

AMERICAN UNIVERSITY OF BEIRUT

DEVELOPING A CONSTRUCTION AND DEMOLITION  
WASTE MANAGEMENT MASTER PLAN FRAMEWORK  
WITH APPLICATION TO THE LEBANESE CONTEXT

by  
ANTOINETTE ANTOINE ABOU JAOUDE

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May 9, 2023

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## ABSTRACT OF THE THESIS OF

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Construction and demolition wastes (CDW) exceed a third of total waste generated in many countries worldwide. Developed countries have worked on setting master plans for the management of solid wastes while targeting CDW in the body of their plans; however, these plans do not present the proper structure necessary for the promotion of CDW recycling, reuse, and introduction into the economy. Existing master plans and planning efforts also fall behind in presenting a structured master plan development methodology for duplication. This study establishes a master plan development framework targeted towards CDW management. The methods used consist of thematic and comparative analyses on data collected from literature, an AHP expert supported analysis followed by a case study application of the developed framework to the local context of Lebanon through drafting a CDW management master plan. Finally, to confirm the efficiency of the developed plan, a micro economic assessment of the drafted Lebanese plan is carried out.

## TABLE OF CONTENTS

ACKNOWLEDGEMENTS .....	1
ABSTRACT .....	3
ILLUSTRATIONS .....	6
TABLES .....	7
INTRODUCTION .....	8
LITERATURE REVIEW .....	11
A. Methods for developing master plans	12
B. Methods for assessing master plans	14
C. Methods for assessing master plan impacts	15
1. Facility capacity .....	16
2. Recycling process and equipment.....	17
3. Facility setup costs .....	18
4. CDW production quantities and distribution .....	18
5. Facility operational costs .....	19
6. Facility revenues .....	20
7. Other parameters .....	21
8. Economic model constraints .....	21
D. CDW in Lebanon	22
RESEARCH OBJECTIVE AND METHODOLOGY .....	25
A. Research objective	25

B. Methodology	26
1. Data collection .....	27
2. Thematic analysis.....	28
3. Guideline analysis.....	29
4. Thematic analysis and guideline analysis comparative assessment .....	29
5. AHP analysis.....	29
6. Lebanese local status impact assessment.....	32
7. Lebanese master plan drafting and micro-economic study.....	33
<b>FRAMEWORK DEVELOPMENT RESULTS AND DISCUSSION ...</b>	<b>42</b>
A. Thematic analysis	42
B. Guideline analysis	49
C. Comparative assessment	51
D. AHP assessment	53
E. Master plan development framework	63
<b>FRAMEWORK APPLICATION RESULTS AND DISCUSSION .....</b>	<b>66</b>
A. Lebanese local status impact assessment	66
B. Lebanese construction and demolition waste management master plan	77
C. Micro-economic comparative study	105
<b>CONCLUSION .....</b>	<b>111</b>
<b>APPENDIX .....</b>	<b>113</b>
<b>REFERENCES .....</b>	<b>147</b>



## ILLUSTRATIONS

### Figure

1. Methodological map.....	27
2. Waste management plans distribution by location.....	27
3. Waste management guides distribution by location.....	28
4. Micro-economic case study distribution by location .....	34
5. AHP tree structure .....	54
6. Present state CDW recycling facility NPV versus time .....	107
7. Master plan CDW recycling facility NPV versus time .....	108
8. Reduced gate fee NPV versus time .....	110

## TABLES

Table

1. Saaty's intensity of importance table .....	30
2. Random consistency index table .....	31
3. Micro economic model input and analysis parameters .....	34
4. Equipment information.....	36
5. CDW production by location .....	37
6. Thematic analysis list of master plan sections .....	48
7. Guideline analysis list of master plan assessment criteria .....	51
8. Expert 1 pairwise comparison matrix.....	56
9. Expert 1 normalized pairwise comparison matrix.....	57
10. Expert 1 master plan assessment criteria weights .....	58
11. Expert 1 hierarchal synthesis function .....	58
12. Expert 1 weighted sum and weighted sum over criteria weight values .....	59
13. Expert 1 master plan section importance table.....	60
14. Master plan sections sorted by importance according to the input of expert 1 .....	60
15. Sorted master plan sections for every expert input .....	61
16. Lebanese existing policies (laws, decrees, treaties, ministerial decisions and declarations, and plans) .....	67
17. Present state CDW recycling facility cash inflow and outflow.....	105
18. Master plan CDW recycling facility cash inflow and outflow.....	105
19. Present state CDW recycling facility NPV and IRR.....	106
20. Master plan CDW recycling facility NPV and IRR .....	106
21. Reduced gate fee NPV and IRR results.....	109
22. Thematic analysis matrix results .....	114
23. Master plan assessment criteria table .....	131
24. Guides and guidelines master plan sections.....	132
25. Guides and guidelines master plan sections matrix.....	137

## CHAPTER I INTRODUCTION

The construction industry is one of the largest industries worldwide. With a market valued at 10.7 trillion dollars in 2020 (Marsh, 2021), many efforts are made to incorporate circular economy in construction and particularly in tackling construction and demolition waste (CDW). Such wastes are estimated as 30 to 40% of total urban wastes in China (Zhao, Leeftink, & Rotter, 2010), 15 to 30% of municipal wastes in Kuwait (Kartam, Al-Mutairi, Al-Ghusain, & Al-Humoud, 2004), 50% of annual wastes in the Republic of Korea (Kim, 2021), 140 Million metric tons in the United States in 2012 (Pacheco-Torgal, 2013; Yuan, Chini, Lu, & Shen, 2012), and 374 Million tons in the EU in 2016 making them the most significant weight characterized waste stream in the EU (Hoang et al., 2021).

While CDW recycling has started since the second world war with over 400 built recycling facilities in Germany in 1992 (Brooks & Adamst, 2012; Hoang et al., 2021), large percentages of CDW are still being landfilled in many countries. In Kuwait, 90% of CDW is landfilled (Kartam et al., 2004), and in many developing countries, such wastes are illegally and haphazardly dumped by construction companies into nature (AlZaghrini, Srour, & Srour, 2019; Kim, 2021). Studies have shown that recycling rates can reach 98% for concrete (Dosho, 2007; Hoang et al., 2021) and permit reuse of more than 80% of CDW as studied in Denmark, the Netherlands and Germany (AlZaghrini et al., 2019; Morata & Sandoval, 2012). With demands on raw materials foreseen to double by 2050 from what they were in 2011 (Allwood, Ashby, Gutowski, & Worrell, 2011; Pacheco-Torgal, 2013), and knowing that 40% of these materials are for construction (Kulatunga, Amaratunga, Haigh, & Rameezdeen, 2006; Pacheco-Torgal, 2013), the need for good quality recycled aggregates (RA) is increasing by the day.

The introduction of RA into construction requires a comprehensive nationwide CDW management plan; a plan that raises awareness and motivates owners and construction parties towards recycling CDW and using RA in their constructions. Literature has defined these plans as “master plans”: comprehensive action plans set for the long run to guide future growth and development ("Master Planning ", 2015). In a circular economy framework, master plans take a role in advancing sustainable development locally through proactive societal and ecosystem healing. To achieve such goals, core values as well as methodological approaches are set for solving problems by dividing them into their constituent parts (Wheeler, 2009). In the waste management sector, master plans have focused on solid waste management (SWM) at the country, county, or municipality levels. While some master plans considered CDW in their management strategies, the need for a master plan focusing on construction and demolition wastes in its entirety remains. A CDW master plan paves the way towards recycle and reuse in the construction sector through clear and efficient policies and strategies. Such a plan promotes the establishment of a market and the flow of RA necessary for the functioning of well equipped, efficient CDW recycling plants by the private sector that can handle national CDW streams.

While solid waste master plans exist, most plans fail to present a replicable methodology for their development. National policies, guidelines and expert opinions are often referred to when drafting a waste management plan, followed by cost benefit analyses, life cycle assessments or multi criteria decision making analyses (Karamouz, Zahraie, Kerachian, Jaafarzadeh, & Mahjouri, 2007). Thus the need to establish a proper framework for the development of master plans in general and specifically master plans targeted towards CDW management.

This study presents a framework for the development of CDW management master plans. A thematic analysis of existing waste management master plans and an analysis of master planning guides are first carried out, followed by an AHP assessment leading to the formulation of a CDW management master plan development framework. The framework is then tested in the Lebanese context after an impact assessment of the existing CDW situation in Lebanon.

Since master plans are encompassing plans, their impacts appear on multiple levels, most notably economically, they are therefore assessed based on economic indicators (Neamtu, 2011). The economic viability of building a recycling facility is highly affected by the policies and plans set in waste management plans and is an indicator of the feasibility of the developed master plan (Nunes, Mahler, Valle, & Neves, 2007). In alignment with this theory, the drafted CDW Lebanese master plan is finally assessed through a micro-economic comparative study at the recycling facility level.

## CHAPTER II

### LITERATURE REVIEW

Since the priorities of master plans are threefold, growing the economy, distributing growth and protecting the ecosystem (Neamtu, 2011), an understanding of the content of master plans is necessary for their proper drafting. Chirisa defined master plans as policies oriented towards a community's development visions, defined over a period of time spanning 15 to 30 years (Chirisa, 2021). On the other hand, Kaiser defined multiple classes of master plans; these include verbal policy plans referred to as strategic plans targeting policy statements, as well as development management plans setting out programs and plans that guide development (Kaiser & Godschalk, 1995). Neamtu built on Kaiser's classification to introduce hybrid master plans, a combination of policy and management plans as he believes verbal policy plans lack in substance (Neamtu, 2011).

In waste management, the different classes of plans target a key concept: sustainability, however, defining sustainability in a circular economy environment remains a challenge to master planners. Neamtu indicated that policies cannot be easily labeled as sustainable due to the unclarity in defining the term, his study showed that planners lack the ability to define the term and often do not consider it while setting master plans (Neamtu, 2011). Afshar on the other hand defined sustainable development as meeting the needs of present generations without compromising on the needs of the next (Afshar, Abbaspour, & Lahijanlian, 2019).

Upon classifying master plans and defining sustainability, research has focused on analyzing existing deficiencies and potential improvements in master plans. In his study, Neamtu concluded that efforts put into master plans led managers astray from their intended purpose and transformed them into a goal in themselves rather than a way to achieving the plan's desired

outcome. Other problems appearing in existing master plans included their ease of reproduction as 85% of plans expressed no mention of how the planning was carried out and the strategies formulated (Neamtu, 2011). Moreover, data collection appeared to be cumbersome and emergency cases were misanalysed and mis-accounted for. Lauritzen stressed the importance of aligning long term goals with actions set for the short run (Lauritzen, 1998). Moreover, Afshar highlighted the importance of community participation in master plan brainstorming (Afshar et al., 2019). The European Union master planning guideline (E. C. D.-G. Environment) insisted on the importance of data collection, previous plan assessments and state of the art studies as the foundation to building new master plans.

#### **A. Methods for developing master plans**

To target the deficiencies analyzed, researchers used several methods in developing master plans. Afshar drafted strategies using the SWOT method where strengths, weaknesses, opportunities, and threats of the current system were identified using expert opinion. The SWOT sections were then matched to draft offensive, contingency, adaptation and defensive strategies which were prioritized using a quantitative strategic planning matrix (Afshar et al., 2019). Multiple criteria decision making (MCDM) appeared to be a common method used for the assessment of plans for master plan usage. Pirdashti used MCDM to evaluate the advantages and disadvantages of alternative projects based on preset financial, risk and project ranking criteria. This ranking method was called hybrid selection model and the MCDM chosen was the analytic hierarchy process (AHP), a method relying on the assessment of a number of alternatives using quantifiable performance attributes. Pirdashti showed that 18% of MCDM analyses were performed using AHP. The advantages of the AHP method include its tangibility, focused objectives, structured and oriented discussion and proper coverage (Pirdashti, Ghadi,

Mohammadi, & Shojatalab, 2009). Karamouz also used the AHP method to assess a set of comprehensive direct, indirect, and supporting plans proposed by field experts after a thorough data collection and consequence analysis process (Karamouz et al., 2007). Abdallah used nonlinear mathematical modeling to identify the most beneficial strategies in waste to energy master plans, setting objective functions that maximize profit and energy recovery while minimizing carbon footprint. In this study, preliminary assessment of plans was done through an AHP fuzzy method using the inputs of experts (Abdallah, Hamdan, & Shabib, 2021). On the other hand, several master plan drafting methodologies relied on previous plans and expert input. Yi formulated an action plan based on the achievements of previous plans followed by feedback from expert forums and public hearings with members of the community, officials and authorities (Yi & Yoo, 2014). In Zimbabwe, Chirisa used a thematic analysis based on analyzing existing plans and reporting patterns to identify opportunities in planning for rural settlements (Chirisa, 2021). Other planning methodologies relied on existing planning guides. Among these guides are the “Preparing a master plan for your community” by the Southern New Hampshire Planning Commission as well as the “Preparing a waste management plan” methodological guidance note by the European commission (Commision; E. C. D.-G. Environment). These guides include the content of master plans to be developed, they set the sections, purpose and regulatory floor supporting plans and strategies. In turn, Hitchcock targeted the development of systems, implementation strategies and projects in the “Step-by-step guide to sustainability planning” book. Hitchcock detailed the planning process and suggested methods to formulate strategies and policies (Hitchcock, Willard, & AtKisson, 2008).



## **B. Methods for assessing master plans**

Master plan literature has also focused on methods to assess developed and existing master plans. Kumar used a resilience index to assess resilience in master plans established through sending out questionnaires spanning 5 analysis dimensions: physical, social, economic, institutional and natural to municipalities and conducting a SWOC analysis (Strength, weakness, opportunity and challenges analysis) on the plan (Kumar S & C.A, 2022). Charani on the other hand, assessed energy master plans by adopting a resilient framework based on the resilience trapezoid concept. The concept assessed the 3 layers of resilience including engineering designed resilience, operational resilience, and community resilience through a set of quantitative and qualitative approaches (Charani Shandiz, Foliente, Rismanchi, Wachtel, & Jeffers, 2020). Da Silva used a data analysis approach to master plan assessment starting with an exploratory then a descriptive and an analytical analysis of master plan data followed by a quantitative analysis of environmental, social, economic, and institutional content of the master plans using the NVivo 2012 software (da Silva & Ludwig, 2022). Huang assessed master plan efficiency systematically through adopting an index for urban fire risk considering the severity, dangers and safety addressed. Parameters used for the index were gathered through Delphi and AHP analyses. (Huang, 2015). The use of indices also appeared with Guo who assessed master plans based on the consistency of plan implementation results with the targets set in the plan. For this assessment, Guo set 7 indices to qualitatively and quantitatively evaluate the plan based on its intended output (Guo, Hu, & Zheng, 2020). The use of AHP reappeared in Charani's energy master planning assessment where a critical review and evaluation of the plan was conducted through MCDM using AHP (Charani Shandiz, Rismanchi, & Foliente, 2021). Karamouz on the other hand set up a GIS based spatial and temporal evaluation system monitoring the effects of master plan implementation on pollution load (Karamouz et al., 2007) while Luis relied on a risk

analysis to identify operational risks. Luis based the plan assessment on the practical disconnection between strategic and operational risks and followed an action oriented framework through a bottom-up approach focused around brainstorming, document analysis and interviews to identify operational risks targeted by the plan and evaluated by experts (Luís, Lickorish, & Pollard, 2015). Finally, Yi's master plan drafting method integrated a plan assessment procedure consisting of an environmental review of the plan's draft followed by a governmental review done by authorities (Yi & Yoo, 2014).

### **C. Methods for assessing master plan impacts**

Taking master planning one step further, master plan assessments went beyond content assessment to impact assessment. Neamtu explained that the impacts of master plans are assessed through economic indicators (Neamtu, 2011). CDW recycling plant micro-economic studies are an example of such indicators. Multiple micro-economic analysis methods were used in literature. Govender and Wilburn adopted a discounted cash flow analysis method (Govender, Thopil, & Inglesi-Lotz, 2019; Wilburn & Goonan, 1998) while Hoang and Luciano used an equivalent annual cash flow analysis for assessment (Hoang et al., 2021; Luciano & Peccati, 2001). Dosal and Zhao relied on parameters such as payback periods, internal rates of return (IRR), and breakeven points (Dosal, Viguri, & Andrés, 2013; Zhao et al., 2010), while Agostini used the net present value analysis method (NPV) (Agostini et al., 2016). Agostini also deduced economic viability through comparison of IRR and discount rate while maintaining a high NPV (Agostini et al., 2016). Other decision-making models presented by Pires and Dosal included cost benefit analysis, simulation models, EIAs (environment impact assessments), GIS (geographic information system) methods, optimization models and multi-criteria analysis (Dosal et al., 2013; Pires, Martinho, & Chang, 2011). Although the economic assessment

methodologies differed between researchers, two common steps in the analysis procedures appeared: estimating waste quantities and identifying economic and environmental factors to be used in the model (Madi & Srour, 2019).

These factors were translated into model parameters; Coelho introduced in his analysis parameters such as plant capacity, gate fees, selling price, rejection percentages, percent separation and mass rate (Coelho & de Brito, 2013b). Soukopova, further detailed the calculation of parameters by defining selling price as a function of revenues, operation costs, investment expenditures, facility capacity, income taxes, loan interests, discount rate and facility lifetime (Soukopová & Kalina, 2012). Moreover, Coelho defined operational costs in another study based on energy demands for power, labor needed in management and supervision, and hazardous and non-hazardous waste disposal (Coelho & de Brito, 2013a).

### ***1. Facility capacity***

Several CDW recycling facility capacities appeared across literature. Capacities were based on the types of facility- fixed versus mobile- and the input quantities they were required to accommodate for. Coelho estimated CDW production as 416Kg/person/year (Coelho & de Brito, 2013b) while Srour calculated production as 1.73tons/m<sup>2</sup> of construction and demolition built-up area based on input from 12 residential buildings in Beirut (Srour, Chehab, El-Fadel, & Tamraz, 2013). Bakshan relied on input from 14 residential buildings in Lebanon to calculate CDW production as 38-43Kg/m<sup>2</sup> of construction and demolition built-up area (Bakshan, Srour, Chehab, & El-Fadel, 2015). Using these estimated for CDW production, recycling facility capacities ranged across literature. Duran presented 2 fixed recycling facility options for Ireland, the first in Dublin operating at 140tons/hour and the second in Limerick operating at 50tons/hour (Duran, Lenihan, & O'Regan, 2006). Coelho established that a capacity of 350tons/hour was

enough to accommodate for his Portugal study while Srour estimated the need for a capacity ranging between 250 and 300tons/hour for a fixed CDW recycling facility in Lebanon (Coelho & de Brito, 2013b; Srour et al., 2013). For mobile recycling facilities, operating capacities appeared to be lower than those of fixed facilities. Duran presented a mobile facility alternative for Ireland operating at 100tons/hour while Zhao presented a mobile facility for Chongqing operating at 50tons/hour (Duran et al., 2006; Zhao et al., 2010).

## ***2. Recycling process and equipment***

The CDW recycling process appeared to be uniform across literature with different equipment introduced when high percentages of miscellaneous material were observed in the input CDW. The basic CDW recycling process consisted of crushing and sieving at different stages using crushers and sieves, metal extraction through multiple magnets, and fines and light weight material extraction through different processes. The waste was assumed to be transported across the process through excavators, loaders, or feeders. The number of equipment used in different papers was based on the capacity of the studied facility. For the assessed facilities in Ireland, Duran estimated 2 crushers, 1 screener and 2 loaders for Dublin, and 1 crusher, 1 screener and 1 loader for Limerick (Duran et al., 2006). Coelho introduced more equipment into his studied process including excavators, feeders, magnets, air jigs, and spirals in addition to crushers and screens (Coelho & de Brito, 2013b). In Chongqing, Zhao considered only the 3 types of equipment used by Duran: 1 crusher, 1 screener and 1 loader (Zhao et al., 2010). In Lebanon, Srour used the same 3 equipment for his process in addition to a magnet (Srour et al., 2013).

For equipment and equipment maintenance costs, some papers presented the individual costs of each equipment used while others presented the total cost associated with all recycling

equipment. Duran and Coelho presented individual costs of equipment (Duran et al., 2006; Zhao et al., 2010). Coelho further presented each equipment's service life, associated power usage, and maintenance costs. On the other hand, Zhao estimated a fixed recycling facility's total equipment cost as 342KEur. Zhao also considered the alternative of purchasing used equipment for half the price of new equipment (Zhao et al., 2010). In Lebanon, Srour estimated facility equipment to cost 2.1M\$ while Madi estimated equipment for a facility in Syria to cost 927K\$ (Madi & Srour, 2019). For maintenance costs, Srour estimated both yearly maintenance and insurance to amount to 7% of the equipment's initial cost (Srour et al., 2013).

### ***3. Facility setup costs***

Facility setup costs consisted of land acquisition and setup, facility construction, and associated permits. The values presented in literature were location sensitive and dependent on the area of facility considered. Coelho assumed a land size of 27500m<sup>2</sup> with land purchase and construction costs of 4.7MEur and 2.8MEur respectively (Coelho & de Brito, 2013b). Zhao assumed a land size of 40000m<sup>2</sup> but did not incur any purchase price in his model as he assumed that the land was rented at 6000Eur/year. Zhao's construction costs were estimated as 10640Eur (Zhao et al., 2010). Al Zaghri, Madi and Srour used a land area of 10000m<sup>2</sup> for their recycling facilities with construction and setup costs of 135000\$ (AlZaghri et al., 2019; Madi & Srour, 2019; Srour et al., 2013). Madi estimated land price at 114.5\$/m<sup>2</sup> and permit fees as 6.64\$/m<sup>2</sup> in Syria (Madi & Srour, 2019).

### ***4. CDW production quantities and distribution***

Assessments of CDW composition showed that main elements were identified in CDW across the different countries presented in research studies. These main elements were concrete, wood, and metals. To get the distributions, investigations of several construction and demolition

sites were performed as in Zhao's, Srour's and Al Zaghri's studies (AlZaghri et al., 2019; Srour et al., 2013; Zhao et al., 2010). Al Zaghri only presented the aggregate CDW distribution results separating aggregates into coarse, fine, and non-cementitious.

A common acceptance rate also appeared across literature: 80% acceptance for the studies of Srour, Coelho, Zhao and Bakshan (Bakshan et al., 2015; Coelho & de Brito, 2013a; Srour et al., 2013; Zhao et al., 2010). Madi estimated an acceptance rate of 90% while Duran assumed that only 1% of facility input gets disposed of (Duran et al., 2006; Madi & Srour, 2019).

### ***5. Facility operational costs***

Facility operational costs included maintenance, power, labor, transportation, insurance, and landfilling costs in literature. Maintenance costs were presented per equipment per year as in Duran's and Coelho's studies, or as a percentage of equipment cost as in Zhao's, Srour's and Bakshan's studies where they were assumed as 6% of equipment costs (Bakshan et al., 2015; Coelho & de Brito, 2013b; Duran et al., 2006; Srour et al., 2013; Zhao et al., 2010). Zhao also assumed that maintenance for used equipment is 1.2 times that for new equipment.

Power costs were calculated according to equipment power sheets on KWH consumption in Coelho's and Zhao's studies while they were only calculated based on equipment diesel consumption in Duran's study.

Workers' numbers depended on the size of the facility and the number of equipment used. Workers were mainly split between skilled, unskilled and managers across literature. Their respective wages differed between locations; however, they increased with higher positions as shown in Duran's, Coelho's, and Zhao's studies. For Lebanon, Srour estimated the need for 15 unskilled workers, 8 skilled workers, 1 manager, and 1 loader operator and estimated labor costs as 20-30\$/laborer/day.

The productivity of workers was presented by Coelho as 50ton/8hour shift. A common figure of 8 working hours per day appeared across literature, however, the number of working days per year differed between the areas of study. Coelho and Zhao assumed 300 working days per year in their study while Srour assumed 260 working days per year.

Transportation costs were set either per weight of waste transported or per distance transported. Coelho estimated 2.95Eur/Km in transportation costs while Zhao estimated 0.5 Eur/ton of CDW transported. For Lebanon, Srour estimated a value ranging between 0.5 and 3\$/ton of CDW transported and Al Zaghriini calculated transportation costs as 0.1\$/ton/Km (AlZaghriini et al., 2019).

Landfilling costs were set based on the local regulations in the country of operation. In Ireland, they were set as 15Eur/ton (Duran et al., 2006), in Portugal estimated as 114Eur/ton (Coelho & de Brito, 2013b), in Chongqing estimated as 0.5Eur/ton (Zhao et al., 2010) and in Lebanon estimated as 24\$/ton (Bakshan et al., 2015).

Yearly equipment insurance costs were set by Zhao, Madi and Coelho as 1% of equipment purchase costs (Coelho & de Brito, 2013a; Madi & Srour, 2019; Zhao et al., 2010).

## **6. Facility revenues**

Two sources of revenues were identified in literature for CDW recycling facilities: gate fees and RA sales. The unit values of these revenues varied by location of study and was based on operational costs. In Ireland, 3 different gate fees were observed based on the location of the facility, while in Portugal, 2 gate fees were introduced, the first corresponding to unseparated waste (48.2Eur/ton) and the second corresponding to source separated waste (7.8Eur/ton) (Coelho & de Brito, 2013b; Duran et al., 2006). In Chongqing, the gate fee was set as 1.7Eur/ton (Zhao et al., 2010). In Lebanon, Srour assumed the gate fee as ranging between 0 and 3\$/ton

while Al Zaghrini assumed a gate fee of 15\$/ton (AlZaghrini et al., 2019; Srour et al., 2013). For both Chongqing and Lebanon, the sales price of RA was assumed to equal that of natural aggregates (ranging between 2 and 7\$/ton for Lebanon) (Srour et al., 2013; Zhao et al., 2010).

### **7. Other parameters**

Duran and Srour estimated a yearly 3% increase in operational costs in their economic models (Duran et al., 2006; Srour et al., 2013). Zhao set the economic analysis's rate of return as 5%/year and Duran estimated the increase in RA produced through CDW recycled facilities as 22.4%/year due to a policy introduced in Ireland in 2000 (Duran et al., 2006; Zhao et al., 2010). Other parameters considered by researchers included RA demand quantities. RA demands were compared with the quantities of RA produced in recycling facilities to ensure the existence of sales markets. Al Zaghrini assumed that full replacement of natural aggregates with RA occurs in pavements and non-structural elements and 35% replacement occurs in structural developments (AlZaghrini et al., 2019). Zhao on the other hand estimated the number of kilometers of roads to be constructed and used average road width and thickness to calculate RA demand (Zhao et al., 2010).

### **8. Economic model constraints**

To yield logical results, researchers introduced model constraints on their economic models. Several constraints appeared in many studies. The first constraint was that recycled aggregate costs and gate fees must cover recycling costs, used by Duran, Srour and Madi (Duran et al., 2006; Madi & Srour, 2019; Srour et al., 2013). The second constraint was that the recycled material price must be competitively lower than the natural material price, used by Srour, Bakshan and Madi (Bakshan et al., 2015; Madi & Srour, 2019; Srour et al., 2013). The third



constraint was that the landfill tipping fee must be higher than the recycling fee, used by Bakshan and Madi (Bakshan et al., 2015; Madi & Srour, 2019). The fourth was that the recycling processing capacity exceeded the incoming CDW quantity, used by Madi and Al Zaghri (AlZaghri et al., 2019; Madi & Srour, 2019). The fifth was that operational and fixed initial costs should be less than the sum of the revenues generated through sales of secondary material and through gate fees over a period of time, used by Bakshan (Bakshan et al., 2015).

#### **D. CDW in Lebanon**

In Lebanon, construction and demolition activities were measured through building permits issued by the Order of Engineers. These permits amounted to 9,465 for construction, renovation, and demolition in 2019. While the percentages of permits corresponding to demolition and renovation were not recorded, construction activities were estimated to constitute 40% of issued permits (OEA, 2019). Additional sources of CDW in Lebanon were those generated during emergencies such as the 2006 war (Nasr, Massoud, Khoury, & Kabakian, 2009) or the more recent 2020 Beirut port blast (UNDP, 2020b). Despite the massive waste amounts generated, at present, no legislative framework addressing waste management (WM) exists. Existing frameworks targeted environmental management through plans and policies and only 2 legal instruments addressed SWM. These 2 instruments did not detail WM procedures but assigned the responsibility of hosting management facilities to municipalities (Germany cooperation, 2014). Article 7 of decree 5605 addressed construction wastes in particular by specifying the need to assign dumping locations and treat CDW before its final disposal (B. Barakat, 2021), yet no landfill for CDW is currently operational in Lebanon. The Bsalim landfill previously designed to accept 150 tons of CDW per day was filled and has stopped accepting CDW (Tamraz, Chehab, & Srour, 2012).

On the international level, Lebanon is part of many treaties addressing solid wastes such as the Basel convention, the convention on the prevention of marine pollution and the protocol for the protection of the Mediterranean sea against pollution from base land sources (Germany cooperation, 2014), however, these treaties do not properly address CDW. Among Lebanese WM plans, 3 plans are worth consideration according to Jadam: the 1997 emergency plan for SWM, the 2006 master plan for SWM, and the 2010 waste to energy plan but none of these plans tackle CDW in particular (Jadam, 2010b).

Although the governmental legal foundation does not exist for CDW management in Lebanon, many researchers addressed pertaining questions in Lebanese CDW management. Al Zaghri used GIS modeling and optimization to determine the most suitable quarries for CDW recycling operations (AlZaghri et al., 2019). Srour developed a method for estimating CDW quantities based on construction area (Srour et al., 2013), while Bakshan developed a method for estimating the waste generated at different stages of construction operations as a useful parameter in waste management (Bakshan et al., 2015). Bakshan also assessed the behavioral factors affecting construction WM through considering attitudes, awareness, work experience, and social pressure of workers (Bakshan, Srour, Chehab, El-Fadel, & Karaziwan, 2017). Finally, Barakat developed a multi stakeholder digital platform for CDW management that optimizes the drafting of management plans through addressing the dynamics associated with waste management infrastructure (B. N. Barakat, 2022).

At the operational level, small site initiatives to recycle construction and demolition wastes take place throughout the country. Many elements are deconstructed prior to the demolition of buildings, and construction material wastes are minimized through optimizing material purchase and use in planning. Excess steel bars from construction operations and bars

extracted from demolition operations and sold to local steel buyers who compact and ship them to Turkey and Egypt for recycling. Demolition wastes consisting of cementitious materials are also occasionally crushed to finer pieces and used in backfilling operations (Srour et al., 2013). Large CDW recycling initiatives have been led by the private sector following the Beirut port blast. In 2020, the Rubble to Mountain project led by AUB's neighborhood initiative secured a land for the recycling of CDW and with the help of external funders equipped the land with CDW recycling machinery turning it into a CDW recycling facility able to accommodate for hazardous and non-hazardous waste streams. The facility has a capacity of 500tons/day of CDW, however, with no proper framework, CDW inputs are limited and recycled aggregates are not properly introduced back into the economy (AUB, 2020). Another CDW recycling facility is operated in the South of Lebanon by the Fakhri Brothers contractor entity. The facility uses basic recycling equipment to transform CDW into non-uniform RA. This facility has recently received a grant from the EU to enhance and renew its equipment and increase the supply of good quality RA into the market of Lebanon.

## CHAPTER III

### RESEARCH OBJECTIVE AND METHODOLOGY

#### **A. Research objective**

Background research showed the importance of having a master plan in managing the efforts towards attaining a specified goal. Waste management master planning targeted the solid waste industry as a whole without building a holistic plan around the management of construction and demolition wastes particularly. Such a master plan is necessary to support and promote recycling and reuse efforts in the context of circular economy.

Furthermore, existing master plans failed to present a clear replicable methodology. Research around the development of master plans was built on existing local plans, guides, policies, expert opinions, or the assessment of the environmental and economic impacts of previous master plans. No clear and consistent framework was presented for the development of master plans in countries starting out with no prior experience, plans or experts in the field.

This study establishes a framework for master planning targeted towards the construction and demolition sector. The study focuses on construction and demolition wastes particularly rather than on all solid wastes. The framework forms a baseline which countries getting into recycling of CDW can use to develop their first CDW management master plan. It presents the steps adopted to develop a master plan drafting framework, applies the framework in Lebanon and assesses its impacts at the microeconomic level.

## **B. Methodology**

The methodology in this research is divided into 2 main sections. The first establishes the framework for developing master plans for CDW management, and the second presents an application and evaluation of the framework in the local Lebanese context.

The framework is developed through a thematic analysis of existing master plans, a review and analysis of planning guides and guidelines followed by a comparative assessment of the outputs of the two analyses to draft the master plan framework. The framework is then evaluated using a multi criteria decision making AHP model targeting experts working in the field of construction and demolition waste management using criteria collected from international waste management guidelines. The outputs of the AHP analysis are used to modify the proposed framework and prioritize master plan sections.

After setting the framework, an impact assessment of the current situation in Lebanon is performed followed by the drafting of a CDW management master plan for Lebanon supported by the framework and based on the current analyzed status. Finally, a comparative micro-economic analysis using NPV, and IRR methods is performed to assess the economic viability of a CDW recycling facility before and after adopting the master plan drafted through the developed framework.

A map of the methodology is shown in Figure 1.

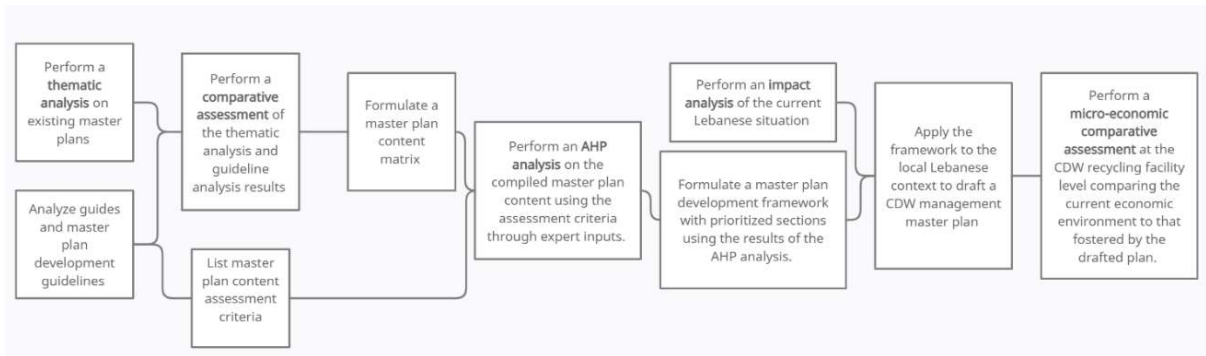


Figure 1 Methodological map

### 1. Data collection

A list of 33 master plans and 13 guides are collected for thematic and guideline analysis.

The master plans are distributed by location as shown in Figure 2.



Figure 2 Waste management plans distribution by location

The plan guides are distributed by location as presented in Figure 3.

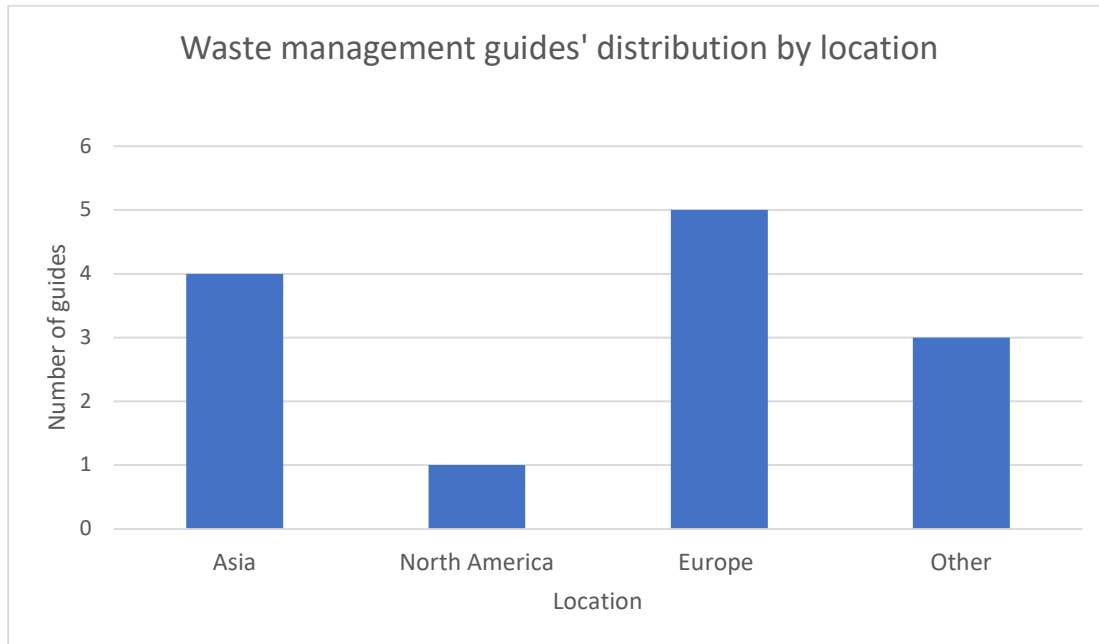


Figure 3 Waste management guides distribution by location

## 2. Thematic analysis

A thematic analysis is performed on the collected master plans. The thematic analysis is used as a process targeting case study methodologies to identify similarities and differences in research (Fox, 2019). Thematic analyses lead to clear and organized results which can be displayed in multiple formats (Fox, 2019). To be trustworthy, precise, consistent, and exhaustive, the following steps for conducting the thematic analysis are followed as drafted and presented by Nowell (Nowell, Norris, White, & Moules, 2017):

- Phase 1: Familiarizing yourself with your data
- Phase 2: Generating initial codes
- Phase 3: Searching for themes
- Phase 4: Reviewing the themes
- Phase 5: Defining and naming themes

- Phase 6: Producing the report

In the present study, the phase 6 report is replaced with a results matrix. The proposed thematic analysis extracts recurring themes in the different master plans using Nowell's methodology and present the themes in terms of their existence or nonexistence in each master plan in matrix format.

### ***3. Guideline analysis***

A thorough review of existing guides and guidelines is performed. The review leads to 2 valuable datasets. The first dataset consists of the master plan sections required and fostered by existing guidelines and the second consists of the promoted and required criteria in waste management master planning. The first dataset is presented in matrix form while the second is presented in the form of a list.

### ***4. Thematic analysis and guideline analysis comparative assessment***

The master plan content reported through the thematic analysis matrix is compared to the master plan sections dataset formed through the guideline analysis. The 2 lists are analyzed in a comparative manner to form a collective list of master plan sections.

### ***5. AHP analysis***

An AHP analysis is performed on the compiled list presented in section 4.4 using the required criteria analyzed through the guidelines in section 4.3. Weights of the criteria are assigned using CDW expert input. Expert input is also used in AHP assessment to determine the importance of the compiled master plan sections using the assessment criteria.



The AHP method is used as an assessment method for master plan content since it does not require attribute quantification but rather the structuring of the problem in a hierarchal way (Pirdashti et al., 2009). The method compares the importance of different criteria while verifying the consistency of comparison (Karamouz et al., 2007). Application of AHP is done according to the steps developed by Saaty and used in Pirdashti’s analysis (Pirdashti et al., 2009; T. L. Saaty, 1990; Thomas L. Saaty, 1994):

- First, the problem and goal of the analysis are defined. A hierarchal structure is developed where the goal is set in the first level, the criteria in the second level and the alternatives in the third level.
- Second, the relative importance of the criteria is calculated using expert inputs. Saaty’s fundamental scale of relative importance is used as the basis to determine the importance of assessment criteria and is shown in Table 1 below (Thomas L. Saaty, 1994).

Table 1 Saaty's intensity of importance table

Intensity of importance on an absolute scale	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between the two adjacent judgments
Reciprocals	Reciprocal values of opposite activities

Intensity of importance on an absolute scale	Definition
Rationals	Ratios arising from the scale

- Third, a pairwise comparison matrix is calculated using the relative importance results.
- Fourth, criteria weights are calculated from the normalized pairwise comparison matrix.
- Fifth, the hierarchal synthesis function is used to weight the eigenvectors by the weights of the criteria. The sum is then taken over all weighted eigenvector entries corresponding to the AHP analysis alternatives (Pirdashti et al., 2009).

- Sixth, the consistency index CI is calculated as

$$CI = \frac{\lambda - n}{n - 1}$$

where n is the matrix size, and lambda is the eigenvalue.

- Seventh, the consistency ratio CR is calculated by dividing CI with the random consistency index. The random consistency index table is presented below (Table 2).

Table 2 Random consistency index table

Size of Matrix	1	2	3	4	5	6	7	8	9	10
<b>Random consistency index</b>	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

- Eighth, the consistency ratio is compared to 0.1 to check for consistency. A result below 0.1 indicates consistent acceptable results.

- Finally, expert opinion is used to rank the master plan section alternatives with respect to the assessment criteria and the results are weighed by the parameter weighing results of the AHP assessment.

The AHP calculations are performed on Microsoft office excel and the results are presented in the form of a list of master plan framework sections with decreasing importance.

#### ***6. Lebanese local status impact assessment***

An assessment of the current Lebanese construction and demolition waste situation is performed through analyzing existing literature, waste management plans and guidelines as well as public policies. An impact matrix is developed with the level of strength and coverage of existing management procedures and policies.

Impact assessment is performed as follows:

- First, policies are reviewed for relevant laws and decrees impacting local CDW management plans.
- Second, guidelines are analyzed for recommended strategies and plans relating to CDW.
- Third, plans and policies pertaining to CDW are listed through an assessment of existing waste management plans.
- Fourth, the collected data from the 3 types of files are compiled and given levels of impact according to their importance, effectiveness, and coverage. Three levels of impact are used:

- High impact for policies, strategies and plans which are well defined through effective quantifiable and monitorable measures, and which properly address the prevalent CDW Lebanese situation.
- Medium impact for policies, strategies and plans which are not well defined in terms of effective quantifiable and monitorable measures, but which address the prevalent CDW Lebanese situation.
- Low impact for policies, strategies and plans which are not well defined in terms of effective quantifiable and monitorable measures, and which do not address the prevalent CDW Lebanese situation.

#### ***7. Lebanese master plan drafting and micro-economic study***

An application of the developed framework is done to the local Lebanese context based on the assessed local status. This is done through applying the framework to develop the Lebanese CDW master plan considering and respecting the high impact policies, strategies and plans while ameliorating those of medium impact and properly addressing those of low impact through quantifiable and measurable effective plans.

The economic environment fostered by the drafted master plan is assessed through a comparative micro-economic NPV and IRR study. The study compares the current economic feasibility of constructing CDW recycling plants to that fostered by the master plan sections. The economic analysis method and parameters are formulated and compiled through a literature review of 30 research papers spanning 18 countries as presented in Figure 1Figure 4. The data necessary for the economic analysis is collected from these research studies.

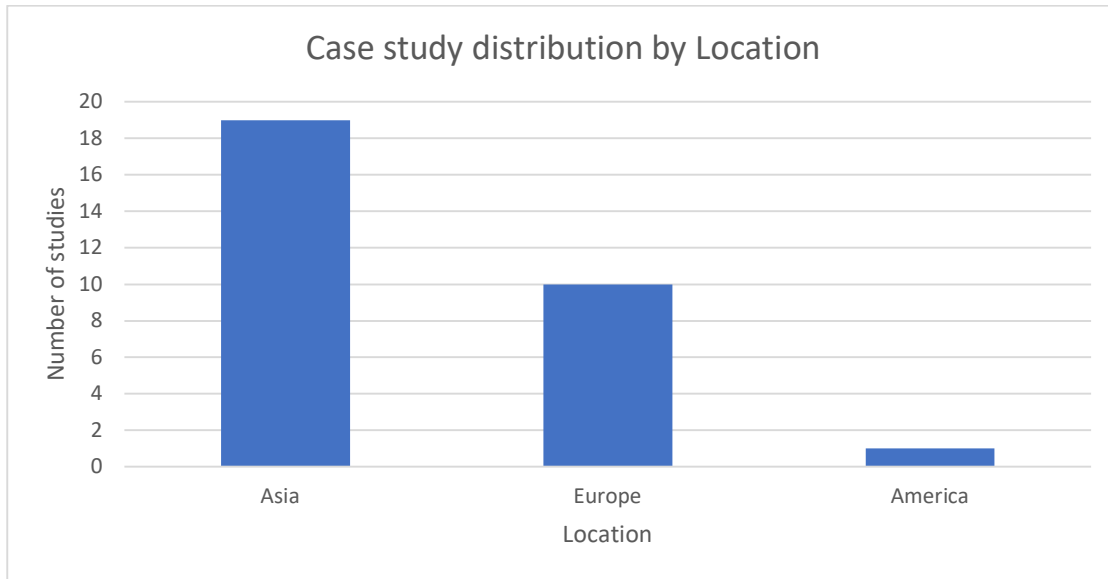


Figure 4 Micro-economic case study distribution by location

Parameters used in the analysis are listed in Table 3 below.

Table 3 Micro economic model input and analysis parameters

Micro economic input and analysis parameters		
Recycling process	Equipment cost	Output aggregate market demand
Equipment types and numbers	Equipment maintenance	Aggregates sales price
Equipment service life	Input waste distribution	Acceptance rate
Equipment power	Input waste quantities	Operational costs
Recycling facility capacity	Insurance costs	Landfilling costs
Work schedule	Transportation costs	Labor and employee numbers and wages
Setup costs	Permit costs	Land purchase costs
Inflation	Labor productivity	Gate fees

The NPV and IRR calculation are performed on Microsoft Excel. The steps, assumption and calculations followed to complete the analysis are presented in the following subsections.

a. Facility capacity

The facility capacity is taken as 350tons/hour which is the typical facility size and that recommended by many studies conducted in Lebanon using local CDW quantities, acceptance rates, and working hours (Srour et al., 2013).

b. Recycling process and equipment

The recycling process is set to mimic that of the ROSE facility in Italy ("R.O.S.E.") since the study is conducted in the context of the RE-MED project and its funding. The waste is visually examined for the presence of hazardous wastes. Nonhazardous CDW is weighed, screened for removal of impurities, passed through 2 magnets, one large magnet and one smaller magnet for the extraction of metals, then crushed and passed through screens for separation into different sizes. Fans and flotation devices are used in the process to remove fines and lighter elements from the recycled aggregates.

The equipment associated with this recycling process with their purchase costs, maintenance costs, service life and power consumption are presented in Table 4 below according to Coelho's numbers (Coelho & de Brito, 2013b). Equipment chosen considers the input CDW quantities into the facility as well as their distribution. It is assumed that every equipment is replaced at the end of its service life and that the old equipment is disposed of and not sold.

Insurance costs are set as 1% of equipment costs (Zhao et al., 2010).

Table 4 Equipment information

Equipment	Price (Eur)	Service		
		life (years)	Maintenance costs (Eur/year)	Power (KWH)
<b>Scales</b>	19170	30	134	0.05
<b>Feeder</b>	114000	8	1117	16.2
<b>Crusher</b>	130000	10	1183	110
<b>Large Magnet</b>	47522	15	257	6.50
<b>Small Magnet</b>	98114	15	257	16.4
<b>4 screens</b>	329300	6	4148	74.0
<b>Fans</b>	300000	20	3888	18.9
<b>Excavator</b>	135000	20	13458	90.0
<b>Manual separation cabinet</b>	7250	30	50.8	0.28
<b>Conveyor belts</b>	344166	20	4460	54.2

c. Facility setup costs

The costs of land acquisition and setup are taken to accommodate for the plant capacity and equipment sizes. A land size of 10,000m<sup>2</sup> is set for the facility (Srouf et al., 2013). This is associated with an estimated land cost of 50,000\$ and facility setup costs of 135,000\$ (Srouf et al., 2013).

Permits required for the construction and operation of the facility are assumed to cost 1000\$ and taxes and legal expenses are ignored.

d. CDW production quantities and distribution

The quantities of CDW produced in Beirut are taken from Srour’s study that relies on the number of demolished buildings, the built-up area per building and the tonnage of waste per built up area to calculate this number (Srour et al., 2013). The number used in Srour’s study is divided by 2 to account for the waste quantity produced in 1 year instead of 2 years. Using the population distribution between the different Lebanese areas taken from the database of the order of engineers, the CDW produced for the other Lebanese areas is calculated in proportion to population. The total quantity of CDW produced in Lebanon is taken as the sum of the quantities produced in each area, these wastes are assumed to consist of aggregates, metals, and woods. Table 5 below details the results.

The construction sector is taken to be growing at a yearly rate of 7.3% (Consultancy, 2022) and therefore, the production of CDW is taken to follow this trend as well.

80% of produced CDW is assumed to be nonhazardous implying an 80% acceptance rate into the recycling facility (Srour et al., 2013).

Table 5 CDW production by location

Location	Beirut	Mount Lebanon	North governate and Akkar	Bekaa and Baalbek El Hermel	South governate	Nabatieh	Total
<b>Population (%)</b>	9.33	35.2	21.7	14.4	11.7	7.67	100
<b>CDW production (tons)</b>	455 596	1719524	1061783	701187	569810	37452 2	4882 421



e. Facility operational costs.

Operational costs include equipment maintenance costs presented in the equipment table (Table 4), electricity costs, labor wages, employee salaries, transportation costs, insurance costs (presented in the equipment section) as well as landfilling costs.

Labor productivity is taken to be 50tons/8hours according to Coelho (Coelho & de Brito, 2013b). Taking into consideration sorting, monitoring, and using the equipment, a total of 10 laborers is needed for recycling facility operations. Labor wages are taken as 10\$/worker/day. In addition, 2 junior engineers are employed in the recycling facility each with a salary of 1000\$/month. The year is taken to include 260 working days, and the day 8 working hours (Srour et al., 2013).

Electricity costs are split between EDL (Electricité du Liban) electricity and private generator electricity in Lebanon. For EDL electricity, the subscription fee is taken as 0.21\$/Ampere and the consumption fee as 0.1\$/KW for the first 100KW and 0.27\$ for every KW over 100KW. The subscription fee is taken to account for 387KWH of consumption considering the equipment power consumption in addition to the power needed to light the offices. For the private generator electricity, the consumption fee is taken as 0.54\$/KW. It is assumed that for every 8 hours, the first 6 hours of electricity are supplied by the private generator and the last 2 hours by EDL.

Transportation costs are taken as 0.1\$/ton/Km (AlZaghrini et al., 2019) and the distances from the recycling facility to both the market as well as to the landfills assumed to be 50Km. The recycled CDW quantities are transported to the market where they are sold. Fines extracted through the process and the CDW corresponding to the 20% facility input rejection are transported to landfills for landfilling. Landfilling costs are set as 10\$/ton.

f. Facility revenues

Facility revenues are twofold; revenues from the gate fee and revenues from the sales of recycled or sorted CDW.

The facility gate fee is set as 15\$/ton of CDW input (AlZaghrini et al., 2019). The prices of metals and wood are taken as 300\$/ton and 92.6\$/ton respectively according to a market inquiry. As for the prices of recycled aggregates, they are taken to equal those of natural aggregates. Coarse aggregates are sold for 6.75\$/ton and fine aggregates are sold for 3.63\$/ton (AlZaghrini et al., 2019).

g. Other parameters

Since the study is conducted in the context of the RE-MED project which is providing an incentive of 60,000 Euros to construct a CDW recycling facility in Lebanon, this value is used to alleviate starting costs in the analysis.

Inflation is set as 3% per year (Srouf et al., 2013) and taken to affect all prices and costs including operational costs, equipment purchase costs and prices of CDW recyclables.

Aggregate market demand quantities are taken as 249Mtons/year for coarse aggregates and 70.5Mtons/year for fine aggregates (AlZaghrini et al., 2019). These quantities are used to check that the sales of recycled aggregates do not exceed the market demand.

The exchange rate of Euros to U.S. Dollars is set as 1.08. The EDL electricity cost is assumed to be collected in USD and not on the Sayrafa exchange rate.

For the NPV analysis, the rate of return (RoR) is set as 5% per year.

#### h. Economic model constraints

Several constraints are placed on the model to ensure logical operation. These include (Madi & Srour, 2019):

- Ensuring that the gate fees are less than the landfilling fees.
- Ensuring that the recycled coarse aggregates price is less than or equal to the natural coarse aggregate price.
- Ensuring that the recycled fine aggregates price is less than or equal to the natural fine aggregate price.
- Ensuring that the revenues (gate fees and recycled aggregates sales revenues) are more than the facility's operational costs (insurance, equipment maintenance, wages and salaries, electricity, transportation, landfilling).

#### i. Economic comparative assessment

The economic analysis is performed on 2 scenarios for a period of 10 years. The first pertains to the present Lebanese situation and the second to the situation created through the implementation of the master plan.

For the present state, 1 recycling facility accounts for the CDW supply of Lebanon. CDW destination distribution is taken as 2% to recycling, 70% to landfilling and 28% to illegal dumping (UNDP, 2018c). Since there is no data around the percentage of recycled CDW used in the construction sector, a value of 10% of recycling facility output is assumed to be sold back into the market for the present situation.

It is assumed for the second scenario that the master plan has been completely implemented and its objectives attained. The master plan objectives that impact the economic analysis include:

- 50% landfill diversion.
- 0% illegal dumping.
- 25% recycled aggregates use for buildings and 50% for infrastructure.
- 4 built recycling facilities in the country.
- 10% reduction in CDW production.

The landfill diversion and illegal dumping percentages as well as the production reduction percentage affect the facility's input quantities and revenues from gate fees. The number of built facilities distributes the total produced CDW quantity to the 4 facilities and therefore affects facility operation time if the quantity is below that required to operate at capacity. The percent usage of aggregates in constructions affects the quantities of recycled aggregates sold into the market and therefore the revenues of the recycling facility.

For both scenarios, the facility's CDW input quantities are used to calculate the number of hours of operation per day. Operational costs are then calculated based on the number of operating hours.

## CHAPTER IV

### FRAMEWORK DEVELOPMENT RESULTS AND DISCUSSION

This section presents the results of the analyses and studies performed according to the set methodology for the first section of the study pertaining to the development of a CDW management master plan framework. The results follow the methodological order of chapter 4.

#### **A. Thematic analysis**

A general overview and understanding of the main components of waste management master plans is developed through a preliminary reading of the collected master plans. The master plans are then analyzed in depth and their components drafted into themes which are reviewed, detailed, named then organized and shortlisted. Themes refer to master plan sections since the thematic analysis is conducted to identify master plan sections.

Through preliminary analysis, 11 master plan sections and 57 master plan subsections - referred to as themes in Nowell's process- are identified. The thematic analysis leading to the formulation of the preliminary master plan sections is present in the appendix (Table 22). These are then organized and shortlisted into clear, well-defined, non-duplicated sections and subsections to form 11 main sections with 29 subsections.

The main sections of the master plans follow a pattern for grouping. Two groups of main sections are identified, the plan framing group and the plan body group. The plan framing group frames and guides the content of the plan body group. In accordance with this grouping pattern, the 11 identified main sections are split into 5 belonging to the plan framing group and 6 belonging to the plan body group.

The plan framing group includes the definition, content, objectives, state of the art, and forecasting sections. The content of these sections including their subsections if present and descriptions is detailed below along with the number of times they appear in existing master plans.

- Definition: This section defines the master plan as one of the different planning alternatives specifying whether the plan is a verbal policy plan, strategic plan, or hybrid plan. It appears in 14 of the plans.
- Content: This section states the content of the plan, it includes 3 subsections, purpose, coverage, and key themes.
  - The purpose subsection establishes the purpose of developing the plan on the national level. It appears in 20 of the plans.
  - The coverage subsection establishes the coverage of the plan in terms of waste, time, sectors, and location (geographical coverage). It appears in 13 of the plans.
  - The key themes subsection lists the key themes and values that are adopted throughout the plan in every section of its body group. It appears in 9 of the plans.
- Objectives: This section translates the purpose subsection of the content section into quantifiable objectives detailed with percentages of completion by a certain date taken to be in the validity timeframe defined in the coverage subsection of the content section. It appears in 23 of the plans.
- State of the art: This section summarizes the status quo in the country of master planning from its different aspects. It includes 3 subsections, existing situation, existing policies, and existing plans.

- The existing situation subsection describes the prevalent waste management situation in the country of master planning. It presents the related statistics to the operations performed under waste management. It appears in 28 of the plans.
- The existing policies subsection lists the policies related to the management of wastes in the country of master planning. It appears in 25 of the plans.
- The existing plans subsection lists the existing master plans or plans that have been implemented or developed for the country of master planning. It appears in 17 of the plans.
- Forecasting: This section uses the data provided in the state-of-the-art section to plan for the future and establish the basis for the following master plan. It includes 2 subsections, deficiencies in existing plans and policies, and expansion strategies.
  - The deficiencies in existing plans and policies subsection analyses the existing plans and policies with respect to their impact and concludes the necessary steps to ameliorate the output of these plans and policies. It appears in 15 of the plans.
  - The expansion strategies subsection identifies future steps that should follow the master plan at hand. This subsection builds on the purpose and objectives section to reach higher goals. It appears in 9 of the plans.

The plan body group includes the legal instruments, infrastructure and operation, knowledge transfer, planning, financing and implementation, and evaluation sections. The content of these sections including their subsections if present and descriptions is detailed below along with the number of times they appear in existing master plans.

- Legal instruments: This section targets the legal supporting structure for master planning. It includes 2 subsections, compliance with existing and drafting and support of new.
  - The compliance with existing subsection develops the strategies and policies necessary to comply with existing legal instruments. These legal instruments are presented under existing policies in the state-of-the-art section of the plan framing group. It appears in 18 of the plans.
  - The drafting and support of new subsection develops new policies that address the deficiencies in existing policies and develops the necessary strategies to support the implementation of these policies. This subsection bases its content on the deficiencies in existing plans of the forecasting section in the plan framing group. It appears in 17 of the plans.
- Infrastructure and operation: This section targets the infrastructure necessary to conduct waste management operations and the processes involved in the operation itself. It includes 4 subsections, hauling, market, processing, and disposal.
  - The hauling subsection develops the strategies necessary to organize transportation operations, collection operations in the waste management process. It appears in 23 of the plans.
  - The market subsection develops the strategies necessary to develop a sales and purchase market for recycled wastes. It appears in 14 of the plans.
  - The processing subsection develops the strategies necessary to reduce and prevent production and enhance the recycling of wastes. It appears in 27 of the plans.



- The disposal subsection develops the strategies necessary to regulate and manage the disposal of wastes including the strategies targeting existing landfills and dumpsites. It appears in 12 of the plans.
- Knowledge transfer: This section targets information sharing, and education related to waste management. It sets the floor to the integration of waste management processes in the community. It includes 2 subsections, awareness and education and marketing.
  - The awareness and education subsection develops strategies necessary to disseminate information to the community including awareness and educational campaigns targeting the different stakeholders from students to habitants to employees, as well as the academic research supporting waste management operations. It appears in 24 of the plans.
  - The marketing subsection develops the strategies necessary to promote waste management operations including advertisement and marketing methods that change the purchase practice. It appears in 17 of the plans.
- Planning: This section targets the development of plans that fit under the master plan and are necessary for its proper functioning and improvement. The content of the plans targets all master plan sections and is established by the proper stakeholders. It includes 7 subsections, hazardous waste, construction and demolition waste operations, technology and innovation, energy efficiency, environmental planning, circular economy, and emergency planning.
  - The hazardous waste subsection develops the strategies necessary to plan and manage hazardous wastes involved in waste management operations. It appears in 18 of the plans.

- The construction and demolition waste operations subsection develops the strategies necessary to plan and manage construction and demolition waste operations at the site level and at the recycling facility level. It appears in 8 of the plans.
- The technology and innovation subsection develops the strategies necessary to introduce innovation and technology in the different process of waste management. It appears in 18 of the plans.
- The energy efficiency subsection develops the strategies necessary to focus on energy efficiency in the different process of waste management. It appears in 19 of the plans.
- The environmental planning subsection develops the strategies necessary to conduct environmental analyses at the different stages of the waste management process. It appears in 16 of the plans.
- The circular economy subsection develops the strategies necessary to introduce circular economy in the different processes of waste management. It appears in 12 of the plans.
- The emergency planning subsection develops the strategies necessary to plan and manage emergency events resulting in the generation of wastes as well as established the recovery methods and environmental assessment needed in such events. It appears in 2 of the plans.
- Financing and implementation: This section details the financial methods adopted to sustain waste management operations as well as the responsibilities assigned to ensure

efficient implementation. It includes 2 subsections, economic instruments, and involvement and responsibility.

- The economic instruments subsection develops the economic instruments that ensure the economic viability of waste management operations including funding, fees, and taxation structures. It appears in 21 of the plans.
- The involvement and responsibility subsection develops the strategies necessary to set stakeholder involvement and responsibility and promote their vertical and horizontal cooperation and partnership. It appears in 25 of the plans.
- Evaluation: This section focuses on evaluation of the master plan content as well as impacts. It includes 2 subsections, master plan impact evaluation and master plan content evaluation.
  - The master plan impact evaluation section develops strategies necessary to evaluate the impacts caused by the implementation of the master plan. It includes strategies targeting compliance, reporting, inspection, licensing, monitoring, data collection and objective assessment. It appears in 19 of the plans.
  - The master plan content evaluation develops the strategies necessary to evaluate the content of the master plan from different points of views including environmental, economic, and social. It appears in 13 of the plans.

Table 6 below shows the finalized list of master plan sections and subsections grouped into the Plan framing and Plan Body groups.

Table 6 Thematic analysis list of master plan sections

Thematic analysis list of master plan sections	
<b>A. Plan framing</b>	
1. Definition	
2. Content	

Thematic analysis list of master plan sections
2.1. Purpose of the plan
2.2. Coverage of the plan
2.3. Key themes
3. Objectives
4. State of the art
4.1. Existing situation
4.2. Existing policies
4.3. Existing plans
5. Forecasting
5.1. Deficiencies in existing plans and policies.
5.2. Expansion strategies
<b>B. Plan Body</b>
1. Legal instruments
1.1 Compliance with existing
1.2. Drafting and support of new
2. Infrastructure/Operation
2.1. Hauling
2.2. Market
2.3. Processing
2.4. Disposal
3. Knowledge transfer
3.1. Awareness and education
3.2. Marketing
4. Planning
4.1. Hazardous waste
4.2. Construction and demolition waste operations
4.3. Technology and innovation
4.4. Energy efficiency
4.5. Environmental planning
4.6. Circular economy
4.7. Emergency planning
5. Financing and implementation
5.1. Economic instruments
5.2. Involvement and responsibility
6. Evaluation
6.1. Master plan impact evaluation
6.2. Master plan content evaluation

## **B. Guideline analysis**

The analysis of existing guides and guidelines led to the formulation of 16 master plan assessment criteria. These criteria are assessed in terms of their presence or non-presence in the

analyzed guides and guidelines and presented in the appendix (Table 23). Criteria with similar general objectives are grouped to generate 10 criteria in total. The finalized list of master plan assessment criteria is presented below with the details of each criterium.

- Regulatory: Having a regulatory framework that supports the master plan strategies.
- Clarity, precision, detail, and measurability: Detailing the content of the master plan strategies and using clear and measurable targets.
- Implementation and monitoring: The ease of implementation and monitoring of the master plan strategies.
- Sustainability and circularity: Focusing on environmental, social, and economic sustainability as well as circularity while formulating the master plan strategies.
- Research and development: Supporting the master plan strategies with scientific research.
- Innovation: Relying on new technology and innovation in developing and defining the master plan strategies.
- Participation and involvement: Engaging the different stakeholders in the formulation of the master plan strategies, their implementation, and the assessment of their impacts.
- Coverage: Covering the entire national geographical area, the previous and future time horizons and the different national sectors involved in waste management operations in the formulation of the content of the master plan strategies.
- Scalability and dependance: Using past information and building on past experiences and strategies to develop the master plan content.
- Consistency: Having consistent master plan content.

Table 7 below shows the finalized list of master plan assessment criteria.

Table 7 Guideline analysis list of master plan assessment criteria

Guideline analysis list of master plan assessment criteria
Regulatory
Clarity, precision, detail, and measurability
Implementation and monitoring
Sustainability and circularity
Research and development
Innovation
Participation and involvement
Coverage
Scalability and dependance
Consistency

A list of master plan sections is extracted from each of the analyzed master planning guides and guidelines. These sections are presented in the appendix (Table 24). The proposed sections by the guides and guidelines focus on defining the plan, its purpose, objectives, coverage and themes, assessing the past and building on it for the future, working on old and new legislations, hauling strategies, processing and disposal methods, market development methods, information dissemination procedures and marketing methods as well as planning taking into account energy efficiency and innovation, considering economic tools and methods, engaging all stakeholders and evaluating the impacts and the content.

An investigation of the master plan sections proposed by guides and guidelines shows that these sections fit under the sections obtained through the thematic analysis of exiting master plan. Therefore, the results of the guides and guidelines analysis are transformed into matrix format and presented in the appendix (Table 25).

### C. Comparative assessment

The comparison of results between the two performed analyses shows that sections not mentioned in guides or guidelines but appearing in the finalized thematic analysis consist of the

definition and key themes sections of the plan framing group. Since these sections appear 14 and 9 times respectively in the analyzed existing master plans, their sections are kept as part of the list of main master plan sections.

Other preliminary sections have not been mentioned in guides or guidelines as well. These include the strategies to change the purchase practice, environmental assessments and recovery plans for emergencies as well as the focus on themes such as discrimination and equity in the plan body. These sections only appear 6, 2, 2 and 4 times respectively in the preliminary thematic analysis and are therefore added as part of existing sections in the finalized thematic analysis results.

On the other hand, 4 of the guides express the importance of including a location studies section in waste management master plans. This section is therefore added onto the thematic analysis table and existing master plans are re-reviewed for the presence of a location studies section. Only 1 of the master plans appears to mention location studies but since the guides highlight the importance of this section, it is added onto the list of master plan sections in the description of the hauling subsection. The updated description of the hauling subsection becomes:

- The hauling subsection develops the strategies necessary to organize transportation operations, collection operations and location studies for all facilities involved in the waste management process.

With this change, the finalized list of master plan sections remains the same as that presented in Table 6

#### **D. AHP assessment**

The structure required to perform the AHP assessment is defined as follows:

- Problem at hand: Lack of a proper framework for the development of CDW management master plans.
- Goal of the analysis: To rank the compiled master plan sections by importance for the management of construction and demolition wastes specifically leading to the development of the master planning framework.

The AHP hierarchal structure is defined in the tree below (Figure 5) using the problem and goal as the first level, the criteria of Table 7 as the second level, and the alternatives -master plan sections- of Table 6 as the third level.



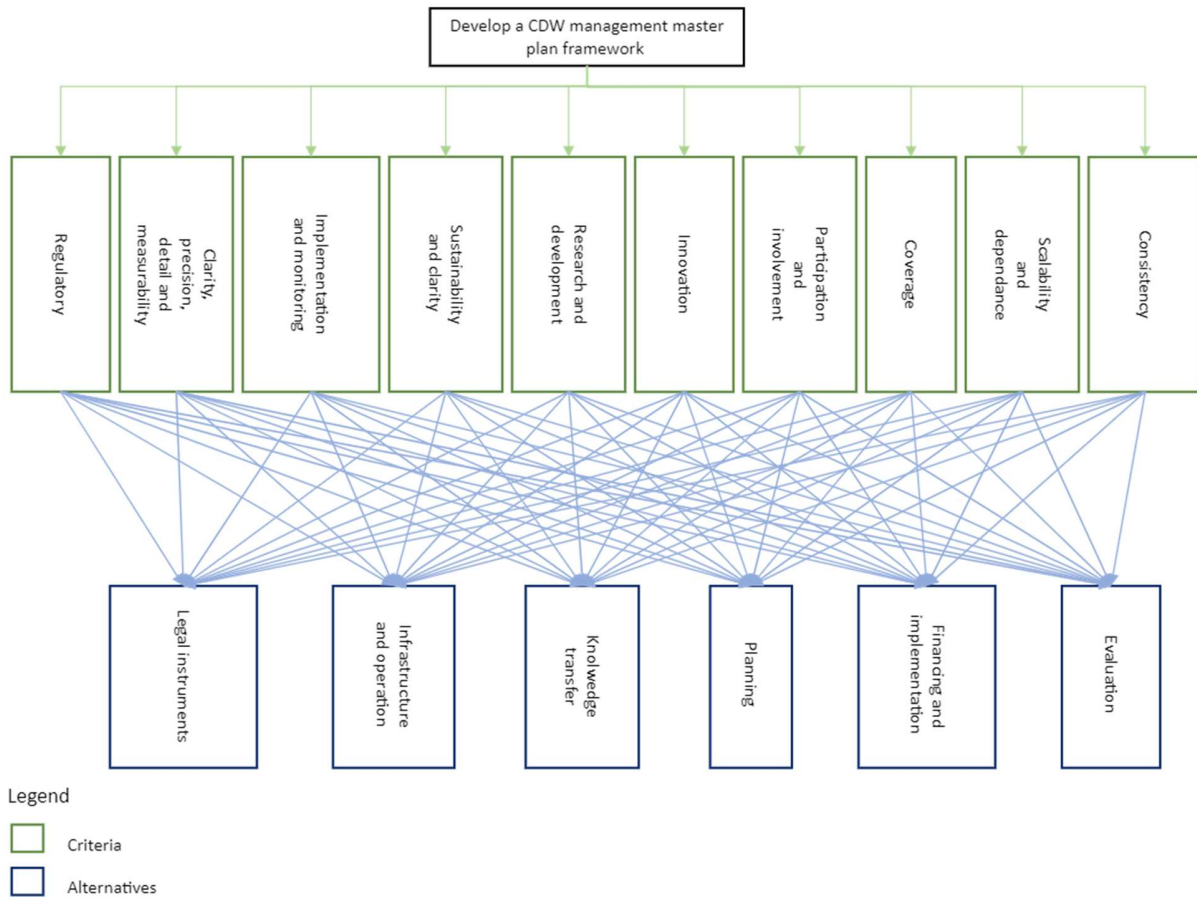


Figure 5 AHP tree structure

AHP calculations and checks are performed on each of the criteria weights and section importance values. The tables below present the detailed results of the AHP procedure for one of the expert inputs. The same procedure is followed for the 6 other expert inputs as presented in the methodology.

The first pairwise comparison matrix is presented in Table 8 below, it corresponds to the inputs of the first expert. The matrix is normalized using the sum of the relative weights to calculate the normalized pairwise comparison matrix presented in Table 9.

From the normalized pairwise comparison matrix, the criteria weights are calculated as the average of the normalized relative weights as presented in Table 10. The hierarchal synthesis

function is then calculated and presented in Table 11. The weighted sum values are calculated from the hierarchal synthesis function and divided by the criteria weights; their results are presented in Table 12. Lambda is then calculated as the average of the weighted sum over criteria weight values and found to be equal to 11.306. The consistency index (CI) is calculated using an n value of 10 given that 10 criteria are used in the analysis.

$$CI = \frac{\lambda - n}{n - 1} = \frac{11.306 - 10}{10 - 1} = 0.1451$$

The consistency ratio (CR) is calculated as:

$$CR = \frac{CI}{1.49} = \frac{0.1451}{1.49} = 0.0974 < 0.1$$

The consistency ratio is less than 0.1 therefore the results are consistent and acceptable. The criteria weights presented in Table 10 can be used to weigh the master plan sections' importance.

Table 13 presents the master plan section importance table corresponding to the criteria weights analyzed (for the first expert). The importance of criteria is weighed using the criteria weights to get a weighted importance of master plan sections. The sections are then ranked based on this weighted importance and sorted by importance (Table 14).

Table 8 Expert 1 pairwise comparison matrix

Criteria	Regulatory	Clarity, precision, detail, and measurability	Implementation and monitoring	Sustainability and circularity	Research and development	Innovation	Participation and involvement	Coverage	Scalability and dependance	Consistency
Regulatory	1.00	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Clarity, precision, detail, and measurability	9.00	1.00	0.33	0.33	1.00	1.00	1.00	0.25	0.20	0.17
Implementation and monitoring	9.00	3.00	1.00	1.00	1.00	3.00	1.00	2.00	1.00	3.00
Sustainability and circularity	9.00	3.00	1.00	1.00	1.00	5.00	1.00	2.00	3.00	4.00
Research and development	9.00	1.00	1.00	1.00	1.00	4.00	2.00	2.00	1.00	3.00
Innovation	9.00	1.00	0.33	0.20	0.25	1.00	0.20	0.33	0.17	0.20
Participation and involvement	9.00	1.00	1.00	1.00	0.50	5.00	1.00	0.33	0.33	1.00
Coverage	9.00	4.00	0.50	0.50	0.50	3.00	3.00	1.00	1.00	1.00
Scalability and dependance	9.00	5.00	1.00	0.33	1.00	6.00	3.00	1.00	1.00	1.00
Consistency	9.00	6.00	0.33	0.25	0.33	5.00	1.00	1.00	1.00	1.00

Table 9 Expert 1 normalized pairwise comparison matrix

Criteria	Regulatory	Clarity, precision, detail, and measurability	Implementation and monitoring	Sustainability and circularity	Research and development	Innovation	Participation and involvement	Coverage	Scalability and dependance	Consistency
Regulatory	0.50	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Clarity, precision, detail, and measurability	0.63	0.07	0.02	0.02	0.07	0.07	0.07	0.02	0.01	0.01
Implementation and monitoring	0.36	0.12	0.04	0.04	0.04	0.12	0.04	0.08	0.04	0.12
Sustainability and circularity	0.30	0.10	0.03	0.03	0.03	0.17	0.03	0.07	0.10	0.13
Research and development	0.36	0.04	0.04	0.04	0.04	0.16	0.08	0.08	0.04	0.12
Innovation	0.71	0.08	0.03	0.02	0.02	0.08	0.02	0.03	0.01	0.02
Participation and involvement	0.45	0.05	0.05	0.05	0.02	0.25	0.05	0.02	0.02	0.05
Coverage	0.38	0.17	0.02	0.02	0.02	0.13	0.13	0.04	0.04	0.04
Scalability and dependance	0.32	0.18	0.04	0.01	0.04	0.21	0.11	0.04	0.04	0.04
Consistency	0.36	0.24	0.01	0.01	0.01	0.20	0.04	0.04	0.04	0.04

Table 10 Expert 1 master plan assessment criteria weights

Criteria	Regulatory	Clarity, precision, detail, and measurability	Implementation and monitoring	Sustainability and circularity	Research and development	Innovation	Participation and involvement	Coverage	Scalability and dependance	Consistency
Criteria weights	0.437	0.110	0.034	0.030	0.035	0.144	0.062	0.046	0.040	0.062

Table 11 Expert 1 hierarchal synthesis function

Criteria	Regulatory	Clarity, precision, detail, and measurability	Implementation and monitoring	Sustainability and circularity	Research and development	Innovation	Participation and involvement	Coverage	Scalability and dependance	Consistency
Regulatory	0.44	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Clarity, precision, detail, and measurability	0.99	0.11	0.04	0.04	0.11	0.11	0.11	0.03	0.02	0.02
Implementation and monitoring	0.30	0.10	0.03	0.03	0.03	0.10	0.03	0.07	0.03	0.10
Sustainability and circularity	0.27	0.09	0.03	0.03	0.03	0.15	0.03	0.06	0.09	0.12
Research and development	0.32	0.04	0.04	0.04	0.04	0.14	0.07	0.07	0.04	0.11
Innovation	1.30	0.14	0.05	0.03	0.04	0.14	0.03	0.05	0.02	0.03
Participation and involvement	0.56	0.06	0.06	0.06	0.03	0.31	0.06	0.02	0.02	0.06

Criteria	Regulatory	Clarity, precision, detail, and measurability	Implementation and monitoring	Sustainability and circularity	Research and development	Innovation	Participation and involvement	Coverage	Scalability and dependance	Consistency
Coverage	0.41	0.18	0.02	0.02	0.02	0.14	0.14	0.05	0.05	0.05
Scalability and dependance	0.36	0.20	0.04	0.01	0.04	0.24	0.12	0.04	0.04	0.04
Consistency	0.56	0.37	0.02	0.02	0.02	0.31	0.06	0.06	0.06	0.06

Table 12 Expert 1 weighted sum and weighted sum over criteria weight values

Criteria	Regulatory	Clarity, precision, detail, and measurability	Implementation and monitoring	Sustainability and circularity	Research and development	Innovation	Participation and involvement	Coverage	Scalability and dependance	Consistency
Weighted sum value	5.51	1.35	0.38	0.33	0.41	1.69	0.70	0.49	0.42	0.63
Weighted sum/Criteria weight	12.6	12.2	11.2	10.9	11.6	11.8	11.4	10.7	10.7	10.2

Table 13 Expert 1 master plan section importance table

Master plan Sections	Master plan assessment criteria									
	Regulatory	Clarity, precision, detail, and measurability	Implementation and monitoring	Sustainability and circularity	Research and development	Innovation	Participation and involvement	Coverage	Scalability and dependance	Consistency
Compliance with existing text	10	8	5	9	9	6	9	3	1	1
Drafting and support of new text	10	7	3	3	3	7	8	5	8	1
Hauling	10	3	3	8	7	8	8	4	2	1
Market	10	6	3	9	3	5	9	3	3	2
Processing	10	7	2	9	7	8	7	3	2	2
Disposal	10	7	2	9	8	8	8	3	3	2
Awareness and education	10	8	3	4	8	5	9	4	1	1
Marketing	10	3	2	9	3	4	8	3	2	1
Hazardous waste	10	5	2	9	8	8	7	4	3	1
Construction and demolition waste operations	10	8	3	9	8	9	7	3	2	2
Technology and innovation	10	7	3	5	9	10	8	7	7	9
Energy efficiency	10	7	3	9	7	9	8	8	4	2
Environmental planning	10	6	3	9	7	9	7	9	3	2
Circular economy	10	6	3	9	8	9	7	8	2	2
Emergency planning	10	4	2	2	4	3	7	9	3	1
Economic instruments	10	6	2	5	6	3	8	9	2	1
Involvement and responsibility	10	8	5	4	3	4	9	9	2	1
Master plan impact evaluation	10	8	1	3	2	3	8	7	1	1
Master plan content evaluation	10	9	1	2	3	2	8	8	1	1

Table 14 Master plan sections sorted by importance according to the input of expert 1

Master plan sections	Weighted importance	Rank
Compliance with existing text	7.67	7

Master plan sections	Weighted importance	Rank
Drafting and support of new text	7.55	9
Hauling	7.26	13
Market	7.16	14
Processing	7.65	8
Disposal	7.79	6
Awareness and education	7.32	12
Marketing	6.49	19
Hazardous waste	7.49	10
Construction and demolition waste operations	7.97	5
Technology and innovation	8.80	1
Energy efficiency	8.20	2
Environmental planning	8.03	3
Circular economy	7.98	4
Emergency planning	6.54	18
Economic instruments	6.94	15
Involvement and responsibility	7.33	11
Master plan impact evaluation	6.79	17
Master plan content evaluation	6.81	16

The same procedure is repeated for every expert input. The sorted master plan section results of the AHP analyses performed on all expert inputs are presented in Table 15 below.

Table 15 Sorted master plan sections for every expert input

Rank	Input 1	Input 2	Input 3	Input 4	Input 5	Input 6	Input 7
1	Technology and innovation	Processing	Environmental planning	Drafting and support of new text	Disposal	Processing	Drafting and support of new text
2	Energy efficiency	Economic instruments	Hazardous waste	Construction and demolition waste operations	Drafting and support of new text	Economic instruments	Construction and demolition waste operations
3	Environmental planning	Disposal	Disposal	Hazardous waste	Economic instruments	Disposal	Hazardous waste
4	Circular economy	Awareness and education	Construction and demolition	Technology and innovation	Processing	Awareness and education	Technology and innovation



Rank	Input 1	Input 2	Input 3	Input 4	Input 5	Input 6	Input 7
			waste operations				
5	Construction and demolition waste operations	Construction and demolition waste operations	Emergency planning	Environmental planning	Involvement and responsibility	Construction and demolition waste operations	Environmental planning
6	Disposal	Involvement and responsibility	Processing	Hauling	Circular economy	Involvement and responsibility	Hauling
7	Compliance with existing text	Circular economy	Circular economy	Master plan impact evaluation	Energy efficiency	Circular economy	Master plan impact evaluation
8	Processing	Hauling	Energy efficiency	Master plan content evaluation	Awareness and education	Hauling	Master plan content evaluation
9	Drafting and support of new text	Environmental planning	Market	Economic instruments	Hazardous waste	Environmental planning	Economic instruments
10	Hazardous waste	Emergency planning	Drafting and support of new text	Marketing	Construction and demolition waste operations	Emergency planning	Marketing
11	Involvement and responsibility	Hazardous waste	Compliance with existing text	Disposal	Market	Hazardous waste	Disposal
12	Awareness and education	Energy efficiency	Technology and innovation	Awareness and education	Environmental planning	Energy efficiency	Awareness and education
13	Hauling	Drafting and support of new text	Hauling	Processing	Hauling	Drafting and support of new text	Processing
14	Market	Master plan impact evaluation	Economic instruments	Market	Marketing	Master plan impact evaluation	Market

Rank	Input 1	Input 2	Input 3	Input 4	Input 5	Input 6	Input 7
15	Economic instruments	Market	Marketing	Circular economy	Emergency planning	Market	Circular economy
16	Master plan content evaluation	Master plan content evaluation	Awareness and education	Involvement and responsibility	Compliance with existing text	Master plan content evaluation	Involvement and responsibility
17	Master plan impact evaluation	Technology and innovation	Involvement and responsibility	Emergency planning	Technology and innovation	Technology and innovation	Emergency planning
18	Emergency planning	Compliance with existing text	Master plan impact evaluation	Energy efficiency	Master plan impact evaluation	Compliance with existing text	Energy efficiency
19	Marketing	Marketing	Master plan content evaluation	Compliance with existing text	Master plan content evaluation	Marketing	Compliance with existing text

### E. Master plan development framework

The sorted master plan section results of the AHP assessment are analyzed for common importance of sections. The 7 expert input results (Table 15) are examined from the highest ranking to the lowest ranking sections. Starting from rank 1 and examining downwards, whenever a section appears for the 4th time across the 7 classifications, its title is added - following its order of 4th appearance with respect to that of the other sections- on the compiled importance list of master plan sections. This led to the formulation of a list of master plan sections with decreasing importance -referred to as the CDW management master plan development framework. The master plan development framework presents the different sections that could be included in a CDW management master plan in decreasing importance order. Based on the set time frame of the plan, the capacities of the planning country and the existing CDW management situation in the planning country, the number of sections to be included in

master plans is chosen by planners. This number is used in parallel with the framework list below to identify the most important sections that should be included and expanded in the CDW management master plan.

***Master plan development framework***

The following CDW management master plan sections are listed in decreasing importance.

1. Disposal
2. Construction and demolition waste management
3. Environmental planning
4. Processing
5. Circular economy
6. Hauling
7. Drafting and support of new
8. Economic instruments
9. Hazardous wastes
10. Involvement and responsibility
11. Energy efficiency
12. Technology and innovation
13. Awareness and education
14. Market
15. Master plan impact evaluation
16. Marketing

17. Emergency planning

18. Master plan content evaluation

19. Compliance with existing texts

## CHAPTER V

### FRAMEWORK APPLICATION RESULTS AND DISCUSSION

This section presents the results of the analyses and studies performed according to the set methodology for the second section of the study pertaining to the application of the framework to the Lebanese context and the evaluation of the framework in this context.

#### **A. Lebanese local status impact assessment**

A list of 13 laws, 1 draft law, 13 decrees, 1 draft decree, 10 ministerial decisions, 1 ministerial declaration, 5 treaties, 10 plans and 2 planning drafts addressing waste management in Lebanon is created through analyzing existing policies, plans, and guides. Since no guidelines or guides are issued by the government, the list does not contain strategies or plans proposed by such guidelines. While the private sector has issued guides, these are examined, and their results presented in the guides and guidelines analysis section in the form of proposed planning sections; therefore, they are not presented again in this section.

The impact assessment is performed on the compiled list according to the principles set in the methodology targeting proper definition and focus on CDW. The final results of the assessment are presented in Table 16 below.

Table 16 Lebanese existing policies (laws, decrees, treaties, ministerial decisions and declarations, and plans)

Type	Number	Year	Title	Content	Impact	Source
Law	28	2017	The Right to Access Information in Lebanon	The right of any person or entity to access administrative information and documents which are held at any governmental and municipal authority.	Medium	(Ricardo Khoury, 2020)
Law	48	2017	PPP and Concession Laws	Regulates public private partnerships.	High	(M. o. Environment, 2018)
Law	64	1988	On Environmental Preservation against Harmful and Hazardous Waste Pollution.	Regulates hazardous wastes as ratified by the Basel convention through assigning responsibility (Article 1) and guiding operations (Articles 2 to 5 and 9 of the reviewed version).	Medium	(Parliament, 1988)
Law	80	2018	The Environmental Protection Law	Sets integrated solid waste management principles and provides guidelines for the management of non-hazardous and hazardous wastes. Assigns responsibility to central authorities in running waste management projects (Article 9) and specifies the role of the national authority in waste management (Article 13 and 16)	High	(Parliament, 2018)
Law	118	1977	Municipal Act	Assigns transportation of wastes as a municipal responsibility (Article 49) and assigns responsibility to the Governor Mohafez in establishing markets and waste disposal (Article 61).	Low	(Parliament, 1977)
Law	212	1993	Ministry of Social Affairs	Founds the Ministry of Social Affairs and sets its responsibilities and organization including the intervention in emergency situations that require relief.	Medium	(Ricardo Khoury, 2020)
Law	216	1993	Ministry of	Founds the Ministry of Environment and	Medium	(Sweepnet,

Type	Number	Year	Title	Content	Impact	Source
			Environment	identifies its tasks and responsibilities including assessing all sources of solid waste generation.		2014a)
<b>Law</b>	251	2014	For Establishing Environmental Persecution	Assigns full time attorneys and investigation judges to attend environmental affairs such as pursuing environmental crimes, filing charges, and identifying offenders and enforce environmental laws. It also stipulates the establishment of an environmental police force with the same capacity as the justice police but for environmental crimes.	High	(Habitat, 2018)
<b>Law</b>	280	2014		Grants financial incentives to the municipalities surrounding the Naameh landfill and exempted them from certain dues and financial cuts. Gives financial benefits (from the Independent Municipal Fund) to the municipalities that observe within their boundaries the construction of waste treatment plants as well as to the affected neighboring municipalities.	High	(M. o. Environment, 2018)
<b>Law</b>	444	1988	On Environmental Protection	Regulates hazardous waste management and defines the basis and norms for environmental protection.	Medium	(Sweepnet, 2014a)
<b>Law</b>	444	2002	On Environmental Protection	Assigns the responsibility of planning, monitoring, setting standards and treatment terms to the Ministry of Environment in order to reduce disposal of hazardous and nonhazardous wastes, facilitate their management, encourage recycling and reuse as well as assign responsibilities and set financial	High	(Eng. Sanaa Al Sairawan, 2012)

Type	Number	Year	Title	Content	Impact	Source
				frameworks, and penalties.		
<b>Law</b>	501	1996		Charges the council for development and reconstruction with the implementation of the world bank funded solid waste environmental management program and with the implementation of the Emergency Plan for SWM in the Greater Beirut area and with developing proposals to improve solid waste management in other Lebanese cities.	High	(Jadam, 2010a)
<b>Law</b>	690	2005		Further defines and emphasizes the important role of the Ministry of Environment with respect to the emerging environmental and international issues.	High	(Ricardo Khoury, 2020)
<b>Draft law</b>		2005		Focuses on integrated solid waste management by emphasizing waste prevention, reduction, material reuse, recovery and power generation. Embraces private sector participation in SWM and sets up sources of financing and cost recovery.	Medium	(Jadam, 2010a)
<b>Decree</b>	118	1977	Municipal Act	Authorizes municipal councils to build solid waste disposal facilities.	Medium	(Jadam, 2010a)
<b>Decree</b>	167	2017	To determine the minutes of application of article 20 of the Law on Environmental Protection No 444 of 2002	Determines the reduction in custom duties and taxes on activities that protect the environment and equipment and technology that limit pollution and preserve the environment.	High	(اللبنانية, 2017)
<b>Decree</b>	2275	2009	Regulating units of the Ministry of Environment and	Lists solid waste issues under the Service of Urban Environment and assigns its responsibilities in reviewing studies	High	(M. o. t. Environment, 2009)



Type	Number	Year	Title	Content	Impact	Source
			defining their functions and terms of appointment	related to solid waste, receiving works linked to solid waste treatment, preparing and formulating master plans for the management of municipal solid waste and defining limiting values for the disposal of wastes.		
<b>Decree</b>	2366	2009	Defining the comprehensive plan for Lebanese territory arrangement	Defines the guidelines that enable land classification and territory organization.	Medium	(Ricardo Khoury, 2020)
<b>Decree</b>	3860	2010		Operates and maintains the facilities constructed through a funding provided by the European Union.	Low	(Jadam, 2010a)
<b>Decree</b>	3989	2016	On the establishment of an environmental police, its mandate, staffing and organization.	Designates an environmental police department within the Ministry of Environment to regulate environmental crimes, enforce penalties and monitor functions to persecute environmental crimes. Also specifies the training content necessary for the built police department.	High	(Ricardo Khoury, 2020)
<b>Decree</b>	5606	2019		Specifies the principles for domestic solid waste sorting, assigns the responsibility of such sorting (Article 5), and its mechanisms (Article 8) as well as determines the principles of management of hazardous wastes including sorting, storage, transport and disposal. Tackles waste generation and transport and defines the obligations of the waste generator.	Medium	(Ricardo Khoury, 2020)
<b>Decree</b>	8003	2012		Develops the Integrated Solid Waste Management Plan	High	(Habitat, 2018)
<b>Decree</b>	8213	2012	Strategic	Determines the mandatory procedures to	High	(M. o. t.

Type	Number	Year	Title	Content	Impact	Source
			environmental assessment decree for public sector policies, plans and programs.	assess the potential environmental impacts of any policy, plan, program, study, investment, or organization targeting the Lebanese region or any of its activity sectors. Also deals with the stages of environmental assessment including mitigation plans and management of implementation impacts.		Environment, 2012)
<b>Decree</b>	8471	2012	Environmental compliance for establishments.	Requires establishments to submit environmental audit reports confirming their environmental compliance to the Ministry of Environment starting 2015.	Medium	(Sweepnet, 2014a)
<b>Decree</b>	8633	2012	Fundamentals for environmental impact assessment	Requires industries to prepare initial environmental examination reports or environmental impact assessment studies for any construction (...) or existing licensed private project which may result in significant environmental consequences and submit it to the Ministry of Environment for approval.	High	(Sweepnet, 2014a)
<b>Decree</b>	8735	1974	On the preservation of public hygiene	Designates solid waste management as a municipal responsibility, assigns the responsibility of collecting and disposing wastes to Municipalities, bans the dumping of wastes in public places or private lands, and determines the criteria for waste transportation.	High	(Jadam, 2010a)
<b>Decree</b>	9093	2002		Specifies the rate of financial incentives given to municipalities that host waste management facilities.	High	(Jadam, 2010a)
<b>Draft Decree</b>			For law on ISWM	Properly assigns responsibility and the means of law implementation for the	Medium	(Sweepnet, 2014a)

Type	Number	Year	Title	Content	Impact	Source
				integrated solid waste management plan and determines the authority responsible for collecting fees, promoting incentives, and establishing a taxation structure.		
<b>Ministerial decision</b>	14	2003		The Council of Ministers requests the Center to Development and Reconstruction to devise a national municipal solid waste management plan.	Medium	(Jadam, 2010a)
<b>Ministerial decision</b>	103	2010		Establishes a national committee for the development of a framework to combat disasters and the development of an emergency management plan for disasters.	Medium	(Ricardo Khoury, 2020)
<b>Ministerial decision</b>	41	2013		Specifies the measures to coordinate disaster response operations in events such as war, natural disasters or crises that threaten the security and safety of the community and environmental and require national level interference.	Low	(Ricardo Khoury, 2020)
<b>Ministerial Decision</b>	55			Facilitates private sector involvement in Turkey collection and treatment projects and proposes stimulating waste management facilities in municipalities. Also mandates on the Ministry of Environment the drafting of regulations and incentives for municipalities to host waste treatment facilities.	High	(Sweepnet, 2014a)
<b>Ministerial Decision</b>	589	2015		Defines the procedure for the review of strategic environmental assessment scoping reports, and strategic environmental assessment reports as well as their required content.	High	(Ricardo Khoury, 2020)
<b>Ministerial</b>	260/1	2015		Defines the mechanisms and procedures to	High	(Ricardo

Type	Number	Year	Title	Content	Impact	Source
<b>I Decision</b>				review the initial environmental examination reports.		Khoury, 2020)
<b>Ministerial Decision</b>	261/1	2015		Defines the mechanism and procedures to review the environmental impact assessment scoping reports and environmental impact assessment reports.	High	(Ricardo Khoury, 2020)
<b>Ministerial Decision</b>	262/1	2015		Defines the procedures for filing and reviewing an objection on the Ministry of Environment's decisions related to the environmental impact assessments.	High	(Ricardo Khoury, 2020)
<b>Ministerial Decision</b>	59/1	2020		Determines the procedures for licensing new and existing hazardous waste management facilities in addition to the requirements for closing hazardous waste management facilities.	Medium	(Ricardo Khoury, 2020)
<b>Ministerial Decision</b>	999/1	2019		Stipulates the procedure and licensing requirements for hazardous waste transportation.	Medium	(Ricardo Khoury, 2020)
<b>Ministerial Declaration</b>	Article 16	2009		Commits the Government of Lebanon to protect the environment by finding alternatives to open dumping and solutions for solid waste management as well as implementing energy conservation measures and technologies in major cities.	Medium	(Jadam, 2010a)
<b>Treaty</b>		1973	Prevention of Marine Pollution by dumping of wastes and other matter.		Low	(Jadam, 2010a)
<b>Treaty</b>		1976	Barcelona convention for protection against pollution in the Mediterranean Sea.		Low	(Jadam, 2010a)

Type	Number	Year	Title	Content	Impact	Source
<b>Treaty</b>		1980	Protocol for the protection of the Mediterranean Sea against sea pollution from land-based sources (In Athens)		Low	(Jadam, 2010a)
<b>Treaty</b>		1994	Basel convention regulating the transboundary movement of hazardous wastes and their disposal.	Requires Lebanon to provide disposal facilities for the sound management of hazardous wastes.	Low	(Jadam, 2010a)
<b>Treaty</b>		2001	Stockholm Convention on reducing and eliminating the release of persistent organic pollutants.	Requires the government to improve waste management, cease open burning of solid waste, minimize the generation of municipal and medical waste through source recovery, reuse, recycling, waste separation, and promoting products that generate less wastes.	High	(Jadam, 2010a)
<b>Plan</b>		1997	Emergency plan for SWM (COM decision number 58, 2 Feb 1997)	Establishes a framework for solid waste management in Beirut and Mount Lebanon and shuts down the Bourj Hammoud and Normandy dumpsites while establishing a waste management system that sorts, stores, and properly disposes of bulky material.	High	(Jadam, 2010a)
<b>Plan</b>		1998	Emergency plan for SWM in greater Beirut	Plans for the collection, sorting, composting and landfilling of 2800 tons per day of municipal waste.	Medium	(Sweepnet, 2014a)
<b>Plan</b>		2005	2005 Waste management plan	Divides Lebanon to 4 service areas and foresees building a sorting and composting facilities in each of the 26	Medium	(Sweepnet, 2014a)

Type	Number	Year	Title	Content	Impact	Source
				districts.		
<b>Plan</b>		2006	Master plan for SWM (COM decision 1/4952, 18 August 2005)	Prepared by the Ministry of Environment and the Center for Development and Reconstruction. Plans an integrated approach to solid waste management including collection, sorting, recycling, composting, and landfilling.	High	(Jadam, 2010a)
<b>Plan</b>		2010	Waste to energy plan (COM decision 55, 1 September 2010)	Advocates waste to energy technologies in large cities and reviews the government's commitment to the 2006 master plan in the rest of the country. Plans for the optimization of land use by reducing reliance on landfills.	Medium	(Jadam, 2010a)
<b>Plan</b>		2022	Harak and Waste Management Coalition plan	Plans for waste sorting, reduction, environmental damage mitigation, the establishment of a waste management hierarchy, the development of institutional capacities for solid waste management, the establishment of mechanisms for monitoring and the reduction of waste management costs through financial sustainability.	High	(Khalil, 2022)
<b>Plan</b>		2010	National integrated strategy for solid waste management	Updates the statistics of the 2002 strategy and divides Lebanon to 4 service areas while promoting technologies for sorting, composting, landfilling, and transferring wastes that decrease costs and assign responsibilities.	High	(Sweepnet, 2014a)
<b>Plan</b>			Solid Waste in Lebanon	Promotes public awareness and the involvement of the Ministry of Education and Higher Education through awareness campaigns and programs set over the long	High	(Jadam, 2010a)

Type	Number	Year	Title	Content	Impact	Source
				run as well. Defines a waste minimization strategy through tax introduction and promotes waste treatment, recycling, and transformation.		
<b>Plan</b>				Assigns stakeholder responsibility in solid waste management operations according to the draft law on Integrated Solid Waste Management.	High	(Sweepnet, 2014a)
<b>Plan</b>	Theme 6	2010-2012	MOE work program	Promotes integrated solid waste management covering municipal, industrial and hazardous waste and calls for the management of uncontrolled dumpsites.	Medium	(Jadam, 2010a)
<b>Plan</b>	Draft		Recommendations for ISWM	Proposes a central regulatory body that oversees and ensures transparency in creating, constructing, and maintaining SWM facilities in which both the public and private sectors are involved. Promotes the use of technology, development of master plans, focus on circular economy, introduction of taxation structures and involvement of citizens and local authorities as well as plans for trainings and the establishment of guides.	Medium	(Verdeil, 2020)
<b>Plan</b>	Draft		Plan proposal	Plans for financial and cost recovery arrangements including allocation of budget to waste management infrastructure and municipal funds, establishment of funding for municipalities and work for international loans and grants.	High	(Sweepnet, 2014a)

## **B. Lebanese construction and demolition waste management master plan**

The Lebanese master plan is developed following the framework of section 4.5. To determine the number of master plan sections for the Lebanese master plan, the mean and median of the numbers of sections in existing master plans, guides and guidelines are calculated. Since the data for the number of sections in existing master plans is skewed, the median measure provides a more indicative and useful insight on the center of the dataset than the mean. 8 is found to be the median number of sections in the analyzed plans, guides, and guidelines. However, the number of sections suggested by Lebanese guidelines sums to 10 according to the results of the guideline analysis, therefore, to account for contextual sensitivity, 10 master plan body sections are developed.

The state-of-the-art section of the master plan is drafted with existing data from reports, news, and research. The rest of the framing group sections, as well as all the body group section strategies are inspired by the content and strategies presented in analyzed plans and are set through an iterative analysis of the state-of-the-art section, the impact assessment presented in section 5.1., and the economic analysis results. Presented strategies are formulated to be supported by high impact policies and to address policies of medium and low impact while targeting construction and demolition wastes in particular rather than solid waste in general.



## Lebanese construction and demolition waste management master plan

### A. Plan framing

#### 1. Definition

The Lebanese construction and demolition waste (CDW) management master plan is a strategic plan that presents strategies for the management of CDW. The plan is developed under the work packages and outputs of the RE-MED project, “Application de l’innovation pour le développement de l’économie circulaire en Méditerranée”. The document has been produced with the financial assistance of the European Union under the ENI CBC Mediterranean Sea Basin Program. The contents of this document are the sole responsibility of AUB -project partner 8 in the RE-MED project- and can in no way be taken to reflect the position of the European Union or that of the management structures of the Program.

#### 2. Content

##### 2.1. Purpose of the plan

The country of Lebanon currently possesses no plan for the management of construction and demolition wastes. While solid waste management plans or planning guides exist, they barely address construction and demolition wastes which constitute approximately 25% of total municipal wastes according to the “Solid waste management in Lebanon: A national plan for Lebanon 2016-2020” report published by the United Nations Development Programme -UNDP- in 2016 (UNDP, 2016). The master plan presents the strategies necessary to manage construction and demolition wastes in a circular economy context while promoting environmental protection and healthier living.

## 2.2.Coverage of the plan

The master plan is set for a period of 10 years (2023-2033) and covers the entire geographical area of Lebanon consisting of its 8 governates: Aakkar, Baalbek-Hermel, Beirut, Beqaa, Mount Lebanon, Nabatiyeh, North Lebanon and South Lebanon.

The following sectors are targeted through the plan:

- Agriculture
- Manufacturing
- Construction and engineering
- Media and communications
- Natural resources
- Information technology
- Financial and professional services
- Transportation and logistics
- Government and public administration

Plans presented in this master plan cover the following construction and demolition wastes:

- Concrete and asphalt rubble
- Brick and masonry
- Wood and lumber
- Plaster and drywall
- Metals including steel and aluminum
- Glass
- Insulation materials including fiberglass and cellulose

- Roofing materials including shingles and tiles
- Ceramic tiles and bathroom fixtures
- Electrical wiring and components
- Plumbing fixtures and pipes
- HVAC systems and ductwork
- Landscaping and site debris including soil, rocks, and trees.

Noting that some of these materials may contain asbestos -which is considered a hazardous material-, this plan covers asbestos containing CDW.

### 2.3. Key themes

The following key themes support the plans presented in this master plan. They present the basis for plan development.

- C. **Sustainability:** Being sustainability oriented in every step and policy implemented.
- D. **Accountability:** Being accountable when meeting C&DW recycling and reuse objectives.
- E. **Organization:** Hierarchical organization and decision making shall promote waste reduction and recycling.
- F. **Responsibility:** Dividing responsibility to all sectors and parties included in the management chain.
- G. **Leadership:** The government shall lead the management process.
- H. **Initiative:** Private sector shall show initiative in taking part in the C&DW sector.
- I. **Environmental orientation:** Developed policies and strategies shall always take into consideration environmental impacts and emissions.

- J. **Circularity:** Developed strategies should be assessed with respect to their circularity.
- K. **Contextual sensibility:** Plans shall be tailored to the contextual environmental and adapted to existing implemented strategies and policies.
- L. **Evaluation:** Feedback from all stakeholders including the general public, private and public sector partaking in the C&DW management process shall be used for updating existing plans.
- M. **Value orientation:** Core values shall be adopted in planning and implementation including:
- a. **Ethicality** portrayed through transparency, honesty, fairness, and accountability between the stakeholders.
  - b. **Quality** of the product.
  - c. **Responsiveness** in service delivery.
  - d. **Respectfulness** towards every member and valuation of their input and comments.
  - e. **Collaboration** between the parties and working as a team.
  - f. **Innovation** in strategic steps and implementation.
  - g. **Integrity** in work delivered through every step of the management chain.

### 3. Objectives

The strategies presented in this master plan aim to achieve the following objectives within the planning timeframe:

1. Reach a 50% construction and demolition waste diversion from landfills to recycling facilities within 5 years.
2. Completely stop illegal construction and demolition waste dumping within 2 years.

3. Establish a system for tracking and reporting the amount of construction and demolition waste generated and recycled within the next 12 months.
4. Reach a reporting percentage of 100% through the tracking and reporting system for construction and demolition waste generated and recycled within the next 3 years.
5. Develop and implement a mandatory construction and demolition waste management plan for all new construction and major renovation projects within the next 2 years.
6. Increase the use of recycled materials with a target of using 25% recycled material for new building constructions within the next 10 years and 50% recycled material for roads and infrastructure projects within the next 10 years.
7. Increase the number of construction and demolition waste recycling facilities to reach 4 facilities within 10 years covering the geographical area of Lebanon.
8. Reduce the total amount of construction and demolition waste generated by 10% within the next 10 years through improved design and construction practices.
9. Implement a fee system for landfilling construction and demolition waste that would make recycling cheaper than landfilling, therefore reducing landfilling by 50% within the next 5 years.
10. Implement a pay-as-you-throw program for construction and demolition waste collection, with a target of reducing the generation of non-aggregate CDW by 25% within the next 3 years.
11. Encourage the use of deconstruction instead of demolition for buildings scheduled for removal, with a target of deconstructing 50% of buildings within the next 10 years.

#### 4. State of the art

##### 4.1. Existing situation

###### Construction and demolition waste recycling

Waste recycling operations in Lebanon have mainly consisted of private sector initiatives. This applies to construction and demolition wastes as well. Until 2020 there existed no recycling facilities for construction and demolition wastes. Following the Beirut port blast of August 4, 2020, several entities including AUB's neighborhood initiative, Development Inc. sal, the UN-Habitat, the Lebanese Reforestation Initiative, UNICEF, Beirut Municipality, Forward Emergency Room of the Lebanese Army, port authorities, Reel-Ly, Spinneys-Lebanon, Diageo Lebanon, and Nestle Pure Life Lebanon came together to address the rubble catastrophe created by the blast. This led to the formation of the Rubble to Mountain project. The Rubble to Mountain project found a place to store rubble and glass debris and secured areas for waste sorting and crushing using crushers imported from India and China through a funding by the UN-Habitat and UNICEF. The built construction and demolition waste recycling facility was equipped to process asbestos with the highest protective measures. The facility also sorts CDW into aggregates, glass and other wastes and produces recycled aggregates from the aggregate wastes through its machinery. The Rubble to Mountain facility can process 500 tons per day of construction and demolition wastes and is located near the Bakalian Mills in Karantina, Beirut.

Another CDW recycling facility call for expression of interest was launched in 2022 as part of the RE-MED project to promote the recycling of CDW in Lebanon. Fakih and Brothers company won the bid for the construction of the facility. A funding of 60,000 Euros was provided by the ENI CBC Med Program to support this construction. The Fakih and Brothers company currently possesses equipment for sorting and crushing construction and demolition

wastes and will use the funding to further improve the output of their recycling operations. The Fakih and Brothers recycling facility is located in Nabatyeh, South of Lebanon.

Other construction and demolition waste recycling initiatives occur at the site level in Lebanon. On construction sites, contractors sell excess steel to steel buyers who ship them for recycling. On demolition sites, glass, aluminum, porcelain, wood, plastic, steel, and copper elements, such as facets, windows, doors, W.C. elements, water system accessories, electric system accessories and cables, false ceilings, balustrades, pipes, and others as well as HVAC and WIFI systems are deconstructed and sold back into the market. Tiles are also removed sometimes and reused in new construction. Steel structural bars are cut from the concrete and are sold to steel buyers who ship them for recycling. Waste resulting from the structural and architectural core of buildings is sometimes also crushed to smaller sizes and used as backfilling material for other construction projects.

#### Production and quantities of construction and demolition wastes

Sources of construction and demolition wastes in Lebanon are threefold: construction and demolition planned operations, natural disasters such as earthquakes, and non-natural disasters such as wars and blasts.

Since no data collection system exists in Lebanon, researchers have adopted different calculation methods based on built up area and the number of construction and demolition permits issued to determine the quantities of CDW from construction and demolition operations. A report issued by the UNDP in 2018 estimated the annual quantity of CDW generated in Lebanon at around 4.2 million tons which is equivalent to around 20% of total waste generated annually in Lebanon (UNDP, 2018b).

The most recent non-natural source of CDW in Lebanon was the Beirut Port blast of 2020. This blast produced 1,051,818 tons of CDW excluding that resulting from clearing the Beirut Port according to the “Demolition waste assessment” report of the UNDP (UNDP, 2020a).

#### Transportation

CDW is transported from its source to its dumping location by privately owned trucks. The trucks are often improperly covered and secured and pollute the air and roads with dust and debris as they move. No organizational or collaboration efforts have been put to manage, regulate or increase the efficiency of CDW collection or transportation operations.

#### Data collection

There exists no data collection mechanism or data storing system for CDW operations.

#### Enforcement

Enforcement of CDW related policies is weak in Lebanon. Political intervention and corruption play a huge role in preventing proper implementation of policies. Moreover, the lack of monitoring and inspection caused by a deficit in capacity and resources within regulatory bodies further prevents proper enforcement of CDW related regulations.

#### Awareness and education

Several awareness campaigns and educational activities targeting CDW have been organized in Lebanon to promote the recycling of CDW.



In 2018 the Ministry of Environment along with the UNDP launched the “Recycling Construction Waste, It’s Not Impossible!” awareness campaign. The campaign included workshops, seminars and training sessions for stakeholders involved in both the construction and waste management sectors to raise awareness on the environmental impacts of CDW and to promote its recycling (UNDP, 2018a).

Other initiatives include the “Green Glass Recycling Initiative” by the Ministry of Environment to promote glass waste recycling (D. Star, 2014), the “Green Lighthouse” project by the Lebanese Center for Energy Conservation to promote sustainability in construction and increase the use of recycled material (T. D. Star, 2016) and the “Jabal Moussa Biosphere Reserve” project that targeted the recycling of CDW in its program (Moussa.).

#### Recycled CDW market

The market for selling recycled CDW in Lebanon is currently very limited. Since natural aggregates are procured locally and there is a lack of awareness on the importance of using recycled material as well as a lack of knowledge on their performance, construction still relies on natural aggregates in design and implementation thus limiting the market for sales of recycled CDW.

#### CDW disposal

The Bsalim Landfill was the only landfill in Lebanon accepting the disposal of construction and demolition wastes with a capacity of 12 tons/day and an area of 60000m<sup>2</sup> (UNDP, 2022). The landfill exceeded its capacity and was closed. Currently, there exists no landfill dedicated to the disposal of construction and demolition wastes in Lebanon. Most CDW

are dumped illegally in dumpsites, on the sides of roads, in water bodies or in private properties, resulting in 324 CDW dumpsites in 2016 (UNDP, 2022).

#### 4.2. Existing policies

Laws and decrees addressing or including CDW management operations in their content are presented below.

- Law 28 (2017) The Right to Access Information in Lebanon: The right of any person or entity to access administrative information and documents which are held at any governmental and municipal authority.
- Law 48 (2017) PPP and Concession Laws: Regulates public private partnerships.
- Law 64 (1988) On Environmental Preservation against Harmful and Hazardous Waste Pollution: Regulates hazardous wastes as ratified by the Basel convention through assigning responsibility (Article 1) and guiding operations (Articles 2 to 5 and 9 of the reviewed version).
- Law 80 (2018) The Environmental Protection Law: Sets integrated solid waste management principles and provides guidelines for the management of non-hazardous and hazardous wastes. Assigns responsibility to central authorities in running waste management projects (Article 9) and specifies the role of the national authority in waste management (Article 13 and 16).
- Law 118 (1977) Municipal Act: Assigns transportation of wastes as a municipal responsibility (Article 49) and assigns responsibility to the Governor Mohafez in establishing markets and waste disposal (Article 61).

- Law 212 (1993) Ministry of Social Affairs: Finds the Ministry of Social Affairs and sets its responsibilities and organization including the intervention in emergency situations that require relief.
- Law 216 (1993) Ministry of Environment : Finds the Ministry of Environment and identifies its tasks and responsibilities including assessing all sources of solid waste generation.
- Law 251 (2014) For Establishing Environmental Persecution: Assigns full time attorneys and investigation judges to attend environmental affairs such as pursuing environmental crimes, filing charges, and identifying offenders and enforce environmental laws. It also stipulates the establishment of an environmental police force with the same capacity as the justice police but for environmental crimes.
- Law 280 (2014): Grants financial incentives to the municipalities surrounding the Naameh landfill and exempted them from certain dues and financial cuts. Gives financial benefits (from the Independent Municipal Fund) to the municipalities that observe within their boundaries the construction of waste treatment plants as well as to the affected neighboring municipalities.
- Law 444 (1988) On Environmental Protection: Regulates hazardous waste management and defines the basis and norms for environmental protection.
- Law 444 (2002) On Environmental Protection: Assigns the responsibility of planning, monitoring, setting standards and treatment terms to the Ministry of Environment in order to reduce disposal of hazardous and nonhazardous wastes, facilitate their management, encourage recycling and reuse as well as assign responsibilities and set financial frameworks, and penalties.

- Law 501 (1996): Charges the council for development and reconstruction with the implementation of the world bank funded solid waste environmental management program and with the implementation of the Emergency Plan for SWM in the Greater Beirut area and with developing proposals to improve solid waste management in other Lebanese cities.
- Law 690 (2005): Further defines and emphasizes the important role of the Ministry of Environment with respect to the emerging environmental and international issues.
- Decree 118 (1977) Municipal Act: Authorizes municipal councils to build solid waste disposal facilities.
- Decree 167 (2017) To determine the minutes of application of article 20 of the Law on Environmental Protection No 444 of 2002: Determines the reduction in custom duties and taxes on activities that protect the environment and equipment and technology that limit pollution and preserve the environment.
- Decree 2275 (2009) Regulating units of the Ministry of Environment and defining their functions and terms of appointment: Lists solid waste issues under the Service of Urban Environment and assigns its responsibilities in reviewing studies related to solid waste, receiving works linked to solid waste treatment, preparing, and formulating master plans for the management of municipal solid waste and defining limiting values for the disposal of wastes.
- Decree 2366 (2009) Defining the comprehensive plan for Lebanese territory arrangement: Defines the guidelines that enable land classification and territory organization.

- Decree 3860 (2010): Operates and maintains the facilities constructed through a funding provided by the European Union.
- Decree 3989 (2016) On the establishment of an environmental police, its mandate, staffing and organization: Designates an environmental police department within the Ministry of Environment to regulate environmental crimes, enforce penalties and monitor functions to persecute environmental crimes. Also specifies the training content necessary for the built police department.
- Decree 5606 (2019): Specifies the principles for domestic solid waste sorting, assigns the responsibility of such sorting (Article 5), and its mechanisms (Article 8) as well as determines the principles of management of hazardous wastes including sorting, storage, transport, and disposal. Tackles waste generation and transport and defines the obligations of the waste generator.
- Decree 8003 (2012): Develops the Integrated Solid Waste Management Plan
- Decree 8213 (2012) Strategic environmental assessment decree for public sector policies, plans and programs: Determines the mandatory procedures to assess the potential environmental impacts of any policy, plan, program, study, investment, or organization targeting the Lebanese region or any of its activity sectors. Also deals with the stages of environmental assessment including mitigation plans and management of implementation impacts.
- Decree 8471 (2012) Environmental compliance for establishments: Requires establishments to submit environmental audit reports confirming their environmental compliance to the Ministry of Environment starting 2015.

- Decree 8633 (2012) Fundamentals for environmental impact assessment: Requires industries to prepare initial environmental examination reports or environmental impact assessment studies for any construction (...) or existing licensed private project which may result in significant environmental consequences and submit it to the Ministry of Environment for approval.
- Decree 8735 (1974) On the preservation of public hygiene: Designates solid waste management as a municipal responsibility, assigns the responsibility of collecting and disposing wastes to Municipalities, bans the dumping of wastes in public places or private lands, and determines the criteria for waste transportation.
- Decree 9093 (2002): Specifies the rate of financial incentives given to municipalities that host waste management facilities.

#### 4.3. Existing plans

Several plans have been drafted by the government or the public sector as stipulated under existing policies. The private sector has also contributed in CDW planning through developing private CDW management plans. Some of the existing CDW management plans for Lebanon are presented below.

- Emergency plan for SWM (COM decision number 58, 2 Feb 1997): Establishes a framework for solid waste management in Beirut and Mount Lebanon and shuts down the Bourj Hammoud and Normandy dumpsites while establishing a waste management system that sorts, stores, and properly disposes of bulky material.
- Emergency plan for SWM in greater Beirut (1998): Plans for the collection, sorting, composting, and landfilling of 2800 tons per day of municipal waste.

- 2005 Waste management plan (2005): Divides Lebanon to 4 service areas and foresees building a sorting and composting facility in each of the 26 districts.
- Master plan for SWM (COM decision 1/4952, 18 August 2005): Prepared by the Ministry of Environment and the Center for Development and Reconstruction. Plans an integrated approach to solid waste management including collection, sorting, recycling, composting, and landfilling.
- Waste to energy plan (COM decision 55, 1 September 2010): Advocates waste to energy technologies in large cities and reviews the government's commitment to the 2006 master plan in the rest of the country. Plans for the optimization of land use by reducing reliance on landfills.
- Harak and Waste Management Coalition plan (2022): Plans for waste sorting, reduction, environmental damage mitigation, the establishment of a waste management hierarchy, the development of institutional capacities for solid waste management, the establishment of mechanisms for monitoring and the reduction of waste management costs through financial sustainability.
- National integrated strategy for solid waste management (2010): Updates the statistics of the 2002 strategy and divides Lebanon to 4 service areas while promoting technologies for sorting, composting, landfilling, and transferring wastes that decrease costs and assign responsibilities.
- Solid Waste in Lebanon: Promotes public awareness and the involvement of the Ministry of Education and Higher Education through awareness campaigns and programs set over the long run as well. Defines a waste minimization strategy through tax introduction and promotes waste treatment, recycling, and transformation.

- MOE work program (2010-2012): Promotes integrated solid waste management covering municipal, industrial and hazardous waste and calls for the management of uncontrolled dumpsites.

## 5. Forecasting

### 5.1. Deficiencies in existing plans and policies

- Existing policies do not specifically address construction and demolition wastes for the most part but rather hazardous and non-hazardous wastes in general. Some policies also fall short in presenting clear content that properly assigns responsibilities while setting standards and procedures.
- Plans address municipal waste management or emergency waste management rather than CDW management particularly.
- Sections targeting the management of CDW in existing plans do not address all processes, sectors and stakeholders involved in management operations.
- Enforcement and implementation strategies in both policies and plans are not efficient.
- Plans fail to present clear data collection systems and good technological methods for information sharing and collaborative efforts.
- Plans fail to engage the different stakeholders in CDW management operations and unite their efforts.
- There is limited focus on awareness and education targeting the different stakeholders involved and impacting CDW management.
- Proper funding and incentives are not presented to incentivize the different stakeholders to partake in CDW management.



## 5.2. Expansion strategies

Possible extension strategies or future objectives for the period that follows the set 10-year time frame of the master plan include:

- Increase the percentage of construction and demolition waste diversion from landfills to reach 100% diversion.
- Introduce awareness campaigns to reach 75% of construction professional and 50% of residents.
- Increase the number of construction and demolition waste recycling facilities to account for the growing production of CDW.
- Implement a building material reuse program that collects, and stores gently used building materials, which can be made available for resale.
- Develop and implement a green building certification program that incentivizes the use of environmentally friendly building materials and practices.
- Establish a green procurement program for public entities that prioritizes the purchase of products and materials made from recycled content or that have a lower environmental impact.
- Provide funding and technical support to research and develop new construction and demolition waste management technologies and practices.
- Implement a carbon accounting program that measures, and reports greenhouse gas emissions associated with the construction and demolition waste management system and establishes a target for reducing emissions over time.

- Develop and implement a program to encourage the use of circular economy principles in construction and demolition waste management, with a target of achieving 80% circularity.
- Increase the use of artificial intelligence and data analytics using the data collected through the implemented tracking system to optimize construction and demolition waste management practices and further reduce waste generated.

## B. Plan Body

### 1. Legal instruments

#### 1.1. Drafting and support of new

- Form a committee of experts from the different sectors involved in CDW management to assess existing policies, identify deficiencies in existing policies and provide recommendations on new policies necessary for proper CDW management.
- Transform the drafted expert recommendation report into a decree.
- Conduct a review of policies adopted in different world countries and compare them with existing local policies. Identify potential improvements and possible policies that could be introduced.
- Conduct a stakeholder assessment targeting members of the community as well as the public and private sector entities involved in waste management to identify their input and suggestions on needed policies for improved CDW management.
- Introduce media awareness campaigns on new policies and organize workshops with involved companies and entities to share any regulatory updates.

- Introduce requirements for permit issuance that support the compliance with new policies.
- Strengthen and extend the work of the environmental police through increasing its number of employees and assigning compliance with new regulations to its program of work.
- Increase the number of inspections and monitoring performed by the environmental police on CDW production sites and CDW recycling facilities to ensure proper adherence to new regulations.
- Regulate the work of the judicial committee that addresses environmental violations and establish a reporting system transmitting the environmental police information to the judicial committee.
- Develop a reporting system for members of the community to report the non-compliance of others with regulations.

## 2. Infrastructure/Operation

### 2.1. Hauling

- Facilitate communication between collection companies through developing a communication platform and enforcing its use through making it a requirement for permit issuance.
- Conduct transportation analyses and provide information to transportation firms on the most efficient routes to use for transport of CDW from the production sites to the recycling facilities and from the recycling facilities to the market.
- Track the movement of CDW through developing and enforcing the use of a geographical CDW information system.

- Establish regional CDW collection plans that minimize environmental emissions and distribute the production quantities among the different collection firms available in the area.
- Regulate the number of CDW collection and transportation companies through limiting the number of permits issued.
- Ensure that operating collection and transportation companies cover the entire geographical area of the country.
- Set standards for the assessment of transportation and collection companies' trucks and machinery based on environmental factors.
- Conduct regular inspections on trucks and machinery to ensure proper maintenance and utilize their lifetime.
- Re-assess the validity of the transportation and collection permits based on performance and technology used to minimize environmental impacts.
- Publish transportation truck requirements for safe transportation of CDW.
- Classify geographical zones based on suitability for recycling operations, transportation and collection firms' placement, storage of CDW and disposal of non-recyclable wastes.
- Limit CDW trucks circulation to specific roads and specific times considering traffic and safety. The outputs of this strategy will be based on geographical modeling and demand analysis performed by hired experts in the field of transportation.
- Perform continuous assessments on transportation and CDW supply and demand trend changes and reassess the number of companies necessary to partake in collection and transportation operations as well as the transportation routes and operation schedule.

## 2.2. Processing

- Enforce the usage of recycled aggregates and recycled CDW material in new constructions through conducting, encouraging, and sharing studies on the feasibility and benefits of such introduction.
- Introduce construction permit requirements that promote circular design and reduce the amount of material used in construction by the private sector.
- Mandate the use of recycled CDW in public sector construction projects contracted to the private sector.
- Conduct and share CDW recycling facility feasibility studies to incentivize the private sector on investing in the recycling process.
- Provide norms for the quality of the recycled aggregates produced through CDW recycling operations.
- Monitor the output quality of recycling facilities through performing regular inspections and collecting samples for testing. Form and train a group of people to conduct these inspections.
- Introduce punitive measures for recycling facilities with non-compliance outputs to the standards.
- Extend the equipment tax reduction environmental law to include recycling facility machinery.
- Issue a list of acceptable equipment and equipment requirements in recycling operations.
- Assess requests for recycling permits based on the technologies used and innovation towards circularity.

- Conduct yearly reassessments of recycling facilities based on set environmental impact indices and the usage of new technologies that promote circularity.

### 2.3.Disposal

- Develop plans for existing landfills that manage the collection, transportation and recycling of previously disposed and recyclable CDW in landfill locations.
- Develop plans involving collection and transportation companies to collect and transport illegally dumped CDW to recycling facilities.
- Introduce a geographical information system to track the locations of illegal dumping sites through input from members of the community.
- Require the development of CDW disposal plans for construction and demolition works and ensure their implementation through local authority monitoring and inspection.
- Follow up with municipalities on new CDW landfilling sites and share information on new establishments for waste disposal on media platforms.
- Encourage studies on reuse opportunities for non-recyclable non-hazardous deconstruction wastes.
- Issue dumping guidelines to minimize noise and air pollution and ensure proper disposal of hazardous materials in landfills.
- Set limits for landfill emissions and conduct regular monitoring to ensure adherence.
- Encourage the private sector to rehabilitate previous dumpsites and illegal disposal areas.

### 3. Planning

#### 3.1. Hazardous waste

- Issue hazardous CDW guidelines spanning the entire management process from collection to treatment to disposal.
- Provide uniform measuring tools for CDW toxicity.
- Assess public buildings for presence of toxic material and develop plans for renovation of such buildings.
- Enforce the development of handling and disposal plans for hazardous waste by contractors when operating on sites containing hazardous materials.
- Adhere to international treaties managing hazardous wastes and extend the treaties' content to CDW hazardous wastes.
- Ban hazardous waste usage in new constructions.
- Identify buildings containing hazardous materials through community feedback forums.
- Promote the renovation of buildings containing hazardous wastes.
- Involve educational entities in environmental impact assessments of different hazardous waste disposal alternatives and in recommending best practices.
- Promote private sector initiative and technologies to deal with hazardous wastes.
- Involve groundwater, soil, and air specialists to develop proper strategies for the disposal of construction wastes containing asbestos.
- Ensure hazardous materials such as asbestos are properly handled in structures where demolition and renovation activities are taking place through local authority monitoring and inspection.

- Issue safety guidelines for personnel dealing with hazardous wastes in CDW recycling facilities and disposal sites.

### 3.2.Construction and demolition waste operations

- Contractors will encourage the reuse of excess materials and recycled CDW in new constructions.
- Recycling facilities will optimize recycling processes to increase efficiency, decrease environmental impacts, and increase the quality of recycled CDW.
- Standard CDW site level management plans will be produced and made available by the government for usage by the private sector.
- A team of experts will be introduced in the permits assessment process to assess the storage, collection, transportation, disposal, and hazardous waste plans -if any- on construction projects.
- Additional personnel will be hired to conduct site visit checks on CDW plan implementation.

### 3.3.Environmental planning

- Environmental impact assessments will be required from all participants in the CDW management chain including producers, designers, contractors, recyclers, transportation and collection firms and all other campaigns and strategies implemented in the context of CDW management.
- Environmental impact assessments will be considered when approving permits for jobs related to CDW management.



- Research performed by private educational institutions and research companies on the reduction of environmental impacts in recycling operations will be encouraged.
- Environmental analysis methods will be set with their respective system boundaries for conformity in conducting environmental impact assessments.
- Feedback loops will be formed with the community for inputs on improvements in the CDW management system taking into account environmental considerations.

### 3.4. Circular economy

- Support circular economy programs targeting non aggregate CDW and promoting their reuse and the maximization of their lifetime.
- Encourage research on potential reuse of all elements constituting CDW.
- Introduce circularity indices for CDW and green passports for recycled material.
- Develop a system to track CDW history and green passports.
- Ensure maximization of the lifetimes of all equipment and machinery used in the CDW management process through proper maintenance and usage.
- Encourage private sector innovation that increases the circularity of construction elements.
- Organize community brainstorming sessions on CDW reuse alternatives and improved circularity in the CDW management process.

## 4. Financing and implementation

### 4.1. Economic instruments

- Set budgets for monitoring CDW management operations through the environmental police.

- Introduce rewards to community members participating in the feedback chains and brainstorming sessions at their different levels.
- Conduct economic studies and set recycling facility gate fees and landfilling fees.
- Introduce financial penalties on illegal dumpers, transportation and collection firms not complying with set operation roads and time schedules, and contractors not complying with CDW plans.
- Set a range for the prices of recycled aggregates sold into the market.
- Reduce permit fees for collection and transportation firms involved in CDW recycling operations and for construction projects with plans that show clear optimization of material usage and introduction of recycled aggregates in building materials.
- Introduce taxes that promote the shift from landfilling to recycling.
- Facilitate debts with lower interest rates for investors in the CDW recycling sector and for contractors promoting circularity and recycled material usage.
- Provide financial incentives to collection and transportation firms that participate in dumpsite cleaning.
- Fine entities and stakeholders for noncompliance with new regulations.

#### 4.2. Involvement and responsibility

- Enhance collaboration between the public and private sector on CDW management through the development of interactive platforms.
- The public sector will lead waste management initiatives through setting policies, guidelines and standards and using different strategies to promote CDW management.

The private sector will adhere to set policies, guidelines and standards and will cooperate and promote at the private sector level, the management of CDW.

- Set the exact responsibilities of all stakeholders including public and private entities in implementing the master planning strategies and achieving the CDW management plan objectives.
- Specify the responsibilities of the different stakeholders in CDW management through an issued decree including the responsibilities of local public authorities in organizing, leading and monitoring management processes.
- Monitor the involvement and responsibility of the different stakeholders through setting key performance indicators.
- Ensure engagement of the community through designing continuous feedback loops, organizing forums, and opening access to information, reporting systems and CDW management platforms.
- Encourage private sector cooperation with the community to enhance CDW management operations.
- Facilitate private sector cooperation between the companies with similar objectives, and between the companies with different objectives involved at the different stages of the management chain.
- Appoint regional and local authorities to monitor, inspect and report environmental noncompliance in CDW management operations when the environmental police is not present.

### C. Micro-economic comparative study

Using the data and assumptions presented in the methodology, the yearly cash inflow and outflow for both the present state and the state fostered by the master plan are presented in the 2 tables below (Table 17 and Table 18)

Table 17 Present state CDW recycling facility cash inflow and outflow

Year	Cash inflow (\$)	Cash outflow (\$)
0	64800.0	-2282483.8
1	1521191.3	-942912.1
2	1681205.4	-1030230.6
3	1858051.5	-1126378.2
4	2053499.9	-1291646.0
5	2269507.5	-1410083.2
6	2508237.0	-1952744.9
7	2772078.5	-1684004.0
8	3063673.4	-1993519.2
9	3385941.2	-2016248.5
10	3742108.4	-2208130.4

Table 18 Master plan CDW recycling facility cash inflow and outflow

Year	Cash inflow (\$)	Cash outflow (\$)
0	64800.0	-2282483.8
1	14839809.2	-6197451.3
2	16400808.8	-6815040.3
3	18126009.8	-6709399.8
4	20032684.8	-7437937.3
5	21285677.4	-7913315.7
6	21924247.8	-8563004.1
7	22581975.2	-8395236.7
8	23259434.5	-8798515.8
9	23957217.5	-8906506.6
10	24675934.0	-9173701.8

These values are used to calculate the NPV at each year of operation as well as the IRR for 10 years of operation as presented below (Table 19 and Table 20). Brackets used in the tables indicate negative numbers.

Table 19 Present state CDW recycling facility NPV and IRR

Year	NPV (\$)
0	(\$2,217,683.8)
1	(\$1,666,941.6)
2	(\$1,076,488.3)
3	(\$444,441.5)
4	\$182,337.6
5	\$855,719.0
6	\$1,270,235.8
7	\$2,043,510.1
8	\$2,767,832.6
9	\$3,650,748.7
10	\$4,592,478.1
IRR	31% (for 10 years)

Table 20 Master plan CDW recycling facility NPV and IRR

Year	NPV
0	(\$2,217,683.8)
1	\$6,013,133.3
2	\$14,707,707.9
3	\$24,569,804.9
4	\$34,931,534.9
5	\$45,409,130.2
6	\$55,379,495.9
7	\$65,461,746.1
8	\$75,249,465.1
9	\$84,951,287.5
10	\$94,468,313.3
IRR	402% (for 10 years)

The following figures (Figure 6 and Figure 7) show the NPV versus time for both scenarios.

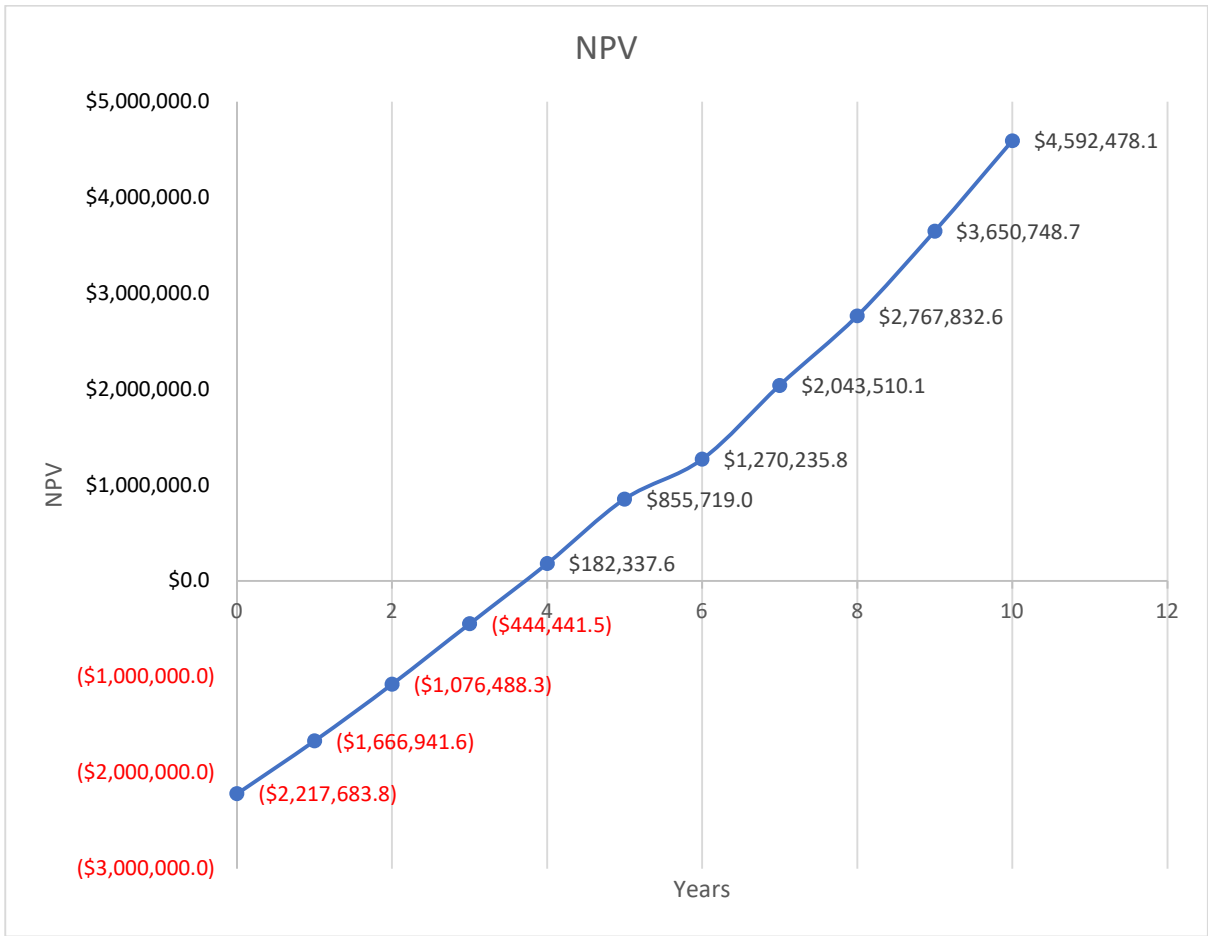


Figure 6 Present state CDW recycling facility NPV versus time

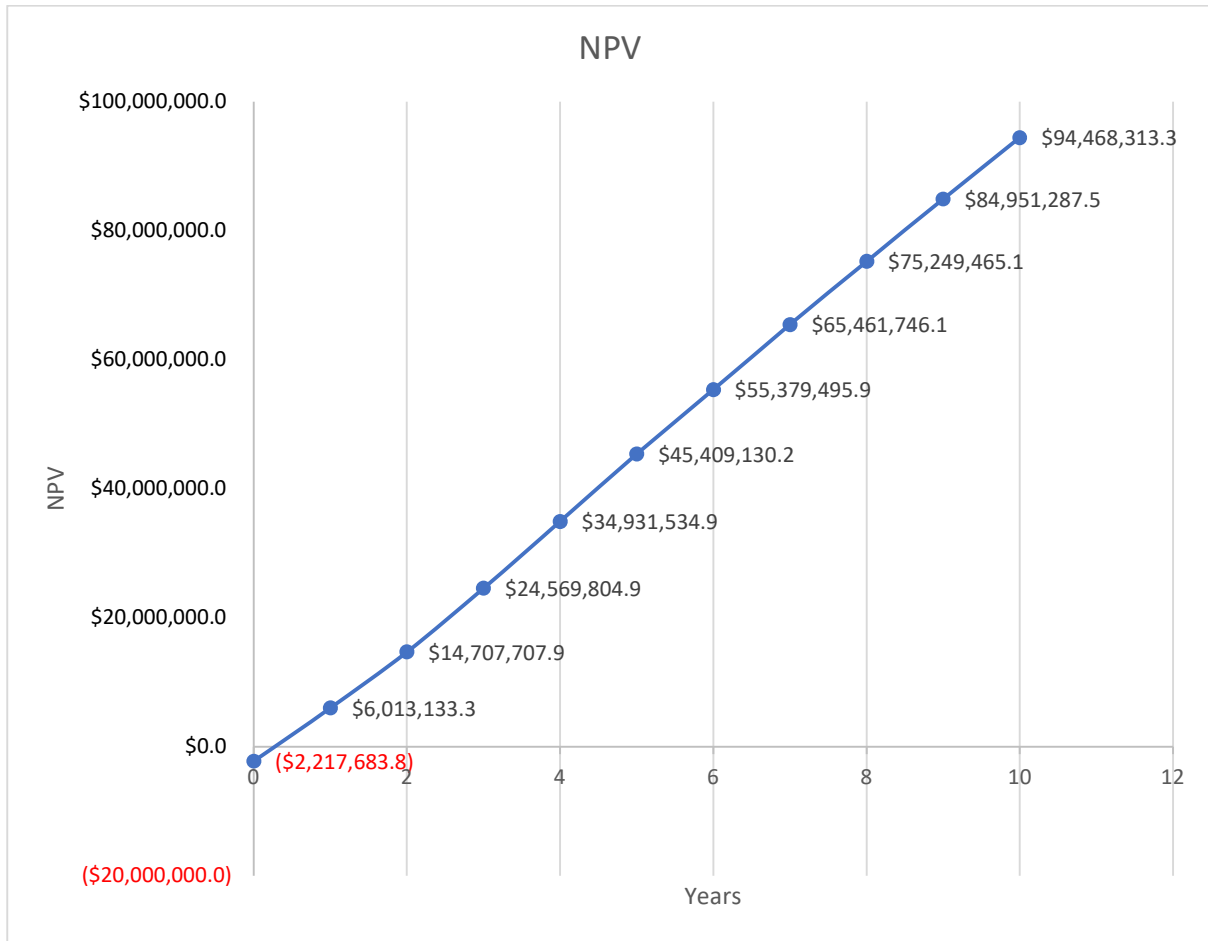


Figure 7 Master plan CDW recycling facility NPV versus time

By looking at the results of the NPV and IRR analysis for both scenarios, it is apparent that the master plan fosters a better economic environment for the construction of a CDW recycling facility.

For the present state, the NPV in 10 years of operation using an RoR of 5% is around 4.6M\$. Considering the initial investment of 2.2M\$, building a CDW recycling facility under the conditions of the present state is an attractive investment. The cash flow breaks even between the 3rd and the 4th year, and the IRR is calculated as 31%. Although the IRR value indicates high profitability, the analysis is performed for a gate fee of 15\$/ton. In Europe and the US, a gate fee of 15\$/ton is considered reasonable, however, for Lebanon it is considered high according to the

input of contractors from the syndicate of Lebanese contractors. In Lebanon a maximum gate fee of 7\$ to 8\$/ton should be targeted in CDW recycling facilities. If the gate fee is changed to 8\$, the net cash flow would be negative, the NPV would reach a negative value of 3.7M\$ in 10 years and the IRR would be non-existent since all cash flows are negative.

For the master plan state, the NPV in 10 years of operation using a RoR of 5% is around 94M\$. In comparison to the initial investment of 2.2M\$, the investment is very attractive. The cash flow breaks even early on in the first year of operation and the IRR is 402% for 10 years of operation indicating that the return on investment exceeds the initial investment which is a sign of very high profitability. Taking into account the input of the contractors from the syndicate of Lebanese contractors and changing the gate fee to 7\$/ton, the facility profitability remains very high with an IRR of 148% in 10 years. The gate fee may be reduced to up to 3\$/ton and the investment would remain profitable with an IRR of 26% and an NPV of around 4M\$ for 10 years of operation. Under these conditions, the facility would break even between the 4th and 5th year of operation. These results are shown in Table 21 and Figure 8 below. Therefore, the construction of a CDW recycling facility under the conditions provided by the master plan is more economically viable than the current economic environment. Profitability is ensured for a gate fee as low as 3\$/ton under the environment fostered by the master plan which incentivizes stakeholders to recycle instead of landfill CDW due to savings in costs.

Table 21 Reduced gate fee NPV and IRR results

Year	NPV (\$)
0	(\$2,217,683.8)
1	(\$2,147,485.3)
2	(\$2,042,466.9)
3	(\$1,221,409.6)
4	(\$375,933.6)
5	\$471,689.4
6	\$995,510.8



Year	NPV (\$)
7	\$1,811,150.8
8	\$2,508,766.4
9	\$3,293,630.4
10	\$4,063,544.6
IRR	26% (for 10 years)

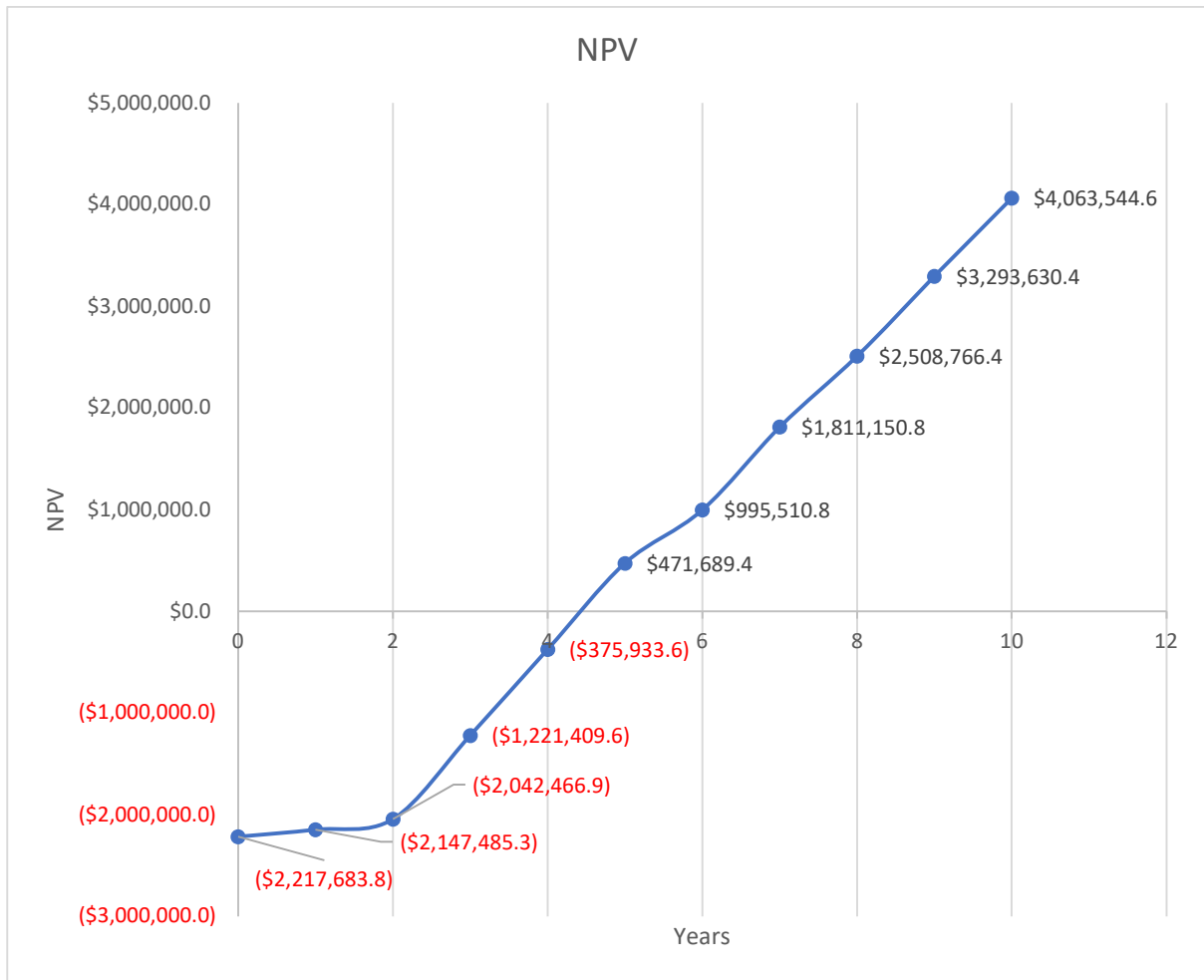


Figure 8 Reduced gate fee NPV versus time

## CHAPTER VI

### CONCLUSION

Increased environmental awareness in recent years has pushed the growth of circular economy in many vital sectors including construction. Being one of the largest sectors worldwide, the construction sector is responsible for up to 50% of produced wastes in some countries establishing the need for circularity in its operations and specifically in the management of its wastes. Existing master plans developed at the country level and targeting the different sectors of the economy have focused on solid waste management in general. These plans have lacked in presenting sufficient strategies that focus on and properly manage construction and demolition waste in particular. In addition, the planning process leading to the formulation of master plans has mainly relied on expert input with no clear framework for master plan development.

This research aimed at developing a framework for the drafting of CDW management master plans, implementing the framework to develop a CDW management master plan for Lebanon, and assessing the impacts of implementing the developed master plan at the microeconomic facility level.

To achieve the research objectives, a thematic analysis of 33 existing master plans and an analysis of 13 guides and guidelines was performed. The analyses led to the formulation of master plan sections and master plan sections' assessment criteria. The sections and criteria were grouped and shortlisted into distinctive sections and criteria and weighed by experts using AHP to determine the sections of most importance in CDW management with respect to the set of assessment criteria. Consistency was checked for AHP criteria weights, and the master plan

sections were listed through the AHP results by decreasing importance. Considering a median of 8 sections, disposal, CDW management, environmental planning, processing, circular economy, hauling, drafting and support of new policies, and economic instruments were found to constitute the 8 most important sections of CDW management master plans. The framework was used to develop a Lebanese CDW management master plan. The content of the master plan was formulated through inspiration from existing master plan strategies tailored to CDW rather than solid waste, coupled with economic analyses and impacts of existing policies. The micro economic analysis was performed for the existing prevalent Lebanese situation and the situation fostered by the master plan assuming that the plan was implemented, and its objectives attained. Results of the analysis showed increased economic viability for recycling facilities operating after the implementation of the master plan with a breakeven for investment period decreasing from less than 4 years to less than 1 year after plan implementation. Considering master plan implementation, the recycling facility gate fee taken initially as 15\$ was reduced to 3\$ -a location sensitive number- and the returns remained positive with a breakeven period of just over 4 years and an IRR of 26% for 10 years.

Limitations to the research outcomes include the number of AHP expert inputs used for classification of master plan sections. This number may be increased from 7 experts. Moreover, the qualifications of experts may be assessed using another AHP assessment to further weigh their inputs on criteria and master plan section importance. Further research may focus on addressing the presented limitations as well as further developing the master planning framework through classifying the subsections -presented in the results of the initial thematic analysis- of each master plan section using multi criteria decision making methods supported by expert input.

## APPENDIX

### **A. Thematic analysis**

The table below presents the preliminary thematic analysis results for master plan sections. A value of 0 indicates that the section is not present in the master plan and a value of 1 indicates that the section is present in the master plan.

Table 22 Thematic analysis matrix results

Master plans	Solid waste management master plan (Frank, 2017)	Municipal waste management in Italy (Matteo Ferraris, 2013)	Report on the solid waste management in Tunisia (Sweepnet, 2014b)	Municipal waste management in France(Gentil, 2013)	Waste management master plan (County, 2017)	Solid waste management master plan (KOKUSAI KOGYO CO., 2007)	Guide de gestion des déchets de construction et de démolition (IBGE, 2009)	La gestion des déchets du secteur de la construction (IBGE, 2011)	Waste management master plan (Environmental, 2012)	Solid waste management master plan (Limited, 2021)
Master plan sections										
<b>A. Plan framing</b>										
1. Definition	1	0	1	0	1	0	0	0	0	1
2. Content										
2.1. Purpose of the plan	1	0	1	0	1	1	0	0	1	1
2.2. Coverage of the plan	1	0	0	0	0	1	0	0	0	1
2.3. Key themes	1	0	1	0	1	0	0	0	0	1
3. Objectives	1	0	0	0	1	1	0	0	1	1
4. State of the art										
4.1. Existing situation	1	1	1	1	0	0	0	0	1	1
4.2. Existing policies	1	1	1	1	1	0	1	1	1	1
4.3. Existing plans	1	0	1	0	0	0	1	1	1	0
5. Forecasting										
5.1. Deficiencies in existing plans	1	1	0	1	0	0	0	1	1	1
5.2. Expansion strategies	0	0	0	0	0	0	0	0	0	0
<b>B. Plan Body</b>										
1. Legal instruments										
1.1 Compliance with existing	1	0	0	0	1	1	0	1	1	0
1.2. Drafting and support of new	1	0	0	0	1	1	1	0	1	1
2.										
Infrastructure/Operation										

Master plan sections	Master plans										
	Solid waste management master plan (Frank, 2017)	Municipal waste management in Italy (Matteo Ferraris, 2013)	Report on the solid waste management in Tunisia (Sweepnet, 2014b)	Municipal waste management in France(Gentil, 2013)	Waste management master plan (County, 2017)	Solid waste management master plan (KOKUSAI KOGYO CO., 2007)	Guide de gestion des déchets de construction et de démolition (IBGE, 2009)	La gestion des déchets du secteur de la construction (IBGE, 2011)	Waste management master plan (Environmental, 2012)	Solid waste management master plan (Limited, 2021)	
2.1. Hauling											
2.1.1. Transportation	0	0	1	0	1	0	1	1	1	1	
2.1.2. Collection	1	0	1	0	0	1	1	0	1	1	
2.1.3. Location	0	0	0	0	0	0	0	0	0	0	
2.2. Market											
2.2.1. Market development	1	0	0	0	0	0	0	0	1	0	
2.2.2. Product	1	0	0	0	0	0	0	0	0	0	
2.3. Processing											
2.3.1. Reduction/Prevention	1	0	0	0	1	1	1	1	1	1	
2.3.2. Recycling	1	0	0	0	1	1	1	0	1	1	
2.3.3. Demolition	1	0	0	0	1	0	0	1	0	0	
2.4. Disposal											
2.4.1. Landfill	1	0	0	0	0	1	0	0	1	0	
2.4.2. Dumpsites	1	0	0	0	0	1	0	0	0	0	
3. Knowledge transfer											
3.1. Awareness and education											
3.1.1. Education and awareness campaigns /Research studies	1	0	1	0	1	1	0	0	1	1	
3.1.2. Employee awareness	1	0	0	0	0	0	0	0	1	0	
3.1.3. Student education	1	0	0	0	1	0	0	0	0	1	

	Master plans									
Master plan sections	Solid waste management master plan (Frank, 2017)	Municipal waste management in Italy (Matteo Ferraris, 2013)	Report on the solid waste management in Tunisia (Sweepnet, 2014b)	Municipal waste management in France(Gentil, 2013)	Waste management master plan (County, 2017)	Solid waste management master plan (KOKUSAI KOGYO CO., 2007)	Guide de gestion des déchets de construction et de démolition (IBGE, 2009)	La gestion des déchets du secteur de la construction (IBGE, 2011)	Waste management master plan (Environmental, 2012)	Solid waste management master plan (Limited, 2021)
3.2. Marketing										
3.2.1. Marketing	1	0	0	0	0	0	1	0	0	0
3.2.2. Promotion	1	0	0	0	0	0	0	0	1	1
3.2.3. Purchase practice	1	0	0	0	0	0	0	0	0	0
4. Planning										
4.1. Hazardous waste	1	0	0	0	1	0	1	1	0	0
4.2. Construction and demolition waste operations	1	0	0	0	1	0	1	1	1	0
4.3. Technology and innovation	1	0	0	0	1	0	0	0	0	0
4.4. Energy efficiency	1	0	0	0	1	1	1	1	1	0
4.5. Environmental planning	1	0	0	0	1	1	0	0	0	0
4.6. Circular economy	1	0	0	0	1	1	0	0	1	1
4.7. Emergency planning										
4.7.1. Emergency environmental assessment	1	0	0	0	1	0	0	0	0	0
4.7.2. Emergency recovery methods	1	0	0	0	0	0	0	0	0	0
5. Financing and implementation										
5.1. Economic instruments										
5.1.1. Funding	1	0	1	0	1	1	0	0	1	0

Master plans	Solid waste management master plan (Frank, 2017)	Municipal waste management in Italy (Matteo Ferraris, 2013)	Report on the solid waste management in Tunisia (Sweepnet, 2014b)	Municipal waste management in France(Gentil, 2013)	Waste management master plan (County, 2017)	Solid waste management master plan (KOKUSAI KOGYO CO., 2007)	Guide de gestion des déchets de construction et de démolition (IBGE, 2009)	La gestion des déchets du secteur de la construction (IBGE, 2011)	Waste management master plan (Environmental, 2012)	Solid waste management master plan (Limited, 2021)
5.1.2. Fees	1	0	0	0	1	1	1	0	0	1
5.1.3. Tax structure	1	0	1	0	0	0	1	0	0	1
5.2. Involvement and responsibility										
5.2.1. Cooperation on processing	1	0	0	0	0	0	0	0	0	0
5.2.2. Partnership with municipalities	1	0	0	0	1	0	0	0	1	0
5.2.3. Partnership between stakeholders	1	0	0	0	1	1	0	0	1	0
5.2.4. Partnership with the private sector	1	0	1	0	1	1	0	0	0	0
5.2.5. Stakeholder responsibility and engagement	1	0	1	0	0	1	1	1	1	1
5.2.6. No discrimination	1	0	0	0	0	0	0	0	0	0
5.2.7. Fair treatment and equity	1	0	0	0	0	0	0	0	0	1
6. Evaluation										
6.1. Master plan impact evaluation										
6.1.1. Compliance, reporting, inspection, licensing, monitoring	1	0	1	0	1	1	0	0	1	1
6.1.2. Data collection	1	0	0	0	1	1	0	0	0	1
6.1.3. Interactive communication	1	0	1	0	1	1	0	0	1	1



	Master plans	Solid waste management master plan (Frank, 2017)	Municipal waste management in Italy (Matteo Ferraris, 2013)	Report on the solid waste management in Tunisia (Sweepnet, 2014b)	Municipal waste management in France(Gentil, 2013)	Waste management master plan (County, 2017)	Solid waste management master plan (KOKUSAI KOGYO CO., 2007)	Guide de gestion des déchets de construction et de démolition (IBGE, 2009)	La gestion des déchets du secteur de la construction (IBGE, 2011)	Waste management master plan (Environmental, 2012)	Solid waste management master plan (Limited, 2021)
	Master plan sections										
	6.1.4. Assessment of objectives	1	0	0	0	1	1	0	0	1	1
	6.2. Master plan content evaluation										
	6.2.1. Performance measures	1	0	0	0	1	0	0	0	0	1
	6.2.2. Assessment methods	1	0	0	0	1	1	0	0	1	1
	Master plans	Project on master plan study for integrated solid waste management in Bogota, D.C. (JICA. 2013)	Construction and demolition waste management in France (Deloitte, 2015)	Dechets de demolition et de deconstruction. Gisements, caracterisations, filières de traitement et valorisation (E. VERNUS, 2011)	Plan national de gestion des déchets (solidaire, 2019)	Overview of national waste prevention programmes in Europe: Italy (E. E. Agency, 2021b)	Overview of national waste prevention programmes in Europe: Luxembourg (E. E. Agency, 2021a)	Plan national de gestion des déchets de des ressources (infrastructures, 2018)	City of Baltimore recycling and solid waste management master plan (consultants, 2020)	Massachusetts 2030 solid waste master plan (MassDep. 2021)	City of Hamilton solid waste management master plan (Hamilton, 2012)
	Master plan sections										
	<b>A. Plan framing</b>										
	1. Definition	1	0	0	1	0	0	1	1	1	1

	Project on master plan study for integrated solid waste management in Bogota, D.C. (JICA, 2013)	Construction and demolition waste management in France (Deloitte, 2015)	Dechets de demolition et de deconstruction. Gisements, caracterisations, filieres de traitement et valorisation (E. VERNUS, 2011)	Plan national de gestion des dechets (solidaire, 2019)	Overview of national waste prevention programmes in Europe: Italy (E. E. Agency, 2021b)	Overview of national waste prevention programmes in Europe: Luxembourg (E. E. Agency, 2021a)	Plan national de gestion des dechets de des ressources (infrastructures, 2018)	City of Baltimore recycling and solid waste management master plan (consultants, 2020)	Massachusetts 2030 solid waste master plan (MassDep, 2021)	City of Hamilton solid waste management master plan (Hamilton, 2012)
Master plans										
Master plan sections										
2. Content										
2.1. Purpose of the plan	1	0	0	0	0	0	1	1	1	1
2.2. Coverage of the plan	1	0	0	0	1	1	1	0	0	1
2.3. Key themes	1	0	0	0	0	0	1	0	0	1
3. Objectives	1	1	0	1	1	1	1	1	1	0
4. State of the art										
4.1. Existing situation	1	1	1	1	1	1	1	1	1	1
4.2. Existing policies	1	1	1	1	0	1	1	1	0	0
4.3. Existing plans	1	0	1	0	0	1	0	1	1	1
5. Forecasting										
5.1. Deficiencies in existing plans	0	1	0	0	0	0	0	1	1	1
5.2. Expansion strategies	1	0	0	0	0	0	0	1	1	1
<b>B. Plan Body</b>										
1. Legal instruments										
1.1 Compliance with existing	1	0	0	0	0	1	0	1	0	1
1.2. Drafting and support of new	0	0	0	0	0	0	0	1	1	0
2.										
Infrastructure/Operation										
2.1. Hauling										
2.1.1. Transportation	1	0	0	0	0	1	1	1	0	0
2.1.2. Collection	1	0	1	1	0	0	1	1	0	1

	Project on master plan study for integrated solid waste management in Bogota, D.C. (JICA, 2013)	Construction and demolition waste management in France (Deloitte, 2015)	Dechets de demolition et de deconstruction. Gisements, caracterisations, filieres de traitement et valorisation (E. VERNUS, 2011)	Plan national de gestion des dechets (solidaire, 2019)	Overview of national waste prevention programmes in Europe: Italy (E. E. Agency, 2021b)	Overview of national waste prevention programmes in Europe: Luxembourg (E. E. Agency, 2021a)	Plan national de gestion des dechets de des ressources (infrastructures, 2018)	City of Baltimore recycling and solid waste management master plan (consultants, 2020)	Massachusetts 2030 solid waste master plan (MassDep, 2021)	City of Hamilton solid waste management master plan (Hamilton, 2012)
Master plans										
Master plan sections										
2.1.3. Location	0	0	0	0	0	0	0	0	0	0
2.2. Market										
2.2.1. Market development	1	1	0	0	0	0	1	1	1	0
2.2.2. Product	0	0	0	0	1	0	1	0	1	1
2.3. Processing										
2.3.1. Reduction/Prevention	1	0	1	1	1	1	1	1	1	1
2.3.2. Recycling	1	1	1	1	1	1	1	1	1	1
2.3.3. Demolition	0	1	1	0	0	0	1		1	0
2.4. Disposal										
2.4.1. Landfill	1	0	0	0	0	0	1	0	1	0
2.4.2. Dumpsites	0	0	0	0	0	0	1	0	0	1
3. Knowledge transfer										
3.1. Awareness and education										
3.1.1. Education and awareness campaigns /Research studies	1	0	0	0	1	1	1	1	1	1
3.1.2. Employee awareness	0	0	0	0	0	0	0	0	0	0
3.1.3. Student education	0	0	0	0	1	1	0	0	1	0
3.2. Marketing										
3.2.1. Marketing	1	0	0	0	0	0	0	1	0	0
3.2.2. Promotion	0	0	0	0	1	1	1	0	1	0
3.2.3. Purchase practice	0	0	0	0	1	0	0	0	0	0

	Project on master plan study for integrated solid waste management in Bogota, D.C. (JICA, 2013)	Construction and demolition waste management in France (Deloitte, 2015)	Dechets de demolition et de deconstruction. Gisements, caracterisations, filieres de traitement et valorisation (E. VERNUS, 2011)	Plan national de gestion des dechets (solidaire, 2019)	Overview of national waste prevention programmes in Europe: Italy (E. E. Agency, 2021b)	Overview of national waste prevention programmes in Europe: Luxembourg (E. E. Agency, 2021a)	Plan national de gestion des dechets de des ressources (infrastructures, 2018)	City of Baltimore recycling and solid waste management master plan (consultants, 2020)	Massachusetts 2030 solid waste master plan (MassDep, 2021)	City of Hamilton solid waste management master plan (Hamilton, 2012)
Master plans										
Master plan sections										
4. Planning										
4.1. Hazardous waste	1	1	1	0	1	1	1	0	0	0
4.2. Construction and demolition waste operations	0	0	0	0	0	0	1	0	0	0
4.3. Technology and innovation	1	0	0	1	1	0	1	1	1	0
4.4. Energy efficiency	0	0	0	1	0	0	1	0	1	1
4.5. Environmental planning	1	0	0	0	0	0	0	1	1	1
4.6. Circular economy	0	0	0	0	1	0	1	0	1	0
4.7. Emergency planning										
4.7.1. Emergency environmental assessment	0	0	0	0	0	0	0	0	0	0
4.7.2. Emergency recovery methods	0	0	0	0	0	0	0	0	0	0
5. Financing and implementation										
5.1. Economic instruments										
5.1.1. Funding	0	0	0	1	1	0	1	1	1	0
5.1.2. Fees	1	0	0	0	0	0	1	0	1	0
5.1.3. Tax structure	0	1	0	1	1	0	1	0	0	0
5.2. Involvement and responsibility										
5.2.1. Cooperation on	1	0	0	0	0	0	1	1	0	0

	Project on master plan study for integrated solid waste management in Bogota, D.C. (JICA, 2013)	Construction and demolition waste management in France (Deloitte, 2015)	Dechets de demolition et de deconstruction. Gisements, caracterisations, filieres de traitement et valorisation (E. VERNUS, 2011)	Plan national de gestion des dechets (solidaire, 2019)	Overview of national waste prevention programmes in Europe: Italy (E. E. Agency, 2021b)	Overview of national waste prevention programmes in Europe: Luxembourg (E. E. Agency, 2021a)	Plan national de gestion des dechets de des ressources (infrastructures, 2018)	City of Baltimore recycling and solid waste management master plan (consultants, 2020)	Massachusetts 2030 solid waste master plan (MassDep, 2021)	City of Hamilton solid waste management master plan (Hamilton, 2012)
Master plans										
Master plan sections										
processing										
5.2.2. Partnership with municipalities	1	0	0	0	0	0	1	0	1	1
5.2.3. Partnership between stakeholders	0	0	0	0	0	0	1	0	0	0
5.2.4. Partnership with the private sector	1	1	0	0	1	0	1	0	0	0
5.2.5. Stakeholder responsibility and engagement	1	1	0	0	1	1	1	1	1	0
5.2.6. No discrimination	0	0	0	0	0	1	0	0	0	0
5.2.7. Fair treatment and equity	0	0	0	0	0	0	0	1	0	0
6. Evaluation										
6.1. Master plan impact evaluation										
6.1.1. Compliance, reporting, inspection, licensing, monitoring	1	1	0	0	0	0	1	0	1	0
6.1.2. Data collection	0	0	0	0	0	1	0	1	0	0
6.1.3. Interactive communication	1	0	0	0	0	0	1	1	0	1
6.1.4. Assessment of objectives	1	1	0	0	1	0	0	0	0	0
6.2. Master plan content evaluation										
6.2.1. Performance measures	1	0	0	1	1	0	0	1	0	0

6.2.2. Assessment methods	Master plan sections	Master plans
1	Project on master plan study for integrated solid waste management in Bogota, D.C. (JICA, 2013)	
1	Construction and demolition waste management in France (Deloitte, 2015)	
0	Dechets de demolition et de deconstruction. Gisements, caracterisations, filieres de traitement et valorisation (E. VERNUS, 2011)	
0	Plan national de gestion des dechets (solidaire, 2019)	
1	Overview of national waste prevention programmes in Europe: Italy (E. E. Agency, 2021b)	
0	Overview of national waste prevention programmes in Europe: Luxembourg (E. E. Agency, 2021a)	
0	Plan national de gestion des dechets de des ressources (infrastructures, 2018)	
1	City of Baltimore recycling and solid waste management master plan (consultants, 2020)	
0	Massachusetts 2030 solid waste master plan (MassDep, 2021)	
0	City of Hamilton solid waste management master plan (Hamilton, 2012)	

	National waste management strategy and master plan for Myanmar (Taw, 2018)	County of Northumberland waste management master plan (Ltd., 2014)	Waste management planning in Portugal (Carrola, 2021)	Solid waste management master plan (M. P. C. Agency, 2017)	Spain solid waste management plan (E. Commission, 2016c)	The York region waste management master plan (York, 2020)	National waste management plan 2022 (ministers, 2016)	The zero waste masterplan (Joan Marc Simon, 2020)	The zero waste masterplan (Simon, 2017)
Master plans									
Master plan sections									
<b>A. Plan framing</b>									
1. Definition	1	1	0	1	0	0	1	0	0
2. Content									
2.1. Purpose of the plan	1	1	1	1	0	1	1	0	0
2.2. Coverage of the plan	0	0	1	0	0	0	1	0	0
2.3. Key themes	0	0	0	1	0	0	0	0	0
3. Objectives	1	0	1	1	1	1	1	1	1
4. State of the art									
4.1. Existing situation	1	1	0	1	1	1	1	1	1
4.2. Existing policies	1	0	0	0	1	0	1	1	1
4.3. Existing plans	NA	0	1	0	0	1	1	0	0
5. Forecasting									
5.1. Deficiencies in existing plans	NA	0	0	1	0	0	1	0	0
5.2. Expansion strategies	NA	1	0	0	1	0	1	0	0
<b>B. Plan Body</b>									
1. Legal instruments									
1.1 Compliance with existing	1	0	0	0	1	1	0	1	1
1.2. Drafting and support of new	1	0	1	0	1	1	1	0	0
2.									
Infrastructure/Operation									
2.1. Hauling									
2.1.1. Transportation	0	0	0	1	0	0	1	1	0
2.1.2. Collection	1	1	1	1	1	1	1	1	1

Master plans	National waste management strategy and master plan for Myanmar (Taw, 2018)	County of Northumberland waste management master plan (Ltd., 2014)	Waste management planning in Portugal (Carrola, 2021)	Solid waste management master plan (M. P. C. Agency, 2017)	Spain solid waste management plan (E. Commission, 2016c)	The York region waste management master plan (York, 2020)	National waste management plan 2022 (ministers, 2016)	The zero waste masterplan (Joan Marc Simon, 2020)	The zero waste masterplan (Simon, 2017)
Master plan sections									
2.1.3. Location	0	0	0	0	0	0	0	0	0
2.2. Market									
2.2.1. Market development	0	0	1	0	0	1	1	1	0
2.2.2. Product	0	0	0	0	1	1	1	0	0
2.3. Processing									
2.3.1. Reduction/Prevention	1	1	1	1	1	1	1	1	1
2.3.2. Recycling	1	0	1	0	1	1	1	1	1
2.3.3. Demolition	0	0	0	1	1	0	0	0	0
2.4. Disposal									
2.4.1. Landfill	1	0	0	0	1	0	0	1	1
2.4.2. Dumpsites	0	0	0	0	0	0	1	0	0
3. Knowledge transfer									
3.1. Awareness and education									
3.1.1. Education and awareness campaigns /Research studies	1	0	1	1	1	1	1	1	0
3.1.2. Employee awareness	0	0	0	1	0	0	0	0	0
3.1.3. Student education	1	0	0	1	0	0	1	0	0
3.2. Marketing									
3.2.1. Marketing	0	0	0	0	0	0	0	0	0
3.2.2. Promotion	1	0	1	0	1	1	1	1	0
3.2.3. Purchase practice	0	0	0	0	0	1	0	1	0
4. Planning									
4.1. Hazardous waste	1	0	1	1	0	0	1	0	0



Master plans	National waste management strategy and master plan for Myanmar (Taw, 2018)	County of Northumberland waste management master plan (Ltd., 2014)	Waste management planning in Portugal (Carrola, 2021)	Solid waste management master plan (M. P. C. Agency, 2017)	Spain solid waste management plan (E. Commission, 2016c)	The York region waste management master plan (York, 2020)	National waste management plan 2022 (ministers, 2016)	The zero waste masterplan (Joan Marc Simon, 2020)	The zero waste masterplan (Simon, 2017)
Master plan sections									
4.2. Construction and demolition waste operations	0	0	0	1	0	1	0	0	0
4.3. Technology and innovation	1	1	0	1	1	1	1	1	0
4.4. Energy efficiency	1	1	1	1	0	1	0	1	1
4.5. Environmental planning	1	0	1	1	1	0	1	1	0
4.6. Circular economy	1	0	0	1	1	0	0	0	0
4.7. Emergency planning									
4.7.1. Emergency environmental assessment	0	0	0	0	0	0	0	0	0
4.7.2. Emergency recovery methods	0	0	0	0	0	0	0	0	0
5. Financing and implementation									
5.1. Economic instruments									
5.1.1. Funding	1	1	1	1	1	0	1	1	0
5.1.2. Fees	1	1	0	0	0	0	1	1	1
5.1.3. Tax structure	1	1	0	0	1	0	1		
5.2. Involvement and responsibility									
5.2.1. Cooperation on processing	0	0	0	1	0	1	1	0	0
5.2.2. Partnership with municipalities	0	1	0	1	1	1	0	1	0
5.2.3. Partnership between stakeholders	1	0	0	0	0	1	0	0	0

Master plans	National waste management strategy and master plan for Myanmar (Taw, 2018)	County of Northumberland waste management master plan (Ltd., 2014)	Waste management planning in Portugal (Carrola, 2021)	Solid waste management master plan (M. P. C. Agency, 2017)	Spain solid waste management plan (E. Commission, 2016c)	The York region waste management master plan (York, 2020)	National waste management plan 2022 (ministers, 2016)	The zero waste masterplan (Joan Marc Simon, 2020)	The zero waste masterplan (Simon, 2017)
Master plan sections									
5.2.4. Partnership with the private sector	1	1	1	1	0	1	1	0	1
5.2.5. Stakeholder responsibility and engagement	1	0	1	1	1	1	0	1	1
5.2.6. No discrimination	0	0	0	0	0	0	0	0	0
5.2.7. Fair treatment and equity	0	0	0	1	0	0	0	0	0
6. Evaluation									
6.1. Master plan impact evaluation									
6.1.1. Compliance, reporting, inspection, licensing, monitoring	1	0	1	1	1	0	1	0	0
6.1.2. Data collection	1	0	1	1	1	1	1	0	0
6.1.3. Interactive communication	1	0	1	1	0	1	0	0	0
6.1.4. Assessment of objectives	1	0	0	0	0	1	1	1	0
6.2. Master plan content evaluation									
6.2.1. Performance measures	0	0	0	0	0	1	1	0	0
6.2.2. Assessment methods	0	0	0	0	0	1	1	1	0

Master plans	Detailed assessment of waste management plans (E. Commission, 2016a)	Waste management plan for the Czech Republic for the period 2015-2024 (M. o. t. Environment, 2014)	Wasteless Lebanon 2022 (Habitat, 2015)	Elaboration de plans de gestion des déchets pour les missions des Nations Unies (Unies, 2019)
<b>Master plan sections</b>				
<b>A. Plan framing</b>				
1. Definition	0	0	0	0
2. Content				
2.1. Purpose of the plan	0	1	1	1
2.2. Coverage of the plan	1	1	0	1
2.3. Key themes	0	1	0	0
3. Objectives	0	1	0	1
4. State of the art				
4.1. Existing situation	1	1	1	1
4.2. Existing policies	1	1	1	1
4.3. Existing plans	1	1	1	0
5. Forecasting				
5.1. Deficiencies in existing plans	1	0	1	1
5.2. Expansion strategies	1	1	0	0
<b>B. Plan Body</b>				
1. Legal instruments				
1.1 Compliance with existing	1	1	1	1
1.2. Drafting and support of new	1	1	1	1
2. Infrastructure/Operation				
2.1. Hauling				
2.1.1. Transportation	1	1	1	0
2.1.2. Collection	1	1	0	0
2.1.3. Location	1	0	0	0
2.2. Market				
2.2.1. Market development	1	1	1	0
2.2.2. Product	1	1	0	0
2.3. Processing				
2.3.1. Reduction/Prevention	0	1	0	1
2.3.2. Recycling	1	1	1	1

Master plans	Detailed assessment of waste management plans (E. Commission, 2016a)	Waste management plan for the Czech Republic for the period 2015-2024 (M. o. t. Environment, 2014)	Wasteless Lebanon 2022 (Habitat, 2015)	Elaboration de plans de gestion des déchets pour les missions des Nations Unies (Unies, 2019)
Master plan sections				
2.3.3. Demolition	0	1	0	0
2.4. Disposal				
2.4.1. Landfill	0	1	1	0
2.4.2. Dumpsites	1	1	0	0
3. Knowledge transfer				
3.1. Awareness and education				
3.1.1. Education and awareness campaigns /Research studies	1	1	1	1
3.1.2. Employee awareness	0	0	0	1
3.1.3. Student education	1	0	1	0
3.2. Marketing				
3.2.1. Marketing	0	0	0	0
3.2.2. Promotion	1	1	1	1
3.2.3. Purchase practice	1	1	0	0
4. Planning				
4.1. Hazardous waste	1	1	1	1
4.2. Construction and demolition waste operations	0	0	0	0
4.3. Technology and innovation	1	1	1	0
4.4. Energy efficiency	0	1	1	0
4.5. Environmental planning	0	1	1	1
4.6. Circular economy	0	1	0	0
4.7. Emergency planning				
4.7.1. Emergency environmental assessment	0	0	0	0
4.7.2. Emergency recovery methods	0	0	1	0
5. Financing and implementation				
5.1. Economic instruments				
5.1.1. Funding	1	1	1	1
5.1.2. Fees	1	1	0	0

Master plans	Detailed assessment of waste management plans (E. Commission, 2016a)	Waste management plan for the Czech Republic for the period 2015-2024 (M. o. t. Environment, 2014)	Wasteless Lebanon 2022 (Habitat, 2015)	Elaboration de plans de gestion des déchets pour les missions des Nations Unies (Unies, 2019)
Master plan sections				
5.1.3. Tax structure	1	0	0	0
5.2. Involvement and responsibility				
5.2.1. Cooperation on processing	1	1	0	0
5.2.2. Partnership with municipalities	1	1	1	0
5.2.3. Partnership between stakeholders	0	1	1	0
5.2.4. Partnership with the private sector	1	1	1	0
5.2.5. Stakeholder responsibility and engagement	1	1	1	1
5.2.6. No discrimination	0	0	0	0
5.2.7. Fair treatment and equity	0	0	0	0
6. Evaluation				
6.1. Master plan impact evaluation				
6.1.1. Compliance, reporting, inspection, licensing, monitoring	1	1	1	1
6.1.2. Data collection	1	1	1	0
6.1.3. Interactive communication	0	0	1	0
6.1.4. Assessment of objectives	1	1	0	0
6.2. Master plan content evaluation				
6.2.1. Performance measures	0	1	0	0
6.2.2. Assessment methods	0	1	0	0

## B. Master plan assessment criteria

Table 23 Master plan assessment criteria table

Preliminary criteria/ Guides	Preparing a waste management plan (consortium, 2012)	Developing an implementation strategy and choosing projects (Willard, 2008b)	Developing effective management systems (Willard, 2008c)	Determining the structures needed to manage the effort (Willard, 2008a)	Preparing a master plan for your community (S. N. H. P. Commission, 2004)	EU construction and demolition waste management protocol (E. Commission, 2016b)	Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)	Guide to municipal solid waste management (Massoud, Merhebi, Geha, & American University of Beirut. Nature Conservation, 2016)	Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)	Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)	Plans de prevention et de gestion des dechets de chantiers du BTP (ECOBATP LR, 2012)
Policy and regulatory framework	Yes	Yes	Yes		Yes	Yes			Yes	Yes	Yes
Clarity and measurability of targets	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes		
Content precision and level of details	Yes		Yes		Yes	Yes	Yes	Yes	Yes	Yes	
Implementation and monitoring	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	
Sustainability (environmental, social, and economic)	Yes	Yes	Yes		Yes	Yes		Yes	Yes	Yes	Yes
Circularity orientation and soundness			Yes					Yes	Yes		
Support through research	Yes										
Reliance on technology and innovation	Yes					Yes			Yes		
Engagement and participation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	
Collaboration enhancement	Yes						Yes			Yes	
Impact on stakeholders						Yes				Yes	

<b>Preliminary criteria/ Guides</b>	Preparing a waste management plan (consortium, 2012)	Developing an implementation strategy and choosing projects (Willard, 2008b)	Developing effective management systems (Willard, 2008c)	Determining the structures needed to manage the effort (Willard, 2008a)	Preparing a master plan for your community (S. N. H. P. Commission, 2004)	EU construction and demolition waste management protocol (E. Commission, 2016b)	Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)	Guide to municipal solid waste management (Massoud, Merhebi, Geha, & American University of Beirut: Nature Conservation, 2016)	Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)	Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)	Plans de prevention et de gestion des dechets de chantiers du BTP (ECOBATP LR, 2012)
Geographical coverage	Yes				Yes		Yes		Yes		Yes
Effectiveness (integration and coordination)	Yes				Yes					Yes	
Time coverage	Yes	Yes	Yes	Yes	Yes		Yes		Yes	Yes	
Reliance on past and projection to future	Yes	Yes	Yes		Yes		Yes			Yes	
Consistency with other sections					Yes						Yes

### C. Guides and guidelines master plan sections

Table 24 Guides and guidelines master plan sections

Preparing a waste management plan (consortium, 2012)	Developing an implementation strategy and choosing projects (Willard, 2008b)	Developing effective management systems (Willard, 2008c)	Determining the structures needed to manage the effort (Willard, 2008a)	Preparing a master plan for your community (S. N. H. P. Commission, 2004)
3 main sections: Background, status, and planning.	Identification of goals.	Monitoring.	Assignment of responsibility.	Stakeholder engagement.
Waste problematic.	Identification of stakeholders.	Reviewing the impact of the plan.	Identification of stakeholders.	Setting of goals and objectives.
Legislations.	Economic	Assessing the past.	Monitoring.	Data collection.

Preparing a waste management plan (consortium, 2012)	Developing an implementation strategy and choosing projects (Willard, 2008b)	Developing effective management systems (Willard, 2008c)	Determining the structures needed to manage the effort (Willard, 2008a)	Preparing a master plan for your community (S. N. H. P. Commission, 2004)
	assessment of costs and benefits.			
Objectives of the plan.		Emergency response procedures.	Communication and information dissemination.	Forecasting into the future.
Waste streams and sources.		Environmental plans.	Review of the past.	Monitoring.
Collection and treatment.		Data collection and documentation.	Setting of goals and objectives.	Assessment of the past.
Shipping and transportation.		Legal text drafting and adherence.	Forecasting into the future.	Transportation.
Organization and financing.		Setting of objectives.		Economic development.
Assessment of the past.		Awareness and training programs.		Focus on resources.
Forecasting for the future.		Employee awareness and training.		Hazardous wastes.
Setting measurable goals.		Forecasting into the future.		Adherence to policies.
Monitoring strategies.		Communication and dissemination of information.		Partnerships and collaboration.
		Assignment of responsibility.		Market development.



EU construction and demolition waste management protocol (E. Commission, 2016b)	Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)	Guide to municipal solid waste management (Massoud et al., 2016)	Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)	Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)
Monitoring and supervision.	Storage.	Storage.	Prevention methods.	Collection systems.
Focus on reuse.	Collection and transportation systems.	Recycling and reuse.	Waste reduction.	Treatment.
Focus on recycling.	Treatment procedures.	Collection and transportation.	Reuse methods.	Disposal.
Focus on disposal.	Disposal options.	Modes of disposal.	Recycling methods.	Reduction.
Hazardous wastes.	Maintenance and review.	Waste education.	Disposal methods.	Reuse.
Focus on deconstruction.	Organization of stakeholder involvement.	Energy recovery.	Development of legislations.	Recycling.
Focus on demolition.	Financial planning.	Taxation systems.	Economic instruments.	Stakeholder engagement.
Focus on waste management plans.	Awareness and training campaigns.	Monitoring and supervision.	Market development.	Cooperation between stakeholders.
Data collection and documentation.	Assessment of the past.	Landfilling plans.	Monitoring and supervision.	Policy drafting.
Introduction of technology.	Identification of problems from the past.	Permits and licenses.	Hazardous waste management.	Evaluation of plan content.
Focus on energy recovery.	Projection into the future.		Scope definition.	Awareness campaigns.
Transportation.	Collaboration between the public and the private sector.		Stakeholder identification and involvement.	Data collection.
Permits and licensing.	Assessment of environmental impacts.		Adherence to existing policies.	Adherence to existing laws.

EU construction and demolition waste management protocol (E. Commission, 2016b)	Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)	Guide to municipal solid waste management (Massoud et al., 2016)	Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)	Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)
Landfill management.	Adherence to regulations.		Reporting mechanisms.	Monitoring.
Adherence to policies.	Enforcement of the plan.		Data collection.	Feedback loops.
Development of taxation systems.	Market development.		Transportation and treatment.	Use of technology.
Defining operation locations.	Determination of locations for treatment.		Permits and licensing.	Economic strategies.
Identifying stakeholder roles and focusing on cooperation.	Defining goals and targets.		Energy recovery.	
Enforcement.	Developing new laws.		Awareness campaigns.	
Awareness campaigns.	Introducing taxation systems.		Evaluation and review of plan content.	
	Transportation and transfer.		Cooperation between stakeholders.	
			Assessment of the past.	

Plans de prevention et de gestion des dechets de chantiers du BTP (ECOBATP LR, 2012)	Country report on the Solid waste management in Lebanon (Germany cooperation, 2014)	State and trends of the Lebanese environment (Jadam, 2010a)
Stakeholder identification and roles.	Quantifiable objectives.	Assessment of past.
Monitoring.	Timely objectives.	Existing plans assessment.
Existing legislations.	Assessment of past.	Existing policies assessment.
Waste valorization and recycling.	Existing plans assessment.	Product orientation.
Establishment of a market.	Deficiencies in existing plans.	Landfill diversion.
Waste prevention.	Existing policies.	Environmental orientation.
Environmental assessment strategies.	Expansion strategies.	Focus on new technology.
Data collection and information sharing.	Market development.	Educational campaigns.
Hazardous wastes.	Timely work.	Promotion.
Assessment of the past.	Environmental orientation.	Interactive communication.
Determining facility locations.	New technology.	Student education.
Reuse.	Partnership.	Energy orientation.
Disposal.	Consistency with country policies.	Reducing production.
Transportation.	Educational campaigns.	Reuse opportunities.
Awareness campaigns.	Promotion.	Complying with existing regulation.
Evaluation of master plan content through indicators.	Partnership with municipalities.	Drafting of new legislations.
Identification of objectives.	Interactive communication.	Establishment of a taxation structure.
Storage.	Data collection.	
Drafting of new regulations.	Private sector engagement.	
Economic strategies.	Stakeholder engagement and responsibilities.	
Use of technology.	Marketing strategies.	
Improvement of existing plans.	Student education.	

Waste collection.	Energy orientation.	
	Reduce production.	
	Reuse opportunities.	
	Cooperation.	
	Transportation.	
	Complying with existing regulation.	
	Drafting of new legislations.	
	Establishment of a taxation structure.	
	Funding sources.	
	Location identification.	

The table below presents the analysis results for master plan sections in guides and guidelines. A value of 0 indicates that the section is not present in the guide or guideline and a value of 1 indicates that the section is present in the guide or guideline.

Table 25 Guides and guidelines master plan sections matrix

Guides and guidelines	Master plan sections		
Preparing a waste management plan (consortium, 2012)			
Developing an implementation strategy and choosing projects (Willard, 2008b)			
Developing effective management systems (Willard, 2008c)			
Determining the structures needed to manage the effort (Willard, 2008a)			
Preparing a master plan for your community (S. N. H. P. Commission, 2004)			
EU construction and demolition waste management protocol (E. Commission, 2016b)			
Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)			
Guide to municipal solid waste management (Massoud et al., 2016)			
Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)			
<b>A. Plan framing</b>			
1. Definition			
2. Content			
2.1. Purpose of the plan	1	1	

	Preparing a waste management plan (consortium, 2012)	Developing an implementation strategy and choosing projects (Willard, 2008b)	Developing effective management systems (Willard, 2008c)	Determining the structures needed to manage the effort (Willard, 2008a)	Preparing a master plan for your community (S. N. H. P. Commission, 2004)	EU construction and demolition waste management protocol (E. Commission, 2016b)	Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)	Guide to municipal solid waste management (Massoud et al., 2016)	Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)
Guides and guidelines									
Master plan sections									
2.2. Coverage of the plan									1
2.3. Key themes									
3. Objectives	1	1	1	1	1		1		
4. State of the art									
4.1. Existing situation	1		1	1	1		1		1
4.2. Existing policies	1								
4.3. Existing plans									
5. Forecasting									
5.1. Deficiencies in existing plans							1		
5.2. Expansion strategies	1		1	1	1		1		
<b>B. Plan Body</b>									
1. Legal instruments									
1.1 Compliance with existing			1		1	1	1		1
1.2. Drafting and support of new			1				1		1
2.									
Infrastructure/Operation									
2.1. Hauling									
2.1.1. Transportation	1				1	1	1	1	1
2.1.2. Collection	1						1	1	
2.1.3. Location						1	1		
2.2. Market									

Guides and guidelines	Preparing a waste management plan (consortium, 2012)	Developing an implementation strategy and choosing projects (Willard, 2008b)	Developing effective management systems (Willard, 2008c)	Determining the structures needed to manage the effort (Willard, 2008a)	Preparing a master plan for your community (S. N. H. P. Commission, 2004)	EU construction and demolition waste management protocol (E. Commission, 2016b)	Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)	Guide to municipal solid waste management (Massoud et al., 2016)	Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)
Master plan sections									
2.2.1. Market development					1		1		1
2.2.2. Product									
2.3. Processing									
2.3.1.									
Reduction/Prevention					1	1		1	1
2.3.2. Recycling	1					1		1	1
2.3.3. Demolition						1			
2.4. Disposal									
2.4.1. Landfill						1	1		
2.4.2. Dumpsites								1	1
3. Knowledge transfer									
3.1. Awareness and education									
3.1.1. Education and awareness campaigns /Research studies			1	1		1	1		1
3.1.2. Employee awareness			1						
3.1.3. Student education									
3.2. Marketing									
3.2.1. Marketing			1						
3.2.2. Promotion									
3.2.3. Purchase practice									
4. Planning									
4.1. Hazardous waste					1	1			1

	Preparing a waste management plan (consortium, 2012)	Developing an implementation strategy and choosing projects (Willard, 2008b)	Developing effective management systems (Willard, 2008c)	Determining the structures needed to manage the effort (Willard, 2008a)	Preparing a master plan for your community (S. N. H. P. Commission, 2004)	EU construction and demolition waste management protocol (E. Commission, 2016b)	Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)	Guide to municipal solid waste management (Massoud et al., 2016)	Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)
Guides and guidelines									
Master plan sections									
4.2. Construction and demolition waste operations									
4.3. Technology and innovation						1			
4.4. Energy efficiency						1		1	1
4.5. Environmental planning			1				1		
4.6. Circular economy							1		
4.7. Emergency planning									
4.7.1. Emergency environmental assessment									
4.7.2. Emergency recovery methods									
5. Financing and implementation									
5.1. Economic instruments									
5.1.1. Funding	1	1			1		1		1
5.1.2. Fees									
5.1.3. Tax structure						1	1	1	
5.2. Involvement and responsibility									
5.2.1. Cooperation on processing					1		1		1
5.2.2. Partnership with municipalities					1				

	Preparing a waste management plan (consortium, 2012)	Developing an implementation strategy and choosing projects (Willard, 2008b)	Developing effective management systems (Willard, 2008c)	Determining the structures needed to manage the effort (Willard, 2008a)	Preparing a master plan for your community (S. N. H. P. Commission, 2004)	EU construction and demolition waste management protocol (E. Commission, 2016b)	Manual for formulation and implementation of MSWM master plan (KOKUSAI KOGYO CO., 1993)	Guide to municipal solid waste management (Massoud et al., 2016)	Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives (Union, 2018)
Guides and guidelines									
Master plan sections									
5.2.3. Partnership between stakeholders									
5.2.4. Partnership with the private sector							1		
5.2.5. Stakeholder responsibility and engagement		1	1	1	1	1	1		1
5.2.6. No discrimination									
5.2.7. Fair treatment and equity									
6. Evaluation									
6.1. Master plan impact evaluation									
6.1.1. Compliance, reporting, inspection, licensing, monitoring	1		1	1	1	1	1	1	1
6.1.2. Data collection			1		1	1			1
6.1.3. Interactive communication				1					
6.1.4. Assessment of objectives									
6.2. Master plan content evaluation									
6.2.1. Performance measures									1
6.2.2. Assessment methods			1						1



Master plans	Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)	Plans de prevention et de gestion des dechets de chantiers du BTP (ECOBATP LR, 2012)	Country report on the Solid waste management in Lebanon (Germany cooperation, 2014)	State and trends of the Lebanese environment (Jadam, 2010a)
Master plan sections				
<b>A. Plan framing</b>				
1. Definition				
2. Content				
2.1. Purpose of the plan				
2.2. Coverage of the plan				
2.3. Key themes				
3. Objectives		1	1	
4. State of the art				
4.1. Existing situation		1	1	1
4.2. Existing policies		1	1	1
4.3. Existing plans			1	1
5. Forecasting				
5.1. Deficiencies in existing plans		1	1	
5.2. Expansion strategies		1	1	
<b>B. Plan Body</b>				
1. Legal instruments				
1.1 Compliance with existing	1	1	1	1
1.2. Drafting and support of new	1	1	1	1
2.				
Infrastructure/Operation				
2.1. Hauling				

Master plans	Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)	Plans de prevention et de gestion des dechets de chantiers du BTP (COBATP LR, 2012)	Country report on the Solid waste management in Lebanon (Germany cooperation, 2014)	State and trends of the Lebanese environment (Jadam, 2010a)
Master plan sections				
2.1.1. Transportation		1	1	
2.1.2. Collection	1	1	1	
2.1.3. Location		1	1	
2.2. Market				
2.2.1. Market development		1	1	
2.2.2. Product				1
2.3. Processing				
2.3.1. Reduction/Prevention	1	1	1	1
2.3.2. Recycling	1	1	1	1
2.3.3. Demolition				
2.4. Disposal				
2.4.1. Landfill				1
2.4.2. Dumpsites	1		1	
3. Knowledge transfer				
3.1. Awareness and education				
3.1.1. Education and awareness campaigns /Research studies	1	1	1	1
3.1.2. Employee awareness				
3.1.3. Student education			1	1
3.2. Marketing				
3.2.1. Marketing			1	

Master plans	Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)	Plans de prevention et de gestion des dechets de chantiers du BTP (COBATP LR, 2012)	Country report on the Solid waste management in Lebanon (Germany cooperation 2014)	State and trends of the Lebanese environment (Jadam, 2010a)
Master plan sections				
3.2.2. Promotion			1	1
3.2.3. Purchase practice				
4. Planning				
4.1. Hazardous waste		1	1	
4.2. Construction and demolition waste operations		1		
4.3. Technology and innovation	1	1	1	1
4.4. Energy efficiency			1	1
4.5. Environmental planning		1	1	1
4.6. Circular economy				
4.7. Emergency planning				
4.7.1. Emergency environmental assessment				
4.7.2. Emergency recovery methods				
5. Financing and implementation				
5.1. Economic instruments				
5.1.1. Funding	1	1	1	
5.1.2. Fees	1	1		
5.1.3. Tax structure			1	1
5.2. Involvement and				

Master plans	Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)	Plans de prevention et de gestion des dechets de chantiers du BTP (COBATP LR, 2012)	Country report on the Solid waste management in Lebanon (Germany cooperation 2014)	State and trends of the Lebanese environment (Jadam, 2010a)
Master plan sections				
responsibility				
5.2.1. Cooperation on processing	1		1	
5.2.2. Partnership with municipalities			1	
5.2.3. Partnership between stakeholders			1	
5.2.4. Partnership with the private sector			1	
5.2.5. Stakeholder responsibility and engagement	1	1	1	
5.2.6. No discrimination				
5.2.7. Fair treatment and equity				
6. Evaluation				
6.1. Master plan impact evaluation				
6.1.1. Compliance, reporting, inspection, licensing, monitoring	1	1	1	
6.1.2. Data collection	1	1	1	
6.1.3. Interactive communication			1	1
6.1.4. Assessment of objectives				
6.2. Master plan content evaluation				

Master plans				
Master plan sections				
6.2.1. Performance measures			1	
6.2.2. Assessment methods	1			

Inclusive and sustainable solid waste management in Lebanon (Nardo, 2019)

Plans de prevention et de gestion des dechets de chantiers du BTP (ECOBATP LR, 2012)

Country report on the Solid waste management in Lebanon (Germany connection 2014)

State and trends of the Lebanese environment (Jadam, 2010a)

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