	Debris Generation Rate (t/ 100m2)
Small Single Family	2	100	4	Masonry Bricks, Concrete Blocks and Reinforced Concrete	80
Common House	2	200	6		100
Large Villa	2	500	9		120
Apartment Complex	3	400	40		140
Commercial Buildings	4	400	20		80
Old Single Family	1	100	8	Rough Cut Stone and Steel Sections	120

Once defined, the prevalence of each building type relative to each other was determined in each Municipal Sector by UNEP/UN-Habitat in consultation with Mosul Municipality. The table below shows the distribution of each Building Type for each municipal sector

Table 2: Distribution of Building Types within each Municipal Sector

Municipal Sector	Make-up of Municipal Sector by Building Type					
	Small single family home	Common House	Large Villa	Appartment Complex	Old Single Family Home	Commerical Building
AL-Hadbaa	10%	65%	10%	10%	0%	5%
AL-Zuhur	10%	10%	65%	5%	0%	10%
AL-Salam	20%	80%	0%	0%	0%	0%
Al-Tahreer	25%	50%	10%	10%	0%	5%
AL-Rabee	10%	40%	50%	0%	0%	0%

Municipal Sector	Make-up of Municipal Sector by Building Type					
	Small single family home	Common House	Large Villa	Appartment Complex	Old Single Family Home	Commerical Building
Old City	10%	20%	5%	0%	50%	15%
Mosul AL-Jadeda	25%	60%	10%	0%	0%	5%
Nergaal	20%	20%	60%	0%	0%	0%
AL-Ghizlani	15%	25%	30%	10%	15%	5%

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4.1.3 Types of Debris

Actual options on how to deal with the debris once generated are varied. Potential alternatives are largely dependent on the "quality", quantity and location of the debris as well as potential end use applications, (i.e. market opportunities for the reusable and recycled materials produced). Often the debris management option selected will be highly local, and a result of grassroots initiatives. Where debris management plans and projects are thus brought in by external partners, these local initiatives are to be respected and integrated to ensure community benefits and focus. In the case of Mosul, it was noted that the local population was using the debris to fill in and level low lying areas on top of which buildings may be constructed. However, this is done without crushing the rubble which may affect the structural stability of the construction.

In general, emphasis should be placed on optimising the benefits which can be gained from debris through:

- i. reducing public health risks by removing the debris from populated areas;
- ii. employment generation;
- iii. reusing and recycling the debris;
- iv. substituting quarry materials; and
- v. minimising waste quantities requiring disposal at a landfill.

It is important to recognise that initial handling of the debris can have a significant impact on the options available for debris management. For example, if the debris is mixed with general waste then recycling opportunities are considerably reduced since pre-sorting of the debris/waste would be required. Mixing of debris with general waste can easily happen if the debris is left dumped over a period of time in urban areas where the public will view the debris pile as a "waste" pile and add their own wastes to the heap. Also, if the debris is removed from a localised conflict zone and dumped with other wastes at a municipal "dumpsite", then it can become too mixed to reuse/recycle and the potential opportunities are lost. Both of these situations were observed to be taking place in Mosul.

Options for dealing with the main types of debris include:

Mixed Debris

For debris which is mixed with non-reusable and non-recyclable items, 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 a better use of limited resources to utilize manual labour on repairing water supply to an affected community than on 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 similar applications. 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.), as these 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 could be a risk due to the gradual decomposition of the degradable materials that may be present in the mixed debris.

Photo 8: Recycling value of debris may be lost if it is mixed with household waste

Where the mixed debris contains hazardous materials such as heavy metals, oils, and chemical residues, these will need to be sorted from the debris for separate controlled disposal. Alternatively, 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, and the debris characterised based on the results of the laboratory analyses.

Relatively Clean Debris

Where debris is relatively clean - i.e. only minor quantities of inorganic materials such as paper, plastics and soils is present - 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 percent of the total quantity, then this material can readily be crushed and separated into the required fractions for road-base material. This would be a useful material in Mosul reconstruction programmes where the rehabilitation of roads is an important requirement. Should the economics be viable, then it may be justifiable to separate the non-recyclables from the debris before crushing to improve the quality of the debris in order to meet the road-base 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 materials from quarries. This rational is also applicable to mixed debris. Calculations for these costs are included in the modelling section below.

Photo 9: Debris recovered as part of clean-up operations in Muzaffarabad (Pakistan) was used as engineering fill material

Clean Debris

Where the debris is clean, it can readily be crushed and screened for most applications typically associated with crushed stone from quarries. The only technical limitation being compliance with the relevant engineering 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 application value of the crushed and screened clean debris are often higher since the 'quality' of the recycled material will be similar to natural gravel. It can therefore be used in road construction or in low strength concrete foundations and pavements.

Clean debris is most likely to be producible during the later phases of debris management, where debris is being "released" from structures requiring demolition or explosive ordnance disposal.

Asbestos

To ensure safe handling and management of asbestos that may potentially be found in the debris, it is important that national legal requirements are enforced[1]. Reference can also be made to general guidance on asbestos including "Safe handling of Asbestos in Disaster Response Operations"[2]. During the debris management workshop, it was noted that graduate students from Mosul University's Environment College are planning to conduct a sampling campaign to assess the presence of asbestos in the debris. The results of this survey should provide useful information on the potential extent and nature of asbestos contamination in the debris.

[1] Instructions No 1 of 2002 for Safety for Using of Asbestos available at: http://www.moen.gov.iq/LinkClick.aspx?fileticket=Tor3aqwk2pw%3d&portalid=0&language=ar-IQ

[2] This booklet developed by ProAct Network, Shelter Centre and Disaster Waste Recovery is available at: www.shelterlibrary.org

5.0 DEBRIS MANAGEMENT OPTIONS

The management of debris includes a wide variety of operational choices. Some of the main options available to a municipal entity facing large scale debris management issues are discussed here. The following section will then propose the use of different choices in operational planning.

5.1 Disposal

The disposal of debris on land is often the first option to be considered. It benefits from a sheer simplicity of operation; whereby trucks are simply directed to a predetermined location to deposit their debris loads onto the land. The disposal area can be chosen for a variety of reasons. For example, a previous waste disposal site or an area of low lying land from which the municipality would benefit if the land were raised.

The disadvantage of dumping lies in the wastage of valuable material which could - if thought through carefully - be reused for reconstruction; thereby reducing costs and creating employment opportunities. Additionally, disposal sites are usually by definition located outside of the city and therefore require large scale and potentially long distance transport and complex logistical operations. The costs of dumping may even be rendered prohibitive by the sheer distance between the debris generation location and the disposal site. Furthermore, there is the issue of air pollution generated from vehicle transport including carbon dioxide emissions.

The location of the disposal site also requires proper assessment to ensure that it does not negatively impact nearby residential areas, and potentially sensitive environmental receptors such as water courses or aquifers. The long term liabilities of debris disposal (which may not have been properly sorted and still contain hazardous materials) needs to be carefully considered in selecting a suitable disposal site.

It is important to realise that although a disposal operation is relatively straightforward, it is not cost free. The management of the disposal site itself comes at a price including expenditures on:

i. heavy machinery required to manage the site and reposition the debris safely;
ii. staff required to control access to the site and manage the traffic;
iii. dust suppression operations;
iv. site fencing;
v. basic health and safety facilities.

5.2 Land Reclamation

Land reclamation involves the organised and appropriate disposal of debris in low lying or wet areas to create new usable land. The advantage of this activity include:

i. the sheer quantity of material which can be absorbed;
ii. the creation of an economically valuable space; and
iii. reducing the cost of the transportation.

A good example of this approach is after the 2011 earthquake in Christchurch, New Zealand, where much of the Central Business District's debris was used to extend the Lyttleton Port Authority, as displayed in Map 7.

Map 7: Lyttleton Port Authority Reclamation Plans

Photo 10 Mosul Municipality is considering using the debris to extend the city's waterfront on the Tigris River

Although Mosul does not have a coastline on which to reclaim land, Mosul Municipality has plans to extend its waterfront along a nine kilometre stretch of the Tigris River[3]. These plans are currently being reconsidered and need careful study including ensuring that any debris used is not contaminated with hazardous substances as it may impact river water quality. In addition, Mosul and the surrounding area may benefit from raising land out of high water table levels. For example, high water tables in the Old City of Mosul exacerbated by the lack of a wastewater drainage system has reportedly created underground voids and caused land cave-ins. Significantly, the Old City itself is built on mounds of ancient settlements and buildings made of limestone and gypsum which are susceptible to dissolution by water. This has created a chronic land subsidence problem in the Old City. Raising the land level and filling voids with debris therefore can be explored as a potential reuse option.

[3] On both the eastern and western banks of the river; of which 2 kilometres were reportedly completed.

5.3 Crushing for aggregate

Crushing debris allows for materials of a smaller fraction size to be used in high value aggregate reuse opportunities. Crushing, as described in the previous section can be carried out on clean, or relatively clean debris; meaning that fresh debris may require prior sorting. The process of compression crushing can be carried out by a large variety of differently sized machines. These simply apply a pressure on the inert material to such an extent that its overall size is reduced.

Examples of possible crushers are provided in Annex 1, which illustrates a sample of potential sizes and setups. These are only a selection and the appropriate machine(s) should be chosen based on a range of criteria including:

i. relative crushing capacity;
ii. space available for mobilisation; and
iii. the distance which can be covered by the equipment independently.

5.4 Creation of small scale industries through debris recycling

Debris can also be a resource for small scale industries creating locally valuable materials. These materials will strongly depend on the type of debris available, but most importantly on the market available for the final product. Although these small-scale industries may be scalable and create a large number of employment opportunities, it is important to realise that the capacity of these industries to absorb large quantities of debris will not always be immediately evident. While these enterprises may help create much needed jobs, they should not be regarded as responsible for removing debris from the city.

Photo 11: Recovery of reinforced steel bars from rubble is a source of work in Mosul

6.0 BUILDING SCENARIO 0: CURRENT OPERATIONAL SETTINGS

6.1 How are priorities decided?

Mosul Municipality is prioritizing debris management in the Old City and the immediately surrounding sectors in Western Mosul, where fighting was most intense and where most of the debris is located. The residents of the Old City are presently unable to return to their homes due to the high level of destruction, which is further complicated by widespread contamination with explosives and booby traps. Cleaning-up the debris to enable residents to return to their houses and businesses in the Old City is a top priority for the authorities. Eastern Mosul suffered considerably less damage, and most of the streets are now cleared of debris. Nevertheless, there are a number of buildings in Eastern Mosul which will need to be demolished and which may generate a potentially large volume of debris.

6.2 Key remaining questions that need to be addressed

6.2.1 Selecting a new disposal site

A key question currently under consideration by Mosul Municipality is determining the most efficient location to open a new disposal site. This new site should be able to receive all the debris which is being collected in the Old City as well as from any other part in the right bank of Mosul (i.e. Western Mosul). Furthermore, the site should be located within an acceptable distance of the city (i.e. within an approximately 10 kilometre radius), to ensure economical hauling opportunities and to reduce costs. It is important to realise that the selected site will also require basic preparations to enable efficient safe storage of debris. In particular, a basic understanding of the underlying environmental receptors at the site will need to be gathered. This will include but is not be limited to:

i. soil condition and particularly its permeability;
ii. studies on groundwater movement in the immediate vicinity of the site;
iii. determination of the potential receptors and potential pathways to these receptors; and
iv. pollution sources within the debris.

Mosul Municipality provisionally identified the "Haj Hamad Kreaz Valley" as the preferred disposal site[4]. The appropriateness of this site is tested in the next section to assess its impact on the overall efficiency of the debris management operation.

Photo 12: The Haj Hamad Kreaz Valley Valley which Mosul Municipality is considering as a potential debris disposal site

[4] Where Mosul Municipality owns a large track of land of around 1,000 donums equivalent to 2.5 square kilometres.

6.2.2 Closing transfer stations

Mosul Municipality has so far provisionally identified a total of five transfer stations within and near the Old City. At the same time, there is concern in terms of calculating the most efficient time to put an end to the use of each of these sites, and understand the effect this will have on the progress of the overall debris management operation.

Once a decision to close a site is made, the process of returning the site to its previous use may be more complicated than initially thought. It may, for example, include:

i. the need to study the impacts the debris has had on the local area;
ii. ensure the clean up or mitigation of these impacts;
iii. set about the return of previously existing infrastructure to the site; and
iv. install a monitoring system to track potential pollution hazards.

Significantly, when an area is used as a temporary transfer site, habits may have been created within the local population whereby they will have started to use the ground as a disposal site for their own daily waste generation. Ensuring these types of behaviours, if they exist, are swiftly and efficiently broken is important.

Photos 13 and 14: The Sayha interchange in western Mosul was used as an informal debris dump (left, November 2017), but was later cleared (right, February 2018)

6.2.3 Demolition of structurally unsound buildings

As debris removal operations progress and more streets and neighbourhoods become accessible, and with people continuing to return to their homes, ensuring their safety will be an important priority. Many buildings and structures in Mosul have been damaged in a way that while they are still vertically standing, their structural integrity is compromised. Moreover, it is known that ISIL deliberately sabotaged buildings so as to render them unusable and unsafe; such as by detonating their foundational pillars. There is therefore a serious safety issue with these buildings; both for the people who intend to reoccupy them, but also for the general public using passageways around these buildings. This problem is compounded by the earthquake risk which is inherent to the local area.

It is important for the responsible authorities in Mosul to put together a legally acceptable process for the demolition of these structures. In particular, a fair and transparent process needs to be established to enable Mosul Municipality to enforce the removal of dangerous structures. At the same time, a mechanism to compensate the owners of these structures in an open and just manner should be set-up.

6.3 Environmental impacts of quarrying

While not itself a debris management issue, it is important to recognize that the decision to dispose and/or reuse and recycle debris will have different repercussions on the environment and resource material use. Disposing of all the debris would mean that nearly an equivalent amount of construction aggregate (i.e. gravel and sand) would need to be used in Mosul's reconstruction; assuming that rebuilding plans aim to restore the original city design. Lessons learned from Lebanon's post-2006 reconstruction indicate that the upsurge in quarrying activity resulted in long-lasting environmental impacts which raised tensions amongst local communities. In the case of Mosul, it would effectively mean bringing in around 7.6 million tonnes of raw materials from quarries for the city's reconstruction. Raw material extraction at this scale will have a substantial impact on the local environment. In the Mosul region, the type of quarrying practiced is almost exclusively based on instream gravel and sand mining (as opposed to hard rock mining); which is one of the most environmentally aggressive and destructive forms of quarrying. Instream gravel and sand mining destabilizes river channel morphology, and substantially degrades riverine and wetland habitats. This may cause loss in fishery resources, and lower the water table thereby impacting water supplies to riparian communities. The recreational value of these rivers may also be spoiled.

Along the Great Zab and Al-Khazir rivers where most of the construction aggregate used in Mosul originates, instream quarrying is ravaging valuable agricultural land including orchards. This is because local communities typically cultivate both within the wide seasonal channels and along the river banks. As quarry rehabilitation is typically not carried out in Iraq, the degraded landscape disfigured by deep mining pits represents a permanent loss of livelihood for the local population. Furthermore, increased river bank erosion and turbidity may damage infrastructure assets. For example, the Badush quarries on the Tigris River upstream of Mosul are located opposite the city's main drinking water treatment plant and may impact its operations.

Iraq's water and environmental laws contain provisions for the protection of river banks and channels from degrading activities. However, these laws are generally poorly enforced, especially in the conflict-affected areas where environmental oversight is weak or absent. Moreover, overwhelming reconstruction needs has generally led to environmental considerations being overlooked

The result is that commercial quarrying activities are currently unregulated with many operators not possessing valid permits and/or do not adhere to the limits of their land concessions. Another issue is that the main quarrying sites at Al-Kuwayr (Kanhash) and Al-Khazir are in territories contested by the central government and the Kurdistan Regional Government. As reconstruction steps-up and the scale of environmental impact becomes evident, tensions risk arising with communities living near the quarries. It may also further aggravate jurisdictional disputes between the central government and the Kurdish authorities.

Photo 15: Large-scale quarrying companies operate on the Great Zab River

In February 2018, the cost for one tonne of gravel and sand was respectively USD 3 and USD 4 at instream quarries near Aski Kalak on the Great Zab River. The rate for one trailer trip to Mosul with a capacity of 40 tonnes was USD 140. Therefore, the total cost per one trailer trip of gravel and sand was USD 260 and USD 300 respectively.

Assuming an average cost of USD 280 per trip, the average delivery cost per one tonne of aggregate to Mosul is approximately USD 7. The cost of importing aggregates for the reconstruction of Mosul (ca. 7.65 million) would therefore come to around USD 53.6 million dollars. Moreover, the cost for aggregates is currently considered particularly low and will most likely significantly rise as rebuilding efforts pick-up and demand grows.

Photo 16: Open pit mines in river channels are rarely rehabilitated

In this context, substituting raw materials through debris reuse and recycling would not only have important cost-saving benefits but would also reduce the environmental footprint of quarrying on ecologically sensitive watersheds. At the same time, it is important that the distribution and extent of quarrying activities are monitored and that safeguards are put in place to control and mitigate their social and environmental impacts. This includes rehabilitation of quarry pits and degraded fluvial landscapes.

Map 8:Quarrying opposite the main water treatment plant upstream of Mosul near Hulaylah

Map 9: Quarries encroaching on agricultural land along the Great Zab River at Al-Kuwayr

Table 3: Quarrying in Mosul region by order of priority

Site Name	Latitude	Longitude	Quarry type	Materials extracted
1. Al-Kuwayr/Kanhash	36° 2'18.70"N	43°27'46.55"E	Instream, Great Zab River approximately 50 km south east of Mosul	Sand and Gravel
2. Al-Khazir	36°17'22.09"N	43°31'50.56"E	Instream, Al-Khazir River approximately 40 km of Mosul	Sand and Gravel
3. Badush/Hulaylah	36°23'37.18"N	43° 2'23.72"E	In-stream, Tigris River approximately 12-15 km upstream of Mosul	Sand and Gravel; Sub-base materials
4. Al-Muhallabiyah	36°15'58.51"N	42°42'14.00"E	Rock quarry, approximately 40 km west of Mosul	Sub-base materials
5. Al-Akwar	36°18'7.33"N	43° 0'6.56"E	Rock quarry, approximately 10 km west of Mosul	Gypsum

7.0 MODELLING THE CURRENT DEBRIS SYSTEM

Potential debris management solutions for the city of Mosul were mapped using the URP debris tool. This tool is designed to provide decision making support on debris management. A main advantage of this method is to understand the marginal value of specific debris planning decisions; allowing for the creation of an optimal debris management scenario. The key decisions this tool will support are, for example, whether specific investment in debris management infrastructure would be worthwhile; where the most judicious location for a disposal site might be; or which type and size of debris management equipment would be best suited for a specific location.

7.1 How the tool works

The tool is made-for-purpose software with a variety of data inputs, which run through a series of algorithms and produce an output. Each combination of inputs together is considered a single scenario, the results of which can be displayed to the user. A single change in a data input creates a new scenario, which can be compared to the previous one, thereby creating a basis for decision making. The overall process of the tool is described in the flow chart in Figure 6.

7.1.1 Tool inputs

The data used in the URP debris tool is grouped under four main categories:

i) Debris quantities and locations

The quantities of debris present in the city, distributed according to their location, are a key input for the tool. The input for this element was derived according to the method described in Section 4.1 Quantitative Analysis of Debris in Mosul.

ii) Road-network distances between points

The road network which is usable and available is essential to understand the possible movement of debris through the city. This input allows the tool to understand the distances between all debris locations and their possible destinations including transfer, reprocessing and disposal sites.

In the case of Mosul, as a decision was made to handle debris on the right and left sides of the city as two separate operations, the road network distances were calculated with the assumption that heavy vehicles will not use the bridges to transfer and dispose of debris.

iii) Debris Management Infrastructure

The inputs in this case include the location of existing infrastructure; its daily capacity if this is limited (e.g. crusher); its maximum storage capacity if applicable (e.g. transfer station); and its operational costs.

iv) Available Rolling Stock

To connect all the above inputs, trucks need to be used, which will bring the debris from where it is currently located, along the road network, to where it will be treated or disposed. Trucks come in different sizes and are used for different operational activities. For the tool, the rolling stock is defined according to its capacity, its average daily distance coverage and its unit cost.

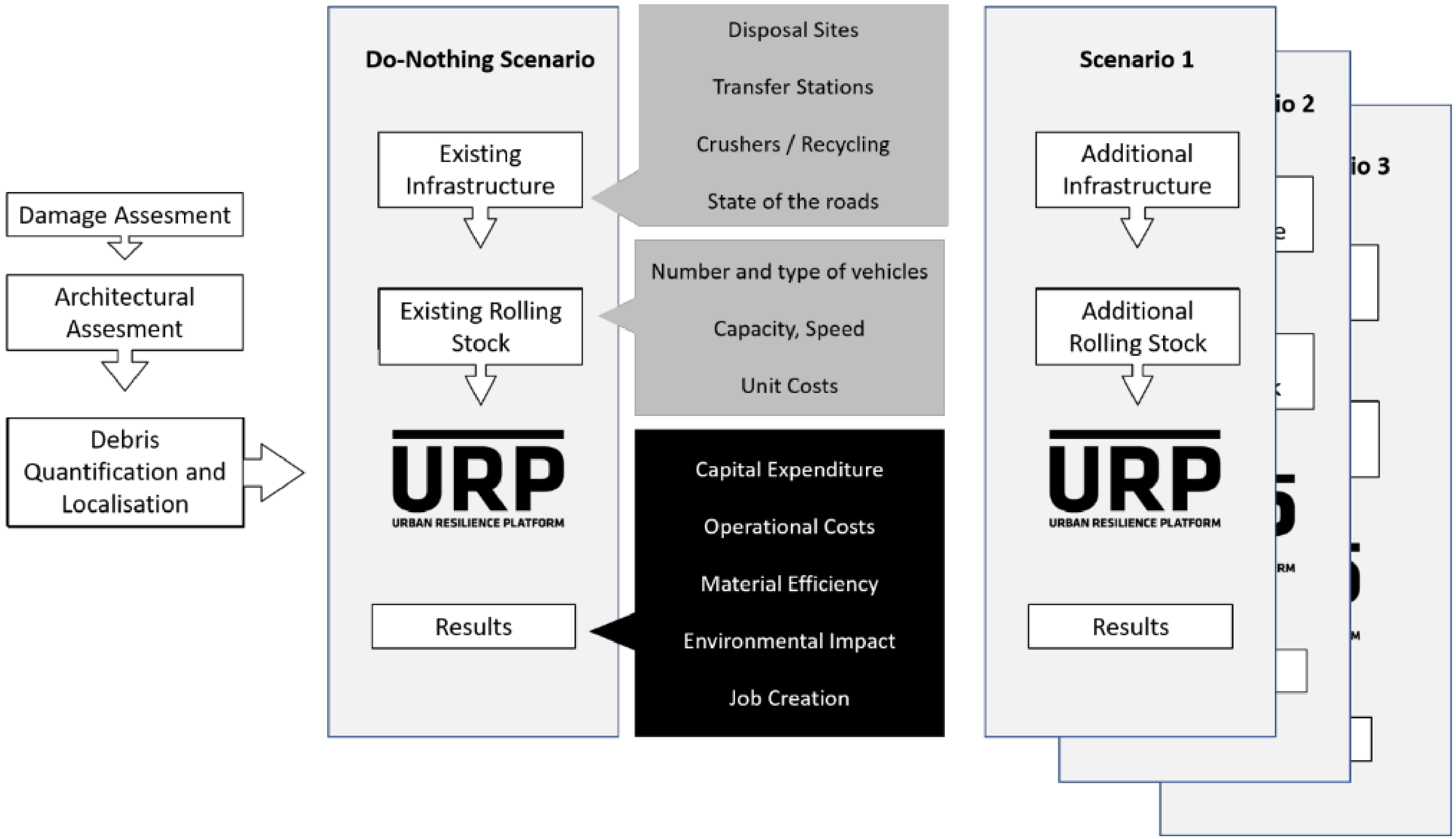

Figure 6: Key process steps of the URP Debris Tool

7.1.2 Tool Calculations

The tool uses all of the inputs described above in a made-for-purpose algorithm, designed by debris management professionals with an in-depth understanding of debris movements in an urban setting.

The algorithm creates an individual daily work plan for each available truck, assigning it to clear debris from urban areas and bringing this debris to available infrastructure. The decisions in the algorithm are designed based on the following priorities:

- ⇒ Clear the streets as fast as possible (move debris to transfer stations if available);
- ⇒ Make the most efficient possible use of recycling infrastructure (i.e. saturate the daily capacity of the crushers);
- ⇒ Make the most efficient use of the rolling stock (small trucks for short journeys, large trucks for longer journeys);
- ⇒ Reduce the overall distances covered by the rolling stock.

7.1.3 Tool Outputs

Using the inputs, and processing them through the calculations, the tool provides a series of outputs, which can be used to inform decision making. It is important to remember that the tool is scenario-based, and therefore returns a value for these results on each change of inputs. The marginal value of that change of input can therefore be examined by comparing it to previously modelled scenarios in an iterative manner until the optimal scenario is selected as a basis for operational planning.

Overall Cost of Scenario

The cost of the scenario over its entire duration is given as a total. The cost breakdown includes the cost of transport, the cost of running the debris infrastructure, and the disposal cost associated with the use of the disposal grounds. All of these costs are derived from the unit costs entered as inputs and the frequency of use of each material throughout the specific scenario. Baseline costs used were provided by Mosul Municipality.

Overall Time Required to Complete Scenario

The time required to empty the city of its debris is displayed in working days, and can be translated into any useful time unit.

Livelihood Creation

The generation of livelihoods is based on the use of recycling infrastructure, with each item of infrastructure requiring different staff numbers to run.

Material Recovery Rates

As the recycling infrastructure is used differently in various scenarios, the overall rate of material recycling across the city will vary. Recycling rates are calculated in terms of tonnage recovered and its relative percentage of overall debris.

7.2 How the tool was used for Mosul?

7.2.1 Building operational scenarios

Scenario 0: Current Operational Plan

The operational reality on the ground is the basis of what will be referred to as Scenario 0, which converts information on ongoing activities in Mosul into tool data inputs. For this, the damage analysis described in section 0 was used as a debris quantity input. The operational distances were calculated based on Mosul Municipality's "no river crossing" decision for debris.

In terms of infrastructure and rolling stock, the currently available machinery, transfer stations and disposal sites were inputted, based on extensive interactions with the municipality. Details of these inputs are included below.

i. Trucking:

Truck Type	Capacity (tonnes)	Speed (km/day)	Cost (USD/day)	Units deployed
Big	42	200	130	5
Small	14.7	200	90	50

ii. Proposed Transfer Stations:

Name	Maximum Storage Capacity	Tonnage in Storage on Day 0	Type of Crusher on site
Sahat Al-Tawalban	0 (now closed)	20,000	None
Intermediate SWM Station Right Bank	124,000	0	None
Sahat Al-Maydan	30,000	0	None
Sahat Al-Nabi Jarjis	30,000	0	None
Old Municipality Car Park	84,000	0	None

iii. Mobile Crushing Deployed:

None

iv. Disposal Site:

Name	Gate Fee (USD/tonne)
Haj Hamad Kreaz Valley	3

Remotely recommended changes

Using scenario 0 as the baseline, the debris modelling team constructed four additional scenarios to demonstrate the potential value of various input changes, as detailed below.

Scenario 1: Increased Trucking Capacity

Mosul's current transportation fleet was quadrupled as shown in the following table:

Truck Type	Capacity (tonnes)	Speed (km/day)	Cost (USD/day)	Units deployed
Big	42	200	130	20
Small	14.7	200	90	200

All other inputs as per scenario 0.

Scenario 2: Mobile Crushing

Eighteen small mobile crushers are deployed throughout the Old City; with five medium mobile crushers deployed at the proposed transfer stations. All other inputs as per scenario 0.

Scenario 3: Fixed Crushing

Five large fixed crushers are deployed at the proposed transfer station locations. All other inputs as per scenario 0.

Scenario 4: New Disposal Site

Change of final disposal site to an alternative location on the Right Bank at site code 93: Ain Al Iraq Project. All other inputs as per scenario 0.

8.0 MOSUL DEBRIS MANAGEMENT WORKSHOP

A two-day workshop on debris management involving the main city stakeholders was organized by UNEP and UN-Habitat in Mosul on 18-19 March 2018. Key issues in debris management were discussed including the above-mentioned modelling scenarios. The workshop which sought to assist Mosul Municipality in planning its debris work followed the schedule shown below. Participants in attendance are listed in Annex 2.

8.1 Workshop Conclusions

Participation of a wide range of key stakeholders dealing with different debris aspects was critical to ensuring productive discussions at the workshop. The ability for these stakeholders to come together in a single forum and invest time examining the debris challenges they are facing, and the opportunities that may exist, helped set the stage for better coordination of activities.

A key workshop outcome was agreement to develop a comprehensive Debris Management Plan for the city of Mosul. While acknowledging the good start already made by Mosul Municipality under its current debris management plan in addressing the initial clearing stages, it is now considered to be too narrowly focused on road clearing. Therefore, it was agreed that the plan needs to be updated and gaps addressed drawing on the various aspects raised during the workshop.

Furthermore, an important recommendation from the workshop was that that a small technical debris management team comprising 4-5 experts is setup within the Municipality to lead the plan's development. This team will be responsible for integrating the views and needs of all stakeholders through an organized consultative process. A follow-up multi-stakeholder workshop should also be organized to discuss and validate the updated plan.

In moving forward, it was also agreed that the development of the new plan should be carried out in parallel with ongoing debris clearing efforts. Therefore, it is important to underscore that the planning process should not be considered as a brake limiting current debris activities on the ground. On the contrary, the plan is meant to enable these activities to accelerate and scale-up by following a systematic and transparent design processes involving a broad array of stakeholders with legitimate interests.

A suggested structure for this plan is provided in section 0.

8.2 Workshop Agenda

Time	Day 1	Day 2
09.00	Introduction - Opening remarks by the Environment Ministry - Mosul Municipality expectations from workshop - UNEP and UN-Habitat expectations from workshop	**5.** Presentation of main learning points from Workshopped Solutions - Advantages and disadvantages of different strategies - Examples of previous settings where proposed strategies were used
09.30	1. Current Debris Activities [Mosul Municipality] o Share debris ambitions and objectives o Present debris activities to date o Define key debris challenges	
10.30	Coffee Break	Coffee Break
11.00	2. Lessons Learned from Past Post-Conflict Debris Management Programs	**6.** Key Debris Issues [Facilitated by DWR/URP] - Explosive Remnants of War (UNMAS) - Health & Safety - Legal procedures for debris clearance - Hazardous Materials & Asbestos - Debris Logistics Recycling debris – end use applications
13.00	3. UNEP Debris Assessment Initial Modelling Results [DWR/URP] - Mosul debris quantifications and locations - Debris Management scenarios : Disposal vs Recycling Key next steps for debris planning	
13.30	4. Workshop on City Corrections to Model [Facilitated by DWR/URP] – Group work allowing participants to build their own preferred scenarios, or corrections to URP/DWR scenarios.	**7.** Next Steps [Facilitated by UNEP] Designing a process to develop the debris management plan
14.30	Lunch and Close of Day	Lunch and Close of Day

Photos 17 and 18: A key outcome of the Mosul workshop was agreement to develop a comprehensive debris management plan

9.0 USING THE MODELS FOR LONGER TERM PLANNING

9.1 Rapid disposal site selection

The decision on the location of the disposal site is likely to have the most significant impact on the overall cost and timescale for the entire debris operation. It is therefore essential that the selection process is made rapidly using the right decision-making criteria. Different sites might be relatively viable in terms of distance, as indicated by initial modelling results. This, however, does not take into account the cost and difficulty inherent to each site based on its local environmental settings. Some sites may be more expensive to prepare than others, thereby negating the logistical gains of their proximity.

It is therefore recommended that a review of the current proposed disposal sites is carried-out quickly. This study should compare the relative cost for preparation and opening of the suggested sites.

9.2 Ensuring the price assumptions currently used are correct

Modelling results are based on price inputs provided by Mosul Municipality to UNEP and UN-Habitat. These prices are surprisingly low in certain cases. Specifically, the cost associated with running specific vehicles is questionable. One explanation is that certain costs may have been externalised, including the cost of maintenance, asset depreciation and other running costs. During the workshop, Municipality staff pointed out that trucks rented on daily basis are expected to carry-out two to four trips per day. This would help explain the low transport costs reported as the model assumed that on average small trucks would carry-out 7-8 trips per day, and large trucks 4-5 trips per day[5]. If this is confirmed than the overall cost and duration of debris works would likely be significantly higher and would need to be recalculated.

In addition, the cost of debris disposal has so far not been adequately considered by Mosul Municipality. Although the running of a basic disposal site may initially appear cheap, there are long-term running costs which need to be taken into account. This is necessary to enable rehabilitation and aftercare of the disposal site once it is closed to mitigate potential negative impacts.

9.3 Planning for the closure of temporary transfer sites

The long-term cost associated with temporary transfer sites also needs to be factored. This includes returning transfer sites to their former use and aftercare measures to address potentially disruptive impacts. Where private land is used, the full benefit of that land will need to be reclaimed which comes at a cost. Understanding, therefore, at what time and under which conditions it would be most beneficial to close a temporary transfer site will require further investigation.

[5] In reality, the number of trips a truck conducts per day typically depends on the overall distance between the origin and destination.

10.0 A DEBRIS MANAGEMENT PLAN AS AN OUTCOME

The following structure for the debris management plan was discussed at the Mosul workshop, which can provide a guiding template for the drafting process

1. Debris Framework Plan

1.1. Definition of Debris
1.2. Objectives and Strategy
1.3. Success Criteria for Debris Management
1.4. Debris Management Stakeholders
1.5. Assumptions
1.6. Regulatory Framework
1.7. Ratification and endorsement

2. Roles and Responsibilities

3. First Actions

3.1 Implement clear UXO/IED procedures
3.2. Disseminate safety awareness of damaged buildings for returnees
3.3. Damage assessments
3.4. Determine legal procedures for debris removal and demolition works
3.5. Identify and enforce appropriate debris laydown areas
3.6. Emergency demolitions of unstable buildings
3.7. Start with Municipal buildings

4. Integration with unexploded ordinance and explosives removal

5. Damage and Debris Assessment

5.1. Quantifications with Location
5.2. Delineation between debris and demolition

6. Legal Procedures

6.1. Building/Debris ownership procedures
6.2. Demolition approval process

7. Debris Logistics

7.1. Introduction
7.2. Debris Laydowns/Processing sites
7.3. Debris Disposal
7.4. Solid & Hazardous Waste Disposal
7.5. Transport Routes

8. Debris Reuse and Recycling

8.1. Introduction
8.2. Reusing Debris Options
8.3. Recycling Debris Options
8.4. Debris reuse and recycling targets

9. Cultural and Heritage Buildings

10. Environmental Review of Debris Management

11. Debris Removal Implementation

11.1. Scope of Debris Management
11.2. Timing
11.3. Management and Monitoring
11.4. Debris Sequencing
11.5. Pilot Project
11.6. Safety
11.7. Access to Home Owners
11.8. Capacity
11.9. Contracts
11.10. Debris laydown and disposal closure plans

12. Debris Removal Budget

ANNEX 1: CRUSHER INFORMATION BOOKLET

Small mobile crusher

Advantages:

- It can be loaded manually, and is therefore independent of any other expensive machinery
- It can manoeuvre through narrow streets and crush the debris directly at its current location
- It produces aggregate directly on the owner's land, removing the need for transport

General Specifications:

Name	Crushing capacity (tonnes / day)	Procurement Cost (USD)	Running Cost (USD / day)	Staff requirement (people)	Space requirement (ha)
Small Mobile Crusher	90	70,000	270	2	N/A

Medium Mobile Crusher

Advantages:

- It can be loaded by small mechanical equipment (skid steer or front end loader)
- It can move to different debris sites, although it cannot manoeuvre through small streets
- It produces aggregate inside the city, reducing the need for transport

General Specifications:

Name	Crushing capacity (tonnes / day)	Procurement Cost (USD)	Running Cost (USD / day)	Staff requirement (people)	Space requirement (ha)
Medium Mobile Crusher	300	450,000	600	1 Loader Operator and 2 crusher operators	1 - 2

Large fixed crusher

Advantages:

- It can process very large quantities of material and is not mobile
- It operates outside the city centre, avoiding noise and dust creation near sensitive receptors

General Specifications:

Name	Crushing capacity (tonnes / day)	Procurement Cost (USD)	Running Cost (USD / day)	Staff requirement (people)	Space requirement (ha)
Large Stationary Crusher	720	750,000	1000	1 Loader Operator, 3 crusher operators	2 – 3

ANNEX 2: LIST OF PARTICIPANTS:

Mosul Debris Management Workshop, 19 – 20 March 2018

	Name	Position	Institution
1.	Dr. Suhaib Al-Derzi	Director	Engineering Consultation bureau, Mosul University
2.	Dr. Waleed Hameed	Engineering Advisor	Consultant engineer in Iraqi National Parliament
3.	Mr. Mostafa Kareem	Secretary	Committee Supervising the National Effort to Restore Services in Ninewa Governorate
4.	Dr. Abdulraheem Ebraheem	Materials Specialist	Engineering Consultation bureau, Mosul University
5.	Mr. Ahmed Mahmood	Assistant Director	Mosul Municipality
6.	Mr. Adnan Mahmood	Deputy Director, Planning and Monitoring Branch	Mosul Municipality
7.	Mr. Sabri Taher	Chief, GIS department	Mosul Municipality
8.	Mr. Thabit Murad	Chief, Equipment Branch	Mosul Municipality
9.	Mr. Firas Ahmed	Chief, Projects Branch	Mosul Municipality
10.	Ms. Ghada Thanoon	Chief, Planning and Monitoring Branch	Mosul Municipality
11.	Mr. Hussein Hamood	Chief, Transport Engineering Branch	Mosul Municipality

	Name	Position	Institution
12.	Mr. Adnan Hussein	Deputy Director, Projects Branch	Mosul Municipality
13.	Mr. Dreed Muhammed	Director, New Mosul Sector	Mosul Municipality
14.	Mr. Ahmed Muhammed	Officer in charge of Studies and Design Unit	Mosul Municipality
15.	Mr. Muhammed Daood	Al-Rabee Sector	Mosul Municipality
16.	Mr. Ahmed Muhammed	Director, Old City Sector	Mosul Municipality
17.	Mr. Muhammed Hassan	Deputy Director, GIS Unit	Mosul Municipality
18.	Mr. Faisal Zaayan	Project Manager, Right Bank	Mosul Municipality
19.	Mr. Rabee Tha-Noon	Director, Planning and Monitoring	Mosul Municipality
20.	Mr. Mosab Jasim	Inspector of Antiquities	Ninewa, Department of Antiquities
21.	Mr. Mahmoud Aljuamily	Judge	High Judicial Council
22.	Dr. Qusay Al-Ahmady	Dean, Environment Faculty	Mosul University
23.	Dr. Rasheed Yousif	Lecturer Assistant	Mosul University
24.	Dr. Ayman Mohammed	Lecturer	Mosul University

	Name	Position	Institution
25.	Mr. Ali Saeed		Community representative
26.	Mr. Radhwan Shabkhoon		Community representative
27.	Mr. Harith Muzahim		Private quarry operator
28.	Mr. Mohamed Ahmed	Acting Director	Contractor
29.	Mr. Amad Abellah	Acting Director	Real estate company
30.	Mr. Sinan Subhi	Deputy Director	Nineveh Environment Directorate
31.	Mr. Ammar Saleem	Head, Chemist	Nineveh Environment Directorate
32.	Mr. Mohamad Al-Assaf	Chemicals Unit	Ministry of Health and Environment
33.	Mr. Ahmed Khalid	Environment Protection Fund	Ministry of Health and Environment
34.	Mr. Ali Hussain	Public Information	Ministry of Health and Environment
35.	Colonel Zakariya Hassan	Responsible for Demining	Civil Protection
36.	Ms. Baydaa Tarad	Directorate of Mine Affairs	Ministry of Health and Environment
37.	Mr. Hussein Mohammed	Directorate of Mine Affairs	Ministry of Health and Environment

	Name	Position	Institution
38.	Ms. Sara Jassim	Graduate Student, Environment College	Mosul University
39.	Mr. Mohammed Abdelrazak	Lecturer Assistant	Mosul University
40.	Mr. Ahmed Al-Iraqi	Lecturer Assistant	Mosul University
41.	Mr. Karam Mehdi	Lecturer Assistant	Ninewa University
42.	Mr. Ibrahim Zeidi	Project Manager	UNESCO
43.	Mr. Mazin Talat	Senior National Regional Coordinator	UN-Habitat
44.	Mr. Ali Asaady	Senior Engineer	UN-Habitat
45.	Mr. Thaer Ghanim	Engineer	UN-Habitat
46.	Mr. Per Breivik	Senior Project Coordinator	UNMAS
47.	Ms. Rosemary Kabui	Shelter Officer	IOM
48.	Mr. Raja Kuppuswamy	Shelter &Settlement Engineer	IOM
49.	Ms. Katja Dietrich	Stabilization Advisor	GIZ
50.	Mr. Khalid Al-Jubori	Engineer	UNDP

	Name	Position	Institution
51.	Mr. Mohamed Rajab	Engineer	UNDP
52.	Mr. Martin Bjerregaard	Director	Disaster Waster Recovery
53.	Mr. Aiden Short	Director	Urban Resilience Platform
54.	Mr. Hassan Partow	Programme Manager	UN Environment Programme


برنامج الأمم
المتحدة للبيئة