Disaster waste management challenges and enabling factors for strategic planning

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Disaster Waste Management Challenges and Enabling Factors for Strategic Planning: The Case of the Beirut Port Explosion

Abstract

Disasters occur in both developed and developing countries, generating large amounts of disaster waste including construction and demolition (C&D) waste that needs to be appropriately managed. While developed countries are capable of implementing adequate disaster waste management strategies to facilitate their recovery processes, developing countries generally struggle to find the resources and expertise needed to develop such strategies. Lebanon is a developing country vexed by several systemic challenges that hindered its abilities to manage disaster waste. In this paper, we focus on the Beirut port explosion (August 4, 2020), which generated more than 800,000 tonnes of disaster wastes. This study first assesses the executed strategies and identifies their enabling factors and implementation challenges. It then proposes a framework for the proper management of disaster waste, which was validated through 18 in-depth interviews with experts and stakeholders involved in disaster management. Interview notes and transcripts were analyzed using an inductive-deductive process that allowed to identify themes using the constant comparative method. The data revealed that the main barriers towards implementing a successful disaster waste management strategy were the absence of appropriate technologies, infrastructure, expertise, legislative framework, and financial resources. The study concludes by proposing a disaster waste management roadmap that includes contingency, risk reduction, and implementation plans that can enhance decision-making and ease the recovery process.

Keywords: Disaster waste, challenges, roadmap, developing countries.

Introduction

Disasters, defined as intense disruption of the typical functioning of an area or community that implicates vast human, material, economic or environmental losses (UNISDR, 2009), are a common occurrence throughout human history. Natural disasters such as floods, hurricanes, volcanic eruptions, earthquakes, and tornadoes occur unexpectedly as they are beyond human control. The number of recorded global natural disasters has sharply increased in the last two decades (Figure 1) resulting in significant public health, environmental, and economic impacts (CRED/UNDRR, 2020). Man-made disasters that include for example explosions (chemical or nuclear), toxic leakages, severe cases of pollution, and fires can be equally destructive.

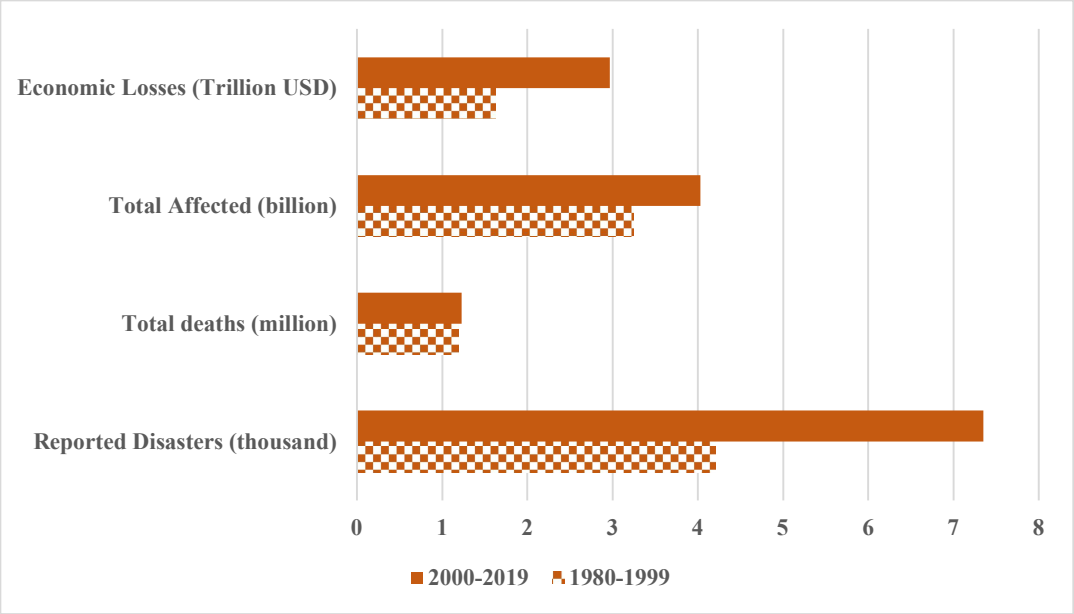

Figure 1. The impacts of natural disasters 1980-1999 vs. 2000-2019

Disasters impact the physical environment of the affected area; consequently they generate significant amounts of unavoidable waste (Luther, 2017). The characteristics of the generated wastes highly depend on the landscape of the impacted environment as well as the type and the

intensity of the disaster itself (Brown et al., 2011). Generally, natural or man-made disasters generate a variety of wastes such as construction and demolition (C&D) wastes, organic wastes, waste from electrical and electronic equipment (WEEE) and white goods, marine wastes and sediments, vehicles, and vessels wastes, commercial or industrial hazardous wastes, infectious wastes, etc. C&D wastes represent the largest component of disaster waste and are primarily constituted of damaged buildings debris such as glass, wood, tiles, gypsum boards, electric wirings, and the remains of damaged public infrastructures (Luther, 2017).

While disasters occur in both developing and developed countries; many developed countries have formulated and implemented effective disaster waste management (DWM) strategies to help them recover (Francesco et al., 2018). For example, Japan enacted a comprehensive disaster waste management law in order to quickly and adequately manage disaster waste. It also managed to assign a financial committee that is capable of funding the management and recovery process from any potential disaster (Asari et al., 2013). Meanwhile, developing countries continue to struggle to effectively develop and implement DWM strategies (Yusof et al., 2016), even though several countries, such as Malaysia, have adopted existing strategies from the developed world. Failures are often a result of the inability of these countries to contextualize the adopted DWM strategies to their local context (Karunasena et al., 2010). Many developing countries lack a DWM legal framework, and even when it does exist, it is rarely enforced (Asari et al., 2013). Large amounts of hazardous waste are produced when several forms of disaster waste are mixed together, particularly with hazardous materials. While developed countries adhere to defined norms and established guidelines as well as advanced treatment technologies to manage such hazardous

61 waste, developing countries lack the standardized guidelines, which results in improper
62 management (Pradhananga et al., 2021).
63
64 Ensuring that DWM strategies are effectively implemented is imperative in order to reduce impacts
65 on public health and the environment (Habib et al., 2019). For example, the generated C&D wastes
66 can expose people to safety hazards resulting from tripping and falling risks due to the scattering
67 of different obstructions such as damaged buildings and infrastructures (OSHA, 2020). Moreover,
68 the presence of disaster wastes such as broken glass, metal, wood, gas tanks, hazardous chemicals
69 and damaged electric wirings all lead to safety hazards that could expose people to several physical
70 injuries such as burns, electrocution, and cuts, or death (OSHA, 2020). Respiratory diseases could
71 also be considered a notable health impact resulting from the persistence of asbestos that is
72 embedded in the walls of old buildings as well as the release of toxic emissions. People are also at
73 high risk of secondary infections caused by the mismanagement of healthcare debris in the affected
74 area (OSHA, 2020). From an environmental perspective, disasters generate large volumes of waste
75 that often overwhelm the existing solid waste management system, resulting in inefficient waste
76 sorting, resorting to open dumping or uncontrolled incineration, and/or decreasing the life
77 expectancy of operational landfills. Inevitably, the inadequate management of disaster wastes
78 remarkably prolongs the recovery time and increases the associated cost of recovery and
79 rehabilitation post-disaster (Brown et al., 2011).
80
81 On August 4, 2020, a large amount of ammonium nitrate (NH_4NO_3) stored in the Port of Beirut
82 exploded, generating an earthquake with a magnitude of 3.3 Richter (Al Hajj et al., 2021). The
83 explosion resulted in more than 210 casualties, 6,000 injured and more than 170,000 displacements

(ReliefWeb, 2020). It also caused significant damage to buildings and infrastructure within an area with a radius of 20 kilometers around the port. The blast impacted more than 47,000 apartments, 120 schools, 20 primary health care centers, and 6 hospitals. The explosion generated around 800,000 tonnes of C&D wastes (ReliefWeb, 2020). Notably, hazardous chemicals previously stored in the port were at risk of exposing the nearby residents and workers to various public health and environmental risks (Al Hajj et al., 2021). The disaster happened during a period when the Lebanese municipal waste management system was already strained and operating under an emergency temporary plan (Massoud et al., 2019). Given that Lebanon is passing through its most severe economic crisis, it is very difficult to find the money to pay for the cleaning up of the environmental degradation resulting from the explosion that is estimated to be $100 Million (UN, 2020). The country was thus caught unprepared and unequipped to accommodate and manage the large quantities of generated disaster waste, especially in the absence of disaster preparedness and response plans.

This study evaluates the executed DWM strategy following the Beirut port blast and aims to describe the enabling factors and the implementation challenges. This investigation is expected to have great significance at the national level, as it tries to improve the current DWM strategy in Lebanon. Given the limited progress in DWM research primarily regarding planning and organizational aspects (Zhang et al., 2019) the proposed contextualized country-specific plan will allow other developing countries to draw from the resemblance between the Lebanese case and their own to be able to follow a similar process and develop their own DWM strategies.

Research Methodology

Study Design and Data Collection Procedures

To explore and evaluate the implemented DWM strategies in Lebanon and identify the national barriers and enabling factors, a qualitative research method, specifically in-depth interviews, was adopted. The study was approved by the Institutional Review Board (ref. number: SBS-2021-0221).

We developed a semi-structured interview guide to probe participants into answering open-ended questions around themes (Millard, 2011). The guide was designed on the basis of a comprehensive analysis (desk review) of government documents and reports, published journals, and books, which allowed us to create an overarching analytical framework. The interviews addressed the following topics: a) the strategies and measures implemented for the management of disaster wastes resulting from the Beirut Port explosion; b) the implementation challenges and the corresponding enabling factors and determinants that could have improved the existing waste management strategies. Table 1 summarizes the in-depth questions of the interview guide related to the study objectives.

All interviews were conducted either in Arabic or English, depending on the preference of the interviewee. Data was collected via handwritten notes and audio recordings, if permission was granted, to increase the accuracy and validity of the gathered information. Before carrying out an interview, consent was taken from the interviewee. Participants were informed that their names would not appear in the notes and transcripts and that no link with their role would be maintained so as to ensure that the information they shared was kept in confidence. The data collected was anonymized.

Table 1. Summary of the interview questions linked to the objectives of the research study

Objectives	*Questions*
Explore and evaluate the implemented strategies and measures for the management of the C&D wastes that resulted from the Beirut Port Explosion.	1. What were the measures adopted to manage the generated 800,000 tonnes of post- disaster wastes? 2. What actually happened to the generated DW? 3. What were the guidelines followed in the management of the waste? 4. Were these measures capable of effectively managing disaster wastes? 5. Who are the institutions that were involved in the DWM?
Identify the national barriers and enabling factors towards implementing current and future DWM strategies.	6. What were the technical, managerial, institutional and financial limitations that challenged the management of DW? 7. What are the underlying factors that forced Lebanon to suffer from the challenges set forth by these limiting factors? 8. What are the enabling factors that should be developed/implemented at the technical, managerial, institutional and financial levels to facilitate the management of the current DW? 9. What are the essential key factors that should be tackled to facilitate the development of a contingency plan for the DWM of future disasters?

Participants Recruitment

We identified potential participants based on their knowledge and expertise on the topic and their involvement in the DWM of the Beirut Port. We tried to maximize variation in the responses by inviting stakeholders representing 20 different governmental, non-governmental, and private organizations. We invited potential participants via email scripts. Out of 20 invitations, 18 agreed to participate as displayed in Table 2.

Table 2. List of organizations

Governmental/non-governmental organizations
Interviewees representing the government
1. Municipality of Beirut
2. OMSAR (Office of the Minister of State for Administrative Reform)
3. Ministry of Environment
4. Ministry of Interior and Municipalities

5.	Ministry of Transport and Public Works
6.	Lebanese Army Force
7.	Ministry of Public Health
8.	Ministry of Economy
9.	CDR (Council for Development and Reconstruction)
10.	Higher Council for Relief
Interviewees representing international organizations	
1.	United Nations Environment/OCHA Joint Unit (JEU)
2.	European Union Delegation
3.	Human Rights Watch
Interviewees representing the non-governmental and private sector	
1.	Arcenciel
2.	RAMCO, a private company involved in DWM
3.	Impacted hospitals in the area (AUBMC)
4.	Khaddit Beirut, a grassroots NGO
5.	Lebanese Red Cross

Data Analysis

We used thematic analysis to analyze, interpret, and evaluate the interview notes and transcripts so as to build a comprehensive understanding of their opinions that tackle the research objectives (Castleberry, 2018). The responses to the interviews were organized according to the two overarching themes (barriers and enabling factors). The transcripts of the interviews were compared and coded to identify the trends and patterns as well as the similarities and the differences between the interviewees' perspectives, using a constant comparative method until an organic structure of inter-connected codes emerged. The codes were organized and further sorted according to higher-order themes for a complete review. Direct quotes from the interviewees were used to support the identified higher-order themes. This was done manually using tables that demonstrated what each of the interviewees believed were the challenges and the solutions to adequately manage DW in the Lebanese context.

Results and Discussion

The Beirut explosion caused massive destruction that left behind huge quantities of C&D waste including hazardous waste. Moreover, the blast severely damaged two central sorting and recycling facilities. Waste characterization initiatives were completed by private international organizations and it was concluded that the disaster waste stream was contaminated by asbestos. The majority of the asbestos contaminated wastes, collected from all areas across Beirut and its suburbs, were randomly transported through unspecialized collection trucks to open dumpsites all across the country. A certain percentage of the C&D waste was dumped in a temporary storage site located next to the port of Beirut. As one representative stated:

> *"The greater problem is that even if the government wants to manage asbestos contaminated wastes, it does not have a hazardous landfill in the country that would allow for the proper disposal."*

Several NGOs and government bodies were involved in the collection, upcycling and recycling of the different waste types generated as a result of the blast (UNDP, 2020). Many of the initiatives were overlapping due to the lack of coordination and comprehensible national strategy for the management of C&D waste. The aforementioned factors decreased the effectiveness of the undertaken initiatives, diminished transparency and contributed to the misappropriation of funds.

DWM Challenges

Several challenges along with the absence of a contingency plan and the inability of the government bodies who are the legal entities responsible for the provision of solid waste services to handle the generated C&D wastes resulted in the mismanagement of the generated disaster

waste. The various challenges that hindered the process of developing and implementing adequate DWM strategies are discussed below in detail and are summarized in Figure 2.

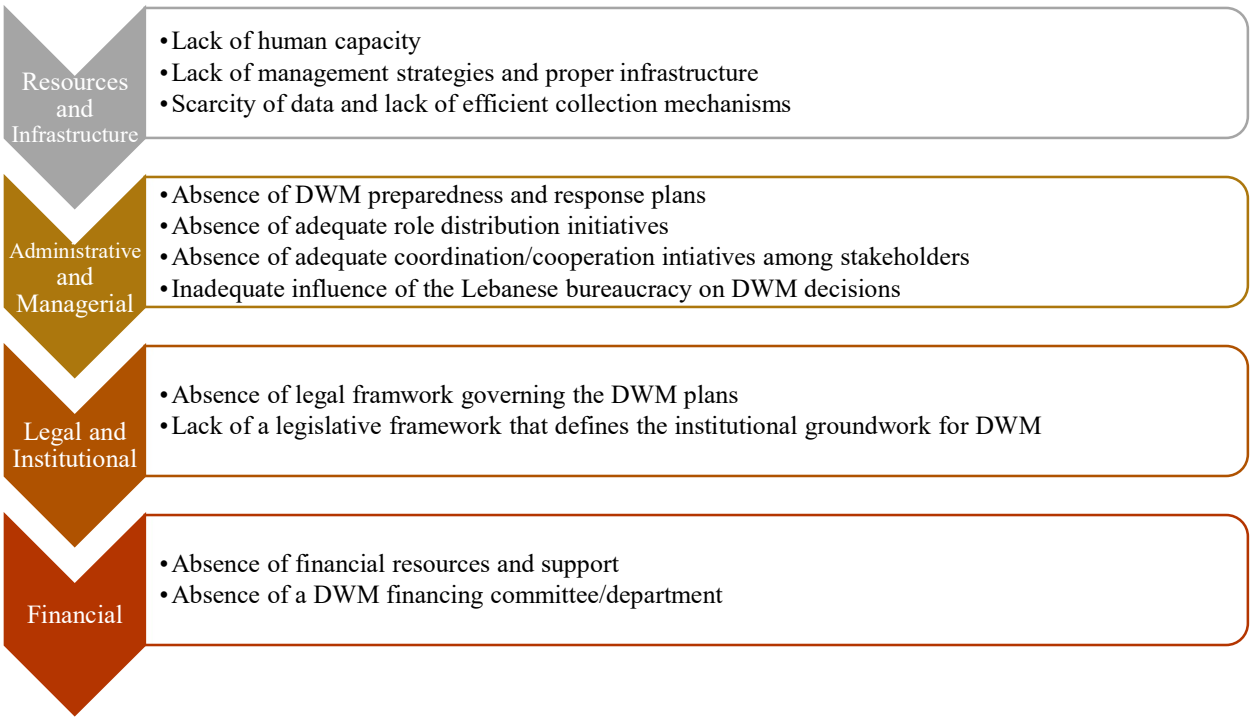

Figure 2. The challenges that hinder the process of developing and implementing adequate DWM strategies

Lack of Resources and Infrastructure

Most interviewees reported that the lack of proper environmental management strategies concerning treatment, recycling potential and disposal sites in addition to the lack of technological resources are main challenges that hinder the management of C&D waste. A representative from the government clearly stated that:

> *"We don't have a company that has the experience to manage disaster wastes properly."*

Lebanon had to get a donor to fund and import a glass crusher for the crushing of sorted glass and other C&D material. With regards to organic wastes, only two functioning mechanical biological

191 treatment facilities (MBT) were located and operational within close proximity to Beirut. One was
192 located in the immediate vicinity of the port and thus was completely destroyed. The other had
193 already reached its capacity long before the explosion. As such, most of the organic waste ended
194 in dumpsites. Moreover, given that the waste was contaminated with asbestos, it should be
195 disposed of in a landfill specifically approved for hazardous waste. Unfortunately, there is no
196 landfill dedicated for hazardous waste or even C&D waste in Lebanon. Respondents made it clear
197 that Lebanon does not have the necessary infrastructure to manage its disaster wastes efficiently.
198
199 Many other developing countries commonly face these challenges (Brown et al., 2011; Yusof et
200 al., 2016). For example, in Sri Lanka, the Indian Ocean tsunami generated significant quantities of
201 C&D waste that was not recycled and reused optimally and ended primarily in landfills
202 (Karunasena and Amaratunga, 2016). Zawawi et al. (2016) reported that C&D waste disposal in
203 temporary areas delayed the recovery phase in Malaysia. Likewise, significant quantities of C&D
204 waste was generated as a result of the 1999 Marmara Earthquake in Turkey. Given that there was
205 no landfill site for such type of waste, the management was uncoordinated and source separation
206 and recycling were not performed (Baycan, 2004).
207
208 *Administrative and managerial*
209 Several management challenges that hindered the management of disaster wastes in Lebanon were
210 identified. One commonly recognized challenge among all participants was the absence of DWM
211 preparedness and response plans. Although disaster specific risk reduction plans were available
212 for cases of fires, earthquakes and other natural disasters, plans to manage C&D wastes specifically
213 and man-made disasters generally did not exist. Even though most of the interviewees believed

214 that even if a management plan had been previously developed, it would have been difficult for
215 such a plan to have predicted the scale of the disaster.
216
217 Yet, it has been shown that having a preparedness plan allows for a quicker response and recovery
218 post-disaster (Asari et al., 2013). The absence of a plan weakens the cooperation and coordination
219 between the responsible authorities, particularly in developing countries that generally lack a clear
220 distribution of roles between the stakeholders (Brown et al., 2011). Other studies (Domingo and
221 Luo, 2017; Hooper, 2019) considered coordination a key factor for successful DWM. In the case
222 of the Beirut Port, the unsystematic and uncoordinated involvement of various governmental and
223 non-governmental organizations led to the duplication of initiatives, the misallocation of human
224 resources, and consequently the improper management of disaster wastes. According to one
225 representative:
226 *"Many institutions were involved in DWM, which impulsively slowed down the*
227 *disaster response and recovery processes."*
228 *Legal and Institutional*
229 A coherent national legislative framework concerning solid waste management in general and
230 DWM in particular has yet to be established in Lebanon; with policies and laws tackling the solid
231 waste sector being characterized as incomplete or outdated. The lack of enforceable legislation
232 was emphasized in the management of disaster waste particularly in developing countries
233 (Karunasena et al., 2012; Memon, 2015; Yusof et al., 2016). Guidelines and standards serve as
234 templates that clarify the technical, regulatory, operational, and legislative requirements and
235 mandates that govern DWM to public and private firms (Asari et al., 2013). A legislative
236 framework that defines the institutional groundwork for DWM in Lebanon remains unavailable.

This has allowed for certain laws and regulations to be transgressed, caused the development of a fragmented regulatory structure where the responsibilities and jurisdictions of various stakeholders overlap, and hindered the ability of stakeholders to collaborate and communicate amongst each other. According to one interviewee:

> *"An administrative and legislative framework should assign the roles and responsibilities to limit the persisting ambiguity and the presence of many actors in DWM. Such a framework should even explicitly define the definition of C&D wastes and who owns the wastes."*

Financial

All interviewees reported the lack of financial resources as the main challenge hindering the development and implementation of DWM strategies and plans post explosion. Management of disaster wastes after such a crisis requires a significant budget that was unavailable in the case of Lebanon. Accordingly, the most economic and cheap method for handling wastes such as open dumping was relied on. Lebanon's only source to fund such projects was through the provision of funds from international donors. Other studies (Memon, 2015) also reported that the lack of funding was considered a major challenge for DWM.

Enabling Factors towards Developing and Implementing DWM strategies

Several enabling factors were proposed by interviewees to help set up a solid ground for the development and implementation of an adequate DWM strategy for Lebanon. Many interviewees stated that it is crucial to develop preparedness, contingency, and implementation plans to enhance readiness for possible disasters that may occur. Such plans will facilitate response, respectively

shorten the recovery period, and ultimately reduce the impacts on public health and the environment. Moreover, they will reduce the overlapping responsibilities and jurisdictions among the various stakeholders and enhance collaboration and communication amongst each other. In addition, respondents highlighted the necessity to formulate a coherent national legislative framework that defines the institutional groundwork for DWM. Yadav and Barve (2016) reported that disaster waste management planning along with disaster preparedness, partnership and coordination are key enablers for the successful management of disaster waste.

A roadmap for a DWM strategy in Lebanon

Although disaster management strategies vary from country to another, a roadmap that attends to the various challenges that developing countries generally encounter and in line with international best practices will limit the adverse public health and environmental impacts. Our proposed roadmap for DWM is discussed below in details and is depicted in Figure 3.

A pre-disaster preparedness phase (P1) that involves as a first step (S1) the development of a contingency plan (CP) specific for DWM is imperative. The CP should primarily assign the roles and responsibilities across the various stakeholders through stakeholder mapping (S1a). Disaster waste assessment (S1b) should also be done to determine the quality and the quantity of generated wastes. Additionally, an inventory (S1c) consisting of all the technical, human, and financial resources that are needed in DWM could also speed up the implementation of DWM plans and reduce the potential chaos resulting from delays in importing the necessary equipment, searching for funders, and finding the knowledgeable expertise to respond and implement the DWM plans (UNOCHA, 2011). A CP must consist of a list of all the needed infrastructure that are available, functional, and capable of accommodating significant quantities of wastes at any time (Ministry

284 of Environment in Japan, 2018). Moreover, a CP should consist of a decision tree (Figure 4) for
285 the treatment of disaster waste (S1d) that can facilitate and optimize decision making in regards to
286 the best treatment method to be implemented to manage waste. It is also significant to mention the
287 importance of developing closure and monitoring plans (S1f) for the infrastructure that were used
288 in DWM such as the temporary storage site.

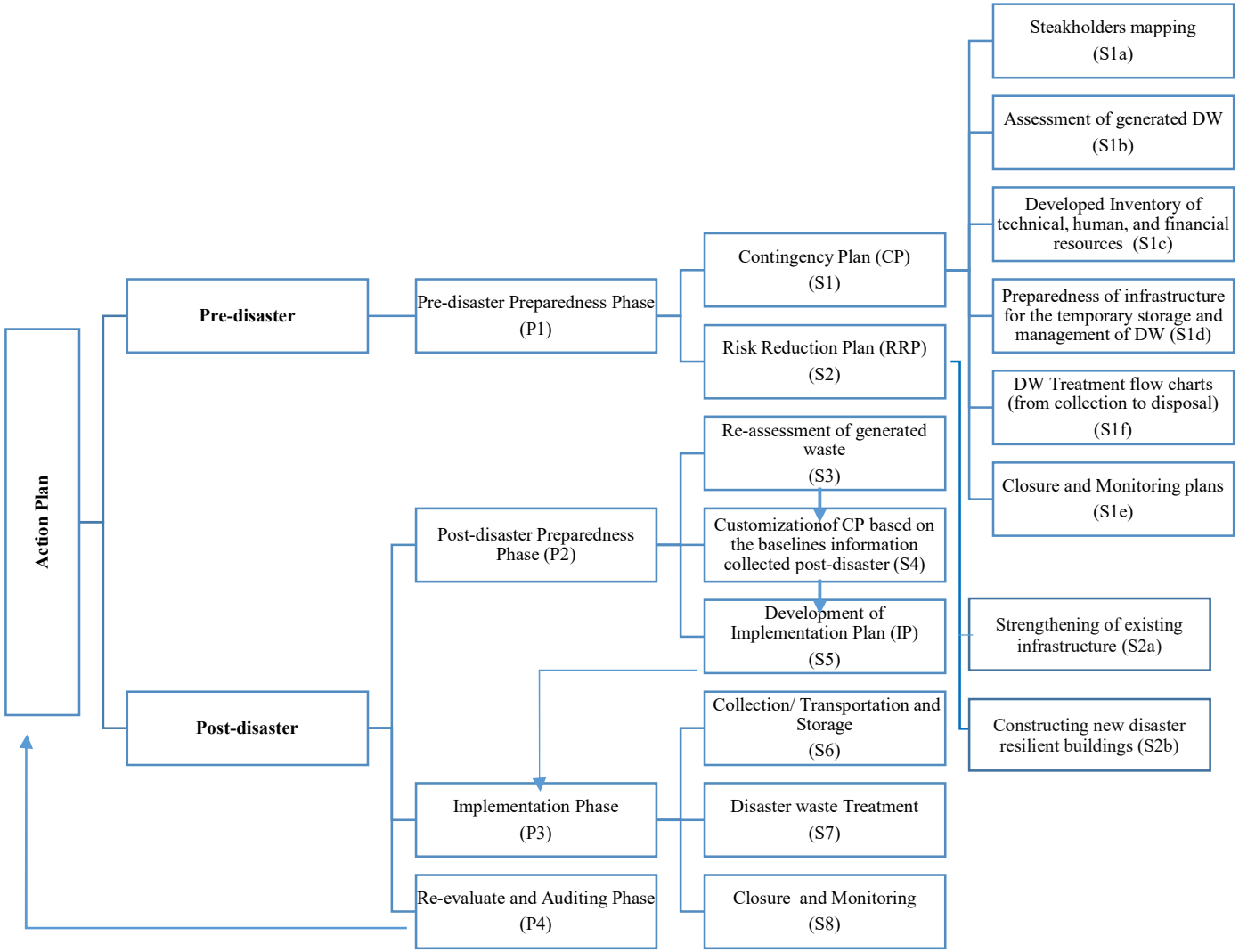

Figure 3. Proposed roadmap to the management of disaster waste

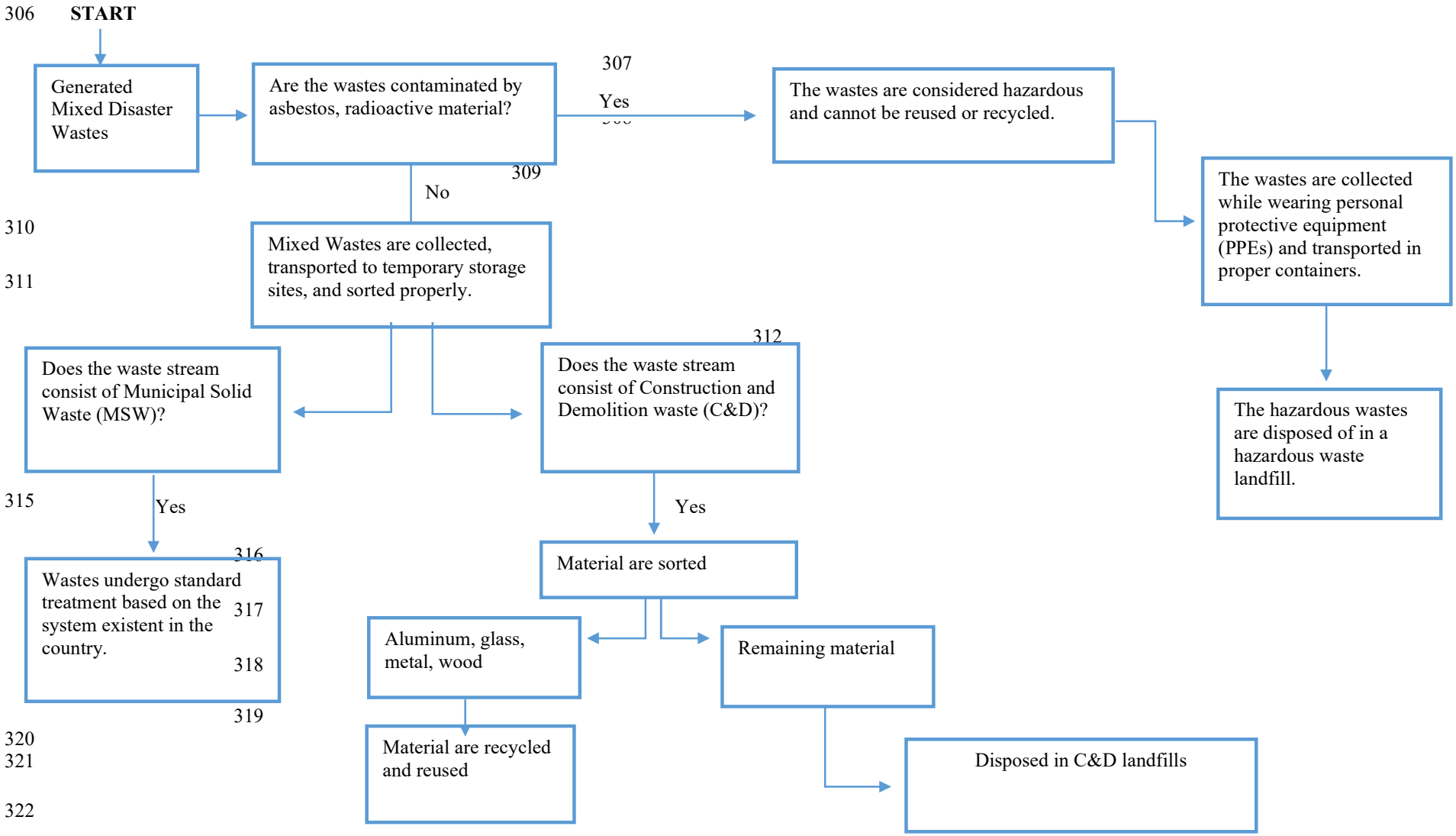

Figure 4. Proposed decision tree for the management of disaster waste

A Risk Reduction Plan (S2) should also be developed and implemented as part of the pre-disaster preparedness phase, since it consists of a set of country specific initiatives, that if implemented, could reduce the cumulative quantities of disaster wastes generated post-disaster (Ministry of Environment in Japan, 2018). For instance, if the infrastructural stability of old buildings is constantly monitored, this could significantly reduce the risk of collapse of such buildings and therefore reduce from the quantity of C&D wastes generated post-disaster. As such, initiatives could be directed either towards strengthening existing infrastructure (S2a) or towards setting criteria for the construction of new buildings that are disaster resilient (S2b) (UNOCHA, 2011).

After the occurrence of a disaster and as part of the post-disaster preparedness phase (P2), stakeholders should initiate their work by re-assessing the generated waste (S3) before collection to be able to identify potential hazards that could cause health and safety risks. This step will also provide baseline information that is enough for the stakeholders to know the potential quantity, quality, and waste composition of the disaster waste stream (USEPA, 2008; Zhang and Huang, 2018). Consequently, this will allow them to customize the CP (S4) to become more disaster specific rather than theoretical, and thereby develop an implementation plan (IP) (S5) to adequately manage disaster waste during the implementation phase (P3). As such, waste should be collected, transported and stored (S6) and/or treated (S7) in sites pre-assigned in the contingency plan (CP) and reassured in the implementation plan (IP) with proper monitoring and closure (S8). While managing disaster wastes, the management process must be sustainable and as such should include various waste reducing, reusing, recycling, and recovery initiatives. The re-evaluation and auditing phase (P4) is the last phase that should be completed following the implementation of the DWM plans including risk reduction plan (RRP), CP, and IP. Re-evaluation

processes will allow stakeholders to determine the challenges faced in managing disaster waste, think of the enabling factors for these challenges, and correct their pre-existing plans.

Conclusions

Lebanon's DWM strategy suffers from conditions exhibited in other developing nations, which include but are not limited to infrastructural and technological deficits, lack of a legislative framework that defines the institutional groundwork for DWM, and lack of human and financial resources. Evidently, the absence of a DWM plan in Lebanon has led to the mismanagement of waste, which consequently led to considerable public health and environmental impacts. The management of significant quantities of disaster waste requires the development and implementation of a cohesive action plan that takes into consideration the technical, administrative, managerial, legal, institutional, and financial aspects that may be challenging the country's ability to manage disaster waste.

Interviewees considered the development of contingency (CP), risk reduction (RRP) and implementation plan (IP) a major enabling factor that can enhance the decision-making process, facilitate coordination among stakeholders and reduce recovery period. The development of a DWM plan can enhance the diversion of the waste from landfills and become a valuable resource in the recovery and rebuilding process. The success of such a plan is contingent on the implementation of a set of interdependent measures that include the formation of a coherent regulatory structure, the establishment of a financially sustainable system, and the inclusion of miscellaneous stakeholders in the structural and operational scheme. Furthermore, investments in

local infrastructural capacity have yet to be made, an issue that is amplified by the lack of financial resources.

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