BEIRUT PORT EXPLOSION ADVISORY NOTE ON DEBRIS MANAGEMENT OPTIONS

Draft for Consultation

1. OBJECTIVE

The objective of this Advisory Note is to help government and UN stakeholders in making informed decisions on the cost-effective and sustainable management of debris arising from the 4th August 2020 Beirut Port Explosion. It seeks to provide an overview picture of the benefits and costs of the three main debris management options: recycling, recovery for quarry rehabilitation and disposal.

Specifically, this advisory note is based on a high-level cost-benefit analysis (CBA) examining the costs, time and resource requirements for the management of this debris. The note also reviews the environmental and societal benefits of recycling and quarry rehabilitation. And finally, it considers the opportunity of linking management of Port explosion debris with conventional construction and demolition waste (CDW), thereby helping embed circular economy principles in the construction sector and a "building back better" approach in disaster recovery.

2. TYPES OF DEBRIS: DEFINITIONS AND CONCEPTS

For the purposes of this cost-benefit analysis, three types of debris are considered as defined below:

Mixed Debris:
This is debris that is present on the roads and public spaces as a direct impact of the blast and the rapid clean-up effort. It is generally also referred to as 'street debris' where some is currently located in temporary storage sites.

Demolition Waste:
This is waste that arises from the demolition and refurbishment of buildings damaged by the Port explosion and is expected to include a high proportion of inert materials such as concrete, masonry and stones.

Construction & Demolition Waste:
This is the daily, routine waste that the city of Beirut generates as part of the construction industry activities and has been projected to be in excess of 900,000t per annum[1].

[1] *Pilot-based assessment of the economics of recycling construction demolition waste in Waste Management & Research (2015) by Issam M Srour, Ghassan R Chehab, Mutasem El-Fadel and Sandy Tamraz.*

The debris from the Port explosion falls into two main categories in terms of accessibility (Fig. 1):

"Immediately available"
Mixed debris that is currently present on roads, public spaces and at temporary storage sites. Can be further sub-categorized into two groups: inside and outside the Port.

"Unreleased"
Debris that will in the future be generated from the demolition and rehabilitation of damaged buildings and thus is not currently accessible.

In this context, it is important to underscore that the explosion debris is in addition to the daily, normal Construction and Demolition Waste (CDW) generated by the construction sector in Beirut and its environs.

Furthermore, to recycle any debris, demolition waste or CDW, it is important that the resulting recycled product does not contain organic or other wastes (such as plastic, textile, wood). If organic wastes are still present in the recycled product then it is not useable for such purposes as engineering fill or road sub-base. For the purposes of recycling, then this is termed the 'quality' of the debris or demolition waste.

3. BACKGROUND

The Beirut Port explosion caused widespread damage leading to significant volumes of debris, both within the Port as well as outside of the Port. Table 1 provides an overview of the types and quantities of debris generated from the Port explosion based on assessments carried out by the UN Development Programme (UNDP) and the European Union (EU).

Table 1: Debris quantities from Port explosion used in the cost-benefit analysis.

Type of Waste	Debris Quantity in UNDP & EU Assessments	Debris Quantity used in CBA [tonnes]	Percentage of total debris
Immediate debris		**397,000**	**31**
Amount of mixed debris directly generated from the blast in Red Zone.[2]	200,000m³	320,000	25
Amount of mixed debris from damaged buildings and structures (above ground) within the Port.[3]	77,000 tonnes	77,000	6
Unreleased debris		**900,000**	**69**
Estimated potential amount of demolition waste from damaged buildings in Beirut.[4]	800,000 - 1,000,000 tonnes	900,000	69
Total debris from explosion		1,297,000	100

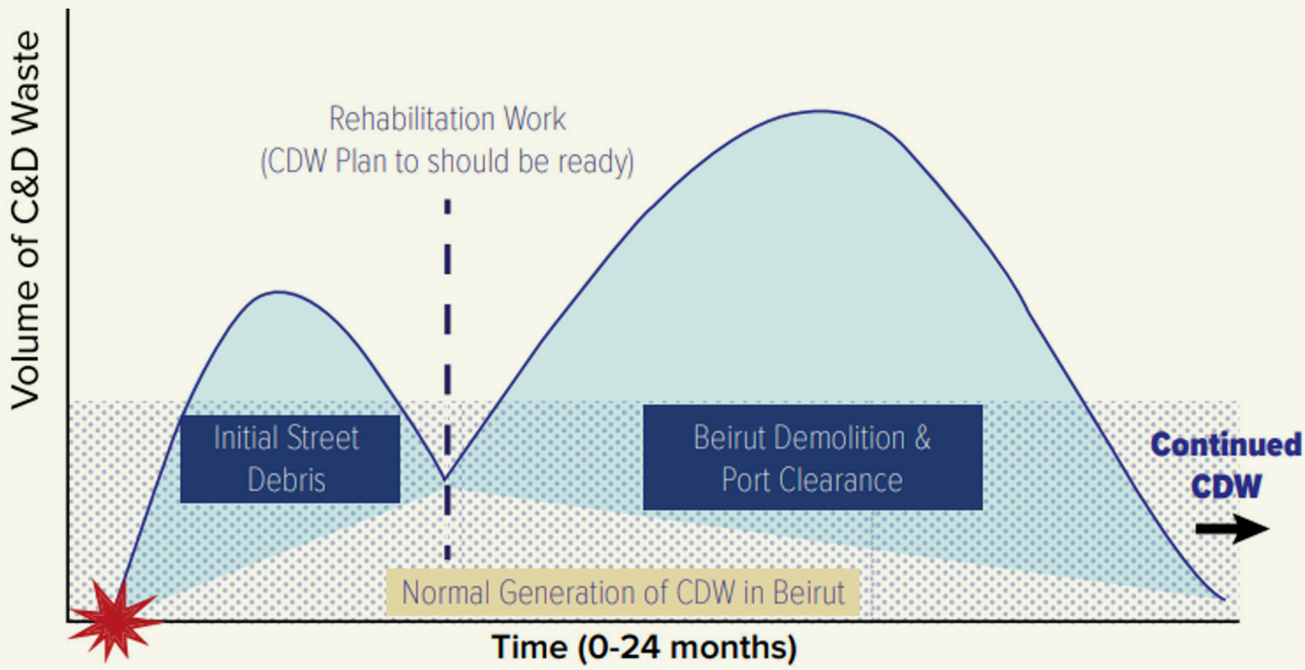

Figure 1: Amount of Construction and Demolition Waste Over Time.[5]

[2] UNDP "Demolition Waste Assessment – Outside the Port of Beirut", October 2020
[3] EU "Beirut Explosion: Construction and Demolition (C&D) Waste Management Plan - Inception Phase" Ref: ENI 2018/396-926 of September 2020
[4] UNDP "Demolition Waste Assessment – Outside the Port of Beirut", October 2020
[5] UNDP "Demolition Waste Assessment – Outside the Port of Beirut", October 2020 and EU "Beirut Explosion: Construction and Demolition (C&D) Waste Management Plan - Inception Phase" Ref: ENI 2018/396-926 of September 2020

Following the Port explosion, a large proportion of the debris in the streets was disposed of in temporary dumpsites (including Bakalian site), with more debris yet to be cleared. This debris is predominantly mixed (i.e., with glass, furnishings, inventories etc.) and with confirmed asbestos contamination of the debris inside the Port and in the main site of Bakalian. This makes a substantial part of the street debris hazardous and difficult to sort and recycle. Based on the waste management principles of Duty of Care and the Precautionary Principle, the debris generated from the blast should be safely disposed of and/or recovered as fill material for use in quarry rehabilitation, in line with international standards. The decision to recover or dispose of the mixed debris will depend to an important extent on the final classification of the debris piles as 'inert hazardous' (non-reactive) or 'hazardous' (chemically reactive).

Accordingly, this CBA assumes that all the immediately released street debris (397,000 tonnes) would be safely disposed of or used as recovery material without recycling (i.e. sorting and crushing). The cost of disposal or recovery also takes into account the disposal of asbestos contaminated debris waste at an authorised facility (either a specific hazardous landfill or at a dedicated hazardous cell within an inert disposal facility). The assumption within the CBA, for practical purposes, is that the quantity of mixed debris contaminated with asbestos is 50% of the total mixed debris. Further and ongoing assessments are required to confirm this on a case-by-case basis; while noting the inherent difficulties of identifying asbestos in highly mixed debris piles.

On the other hand, the CDW that will arise from the demolition and rehabilitation works can be cleaner and more readily sorted as well as recycled. This is possible by surveying for potential asbestos, followed by controlled stripping out of hazardous and non-recyclable materials from a building before demolition works commence, thus generating a cleaner debris for recycling.

4. COST-BENEFIT ANALYSIS

For the purpose of this CBA, 3 different scenarios have been applied, as follows:

A. Recycling: 60% of the sorted demolition waste (from rehabilitation work) is recycled, with the remaining 40% demolition waste being disposed of at an authorized CDW disposal facility. In addition, since the mixed debris is not recyclable, then 100% of all mixed debris is sent for disposal of at an authorized CDW disposal facility[6]. The cost in this scenario also includes an offset for the value of recycled debris materials produced and sold into the construction industry;

[6] In view of the cost, and the health and safety risks of sorting the mixed debris - regardless of whether it is asbestos or chemically contaminated - recycling is not considered a viable option for this part of the waste stream.

B. Recovery: Where all mixed debris is used as fill material for rehabilitation of a quarry as well as the non-recyclable 40% from the demolition waste. 60% of demolition waste is still recycled at a debris recycling facility; and,

C. Disposal: All of the demolition waste and mixed debris is disposed of at an authorized CDW disposal facility.

Note that in all three scenarios, the mixed debris from the blast (397,000 tonnes) is disposed of without recycling due to its potentially hazardous nature or recovered for use as fill material for quarry rehabilitation.

This distinction is important, where mixed debris is of low 'quality' as it is difficult and costly to sort before crushing and screening, whereas CDW from demolition activities can have a higher 'quality' and be more readily sorted and recycled.

5. CBA KEY FINDINGS

The quantities and quality of the debris generated by the Port explosion (as presented in section 3) have been used to assess the potential costs and time required to handle the debris, based on the three presented scenarios.

CBA Costings

Based on the above scenarios and assumptions provided in Appendix A, the key findings of the CBA are presented in Table 2:

Table 2: Recycling vs. disposal of debris from the Beirut Port explosion

Debris management option	Cost [US$]	Time [months]
Scenario A: Recycling 60% of the demolition waste from demolition is recycled, remaining 40% disposed of along with all other mixed debris	12,600,000	62 months for sorting and crushing
Scenario B: Recovery All mixed debris as well as 40% of the demolition waste is used as quarry recovery material with the remaining 60% of demolition waste being recycled	13,600,000	62 months for sorting and crushing
Scenario C: Disposal All mixed debris and demolition waste is disposed of	16,700,000	Only trucking time

Based on the CBA analysis, **the recycling costs are approximately US$4.1 million less than the 'Disposal' option**, which is a significant cost saving. When used for Recovery, the associated costs are closer to the Recycling option and can provide an alternative approach.

Note that the disposal of CDW waste at an authorized CDW disposal site includes for a special cell to accept asbestos contaminated debris, which incurs an additional cost.

There are numerous assumptions to be tested and verified before these results can be used for operational decision making. At the same time, it is important to emphasize that this relatively straightforward cost comparison focuses on direct monetary costs and does not factor in environmental externalities and socio-economic benefits as highlighted in below section 6. In a comprehensive cost-benefit analysis, implicit environmental and socio-economic benefits should also be taken into consideration even though it may be difficult or unfeasible to assign an explicit monetary value to them.

CBA Time Impact

From a time perspective, the total years to complete the recycling option is approximately 5 years, while disposal or quarry recovery of debris would take the time needed for its removal and actual disposal, which is assumed to be shorter . The main variance between the two options being time required for sorting the debris and subsequent crushing and screening compared to solely loading of trucks with debris and disposing of at the disposal facility.

In addition, time will be required to establish an authorized / permitted disposal facility for inert debris, including inert hazardous debris contaminated with asbestos. Note also that the rehabilitation of a quarry with debris will require detailed plans for hydrogeology and operational requirements in line with national standards and specifications.

CBA Environmental Impact

From an environmental aspect, the recycling option (where recyclable demolition waste is transported to a debris recycling site closer than the debris disposal site) leads to less truck fuel consumption and lower truck emissions than both Recovery and Disposal options, estimated as follows:

Diesel consumption
Recycling: ~1,100,000 litres
Recovery: ~1,800,000 litres
Disposal: ~1,700,000 litres

Truck emissions
Recycling: ~20,000 NOx Kg
Recovery: ~33,000 NOx Kg
Disposal: ~30,000 NOx Kg

[7] *Assuming that the total estimated amount of demolition waste that will be generated is correctly determined.*

6. ENVIRONMENTAL AND SOCIO-ECONOMIC BENEFITS OF RECYCLING AND RECOVERY

Along with the abovementioned costs, there are substantial benefits from recycling the debris in Beirut following the 4th August explosion which should be considered in the decision-making process, as it can offset the additional costs incurred.

Environmental benefits:

- Using debris of suitable quality to produce recycled aggregates for construction works which substitute scarce and non-renewable raw materials;
- Reducing long-standing environmental impacts of quarrying (e.g. land take, loss of scenic value, dust, noise, emissions);
- Relieving pressures on the chronic shortage of landfill capacity; and
- Decreasing carbon dioxide and nitrous oxide transport emissions from debris disposal and hauling of natural aggregates.

Socio-economic benefits:

- Creating emergency livelihoods through intensive sorting and recycling of debris;
- Creating much needed jobs and building skills through small-scale recycling and reuse business opportunities;
- Recycling demonstrates to the public that the debris is being managed properly and not just discarded in the environment; and
- Boosting morale by empowering people to overcome the painful visual scars of the Port explosion and become actors in their city's recovery.

Similarly, debris recovery for use as fill in quarry rehabilitation provides important environmental benefits including: i) enhanced landscape and ecological value, especially where the site is revegetated; ii) savings in landfill capacity; and iii) avoiding use of higher-grade material such as recycled aggregates or virgin material in quarry restoration.

7. BUILDING BACK BETTER: RECYCLING DISASTER WASTE AND NORMAL CDW

Pursuing an integrated approach, combining recycling of explosion debris waste with routine CDW, provides a policy option to go beyond the crisis and mainstream recycling into conventional CDW operations. Thereby, practically operationalizing "building back better" in Beirut's recovery by embedding the CDW stream within a circular economy framework. To demonstrate the benefits of recycling CDW in a normal urban context, a CBA of disposal and recycling options for the approximately 500,000 tonnes of CDW generated annually in Beirut was carried out based on a CDW recycling facility within 20km of the city and a recycled debris product of value US$4/t:

Table 3: Recycling vs. disposal of CDW in Beirut

Debris management option	Cost per year [US$]
500,000t CDW waste recycled	3,200,000
500,000t CDW waste disposed	5,600,000

The CBA shows that **recycling of CDW provides a significant cost saving compared to disposal** with an added advantage of all the additional environmental and socio-economic benefits as presented in above section 6. These cost estimates are based on there being a robust CDW management system that includes source segregation at the demolition site and an established CDW recycling facility.

Investing in a debris recycling facility to deal with the disaster waste from the Beirut Port explosion could therefore become an economically advantageous option if it is also designed to handle the normal CDW from Beirut and surrounding areas.

8. CONCLUSIONS AND RECOMMENDATIONS

From a financial and technical perspective, the conclusions of this preliminary CBA are based on debris type as per below:

i) The recycling of demolition waste from the Port explosion combined with longer-term conventional CDW is the preferred option.

ii) Recovery of the mixed street debris for use in quarry rehabilitation is desirable if it qualifies as 'inert' or 'inert hazardous' waste and is carried out in accordance with national and international specifications.

A combination of these two options is considered to be more sustainable and would lead to an improvement in environmental management in the Beirut region, and have positive benefits for the local economy. In addition to its high cost, the disposal option is considered least viable due to severe shortage of landfill capacity and the lack of a licensed facility for hazardous waste in Lebanon.

This conclusion is based on all mixed debris (some of which is contaminated with asbestos and, potentially, other contaminants which are still to be determined), being used as fill material in quarry rehabilitation and demolition waste from demolition and rehabilitation works being recycled. It should also be noted that the Recycling option requires surveying for potential asbestos and controlled stripping out of hazardous and non-recyclable materials from a building before demolition works commence.

Furthermore, a debris recycling facility is required to be established as close to the city of Beirut as possible.

To underpin the recycling of the demolition waste, the produced recycled material will need to comply with the requisite technical specifications. This requires a well designed and implemented CDW recycling intervention based on national engineering standards that can draw on international best practice. Over the longer term, this ultimately calls for development of national protocols and specifications for producing and using recycled aggregates (e.g. in road construction) in order to fully insert a life cycle approach into the management of construction materials in Lebanon.

APPENDIX 1. COST-BENEFIT ANALYSIS ASSUMPTIONS

The following assumptions have been used in the attached Cost-Benefit Analysis:

Rates	Item	Value	Unit	Comment
Densities				
Density of mixed debris		1.4	t/m³	
Density of clean debris		1.6	t/m³	
Density of demolition waste		1.6	t/m³	
Trucking				
Truckload capacity		16	m³/truckload	Beirut conventional trucks have a capacity between 16-20 m³ per truck load
Truckload cost		150	US$/day per truck	Comprises trucking of debris including truck, driver and diesel
Average truck speed		40	Km/hour	An average based on urban and rural travel
Turnaround at destination and pick-up points		20	mins	Assumption
Distance debris to debris disposal site		40	km	Final location to be determined – currently a working assumption
Distance debris to debris recycling site		20	km	Final location to be determined – currently a working assumption and based on Bsalim type location (ca. 18km from city)
Truckload fuel consumption		0.4	litres per km and assume roundtrip	Working assumption based on range of truck types in Beirut
Truckload emission		7.23	NOx g/km	Average of EURO I, II and III 20t-26t trucks. Data source: Table 3-20 of European Environment Agency «EMEP/EEA air pollutant emission inventory guidebook»

Rates	Item	Value	Unit	Comment
Sorting				
Rate of sorting mixed debris		40	t/hr	Based on use of primary mechanical grizzly and manual labour
Cost of sorting mixed debris		5.14	$/t	See "Debris Sorting Costs" sheet from CBA Excel sheet and includes all costs relating to purchase of required plant, machinery as well as establishment of site with subsequent operational costs
Rate of sorting demolition waste		100	t/hr using primary grizzly	Based on use of primary mechanical grizzly and no manual labour required since a cleaner debris
Cost of sorting demolition waste		1.58	$/t	See "Demo Waste Sorting Costs" sheet from CBA Excel sheet and includes all costs relating to purchase of required plant, machinery as well as establishment of site with subsequent operational costs
Hours sorting per day		6	hrs	Based on 8hr shift with the actual operational hours being 6 since there is downtime, blockages, maintenance, start up and shut down etc
days sorting per week		5.75	days	Monday - Friday full time and Saturday reduced hours per week
weeks per month		4.2	weeks	
hours per month		144.9	hours	
% mixed debris for recycling		0	% mixed debris appropriate to crush & screen	A working assumption since the debris is very mixed with non-recyclables and contaminants
% demolition waste for recycling		60	% demolition waste appropriate to crush & screen	Demolition waste which comes from a demolition site where there has already been some removal of non-recyclables during the preparation of the building for demolition

Rates	Item	Value	Unit	Comment
Crushing and Screening				
Rate of Crushing		260	t/hr	Using UNICEF crusher at 75% utilisation
Cost of crushing and screening		3.9	$/t	See “Debris Recycling Costs” sheet from CBA Excel sheet and includes all costs relating to purchase of required plant, machinery as well as establishment of site with subsequent operational costs
Hours crushing per day		6	hrs	Based on 8hr shift with the actual operational hours being 6 since there is downtime, blockages, maintenance, start up and shut down etc
days crushing per week		5.75	days	Monday - Friday full time and Saturday reduced hours per week
weeks per month		4.2	weeks	
hours per month		144.9	hours	
Value of Recycled Debris				
Recycled debris		4	US$/t	Value of the recycled material assumed 50% of value of raw quarry material at US$16/m^3
Disposal Rates				
Cost for disposal of inert CDW waste		15	US$/m^3 from Bsalim CDW disposal costs when in operation	Working assumption and to take into account land surveys, site establishment as well as operational costs. To be revisited once a site is identified
Disposal debris asbestos contaminated		25	US$/m^3 as a best guess	Working assumption taking into account additional cost for hazardous cell at the CDW disposal site