



From Conflict to Cooperation: A Multi-Methodological Approach to Managing the Solid Waste Crisis in Lebanon

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ABSTRACT

The management of solid waste in Lebanon has evolved into a complex issue, marked by its deleterious environmental, economic, and public health ramifications for both civilians and the state exchequer. Despite the longstanding nature of Lebanon's municipal waste predicament, it escalated to catastrophic proportions in 2015 following the closure of Naameh, the nation's largest landfill. The persisting crisis from 2015 endures due to the government's inadequate and poorly conceived solutions, with the potential to rekindle at any juncture. This paper addresses two fundamental concerns. Initially, a comprehensive portrayal of the municipal solid waste scenario in Lebanon is provided, encompassing its diverse facets. Subsequently, the researchers advocate an integrative approach amalgamating centralized and decentralized systems. Pioneering a strategic proposal to address Lebanon's solid waste predicament, the researchers employ a Journey-Making (JM) methodology to discern direct and indirect actors. Subsequently, a game theory approach, facilitated by the Graph Model for Conflict Resolution (GMCR+) software, is utilized to derive solutions that cater to the satisfaction of all involved parties. The selection of the optimal scenario is contingent upon the available options for the primary stakeholders, factoring in the political, sectarian, economic, and environmental landscape of Lebanon.

Keywords

Lebanon, Strategy, Decentralization, JM, SWM.

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1. Introduction

With advancements in solid waste treatment technology, treatment methods have been categorized into thermal processes (including incineration, high thermal dissociation, medium thermal dissociation, moderate thermal dissociation, carbonization, etc.) and biological processes (comprising composting, anaerobic fermentation, landfill, calcining, etc.). Each of these methods presents distinct advantages and is applicable under specific conditions (Awasthi, 2022). Governments are urged to conduct comprehensive research and assessments of these technologies, considering factors such as investment, operational and maintenance costs, geographical requirements, material recovery rates, quality, and adherence to environmental regulations. Subsequently, based on the unique demands of their nation, authorities should embrace the technology or combination of technologies that comprehensively address all facets of integrated treatment.

In the context of Lebanon, characterized by limited open spaces and a substantial organic content (60-70%) in household waste (Abou Jaoude et al., 2022), coupled with financial constraints necessitating judicious choices, there is a call for the adoption and implementation of an integrated technology roadmap in all sanctioned service areas. This strategy should exclude costly and unsuitable technical options.

Lebanon allocates approximately \$420 million annually to solid waste management (Sweid, 2021), excluding associated health costs, amounting to roughly \$150 per ton. In contrast, other nations achieve superior outcomes with significantly lower expenditures. The absence of a comprehensive and efficacious waste management strategy, coupled with a dearth of tangible outcomes, has precipitated a deteriorating situation. Approximately 6,000 tons of waste are generated daily, with a majority being either landfilled (51%) or haphazardly dumped (32%) across more than 1,000 landfills nationwide (Ajeeb, 2017; Sbeih, 2023). Notably, key landfills are approaching maximum capacity, portending severe environmental, health, social, and political crises.

The Lebanese populace contends daily with many economic, social, health, and political challenges, compounded by the collapse of their banking system resulting from years of conflict and corruption. Amid these adversities, the waste management crisis, rooted in the post-civil war era, persists. Subsequent to that period, Lebanese legislators have not accorded adequate attention to the solid waste issue, and no comprehensive plan has been devised, leading to a series of crises (Baumann, 2023). The most conspicuous of these crises unfolded in 2015 when the Naameh landfill reached its saturation point, causing refuse accumulation on the streets of

the capital, Beirut, and its environs. The ensuing health deterioration, direct impact on tourism, and public protests were noteworthy (Menhall and Joseph, 2017). Subsequently, the government attempted to address the crisis through an emergency plan involving a vertical expansion of the landfill, one of the two main landfills serving Beirut and its vicinity. However, this interim measure proved unsuccessful due to a lack of scientific implementation (Boswall, 2019).

Considering the unique standards in Lebanon, influenced by a considerable degree of political, sectarian, and partisan diversity, resolving the waste predicament necessitates a comprehensive plan. Such a plan should consider both environmental and economic standards while garnering acceptance from the populace and the ruling parties in Lebanon.

The cost associated with the collection and treatment of a ton of waste exhibits variability contingent upon factors such as the waste type, national geography, population income, waste collection technology, dietary practices, and the rural or urban nature of the region. In Lebanon, the elevated cost of waste collection is influenced by factors including mismanagement, governmental weaknesses, the absence of a waste-handling culture—such as inadequate household sorting—and the prevalence of a "throwing in the street" mindset. Environmental experts in Lebanon universally assert that the expense incurred by the Lebanese government for collecting and treating a ton of waste stands as the highest globally (Khalil, 2022). The toll of inadequate waste management in Lebanon is approximated at \$15 million annually. Specifically, the public treasury bears an approximate cost of \$155 per ton for waste disposal, ranking as the highest globally. By comparison, in Canada, the cost per ton ranges between \$58 and \$75; in Italy, it varies from \$16 to \$78, and in Syria, it stands at \$2.5 (El Richani, 2017).

2. Methodological background

This section provides a concise literature review encompassing GMCR, Soft OR, and multimethodology intervention. The objective is to delineate the research gap, ultimately guiding the formulation of a solution.

2.1. Graph model for conflict resolution (GMCR)

In challenging circumstances, the GMCR model serves as a decision-making methodology for resolving intricate disputes. The approach involves constructing a graphical model to depict the decision problem and the interconnections among pivotal variables. The model is formulated by identifying these critical variables, delineating their interactions, and subsequently mapping

them onto a graph structure (Xu et al., 2018). Nodes within the graph symbolize decision variables, and edges signify relationships, with nodes and edges assigned weights based on their respective significance and the strength of their connections. Mathematical optimization techniques are employed to solve the model, seeking the optimal solution that maximizes overall benefits and minimizes conflicts. The GMCR model has proven effective across diverse domains, including environmental management, natural resource management, transportation planning, and public policy decision-making (Aghmashhadi et al., 2022). The development and analysis of the GMCR model incorporate algorithms that forecast potential outcomes and facilitate their examination. This encompasses considerations such as decision-makers, potential states, reachability, equilibria, foresight, and stability (Hipel & Fang, 2020). Recognizing the key components of conflicts occurs during the modeling phase. After the user inputs the list of Decision Makers (DMs) and their preferences, the software generates numerous potential configurations of options or states. Given that not all mathematically contemplated scenarios align with agreeable or feasible states in real conflicts, the model excludes infeasible combinations of tactics, thereby reducing the number of considered states (Kinsara et al., 2015).

2.2. Problem structuring methods

The problem structuring methods (PSM) phase in the resolution of operations research (OR) challenges is widely regarded as the most intricate (Smith & Shaw, 2019). Precision and diligence are imperative for a comprehensive understanding of intricate issues, and researchers have proffered diverse methods, each varying in complexity, to facilitate the identification of decision-makers, available options, potential scenarios, and other pertinent aspects. One such method is Soda, subsequently refined into Journey Making (JM), which proves beneficial for aiding decision-making in complex problem domains. Nonetheless, the efficacy of JM experiences a notable decline with an escalation in the number of decision-makers and available options (Eden and Ackermann, 2018). In this investigation, researchers intend to employ JM to ascertain primary and secondary players based on their power and interest levels. This determination will be made through the distribution of questionnaires to experts within the Lebanese domain, focusing on the reality of the waste issue. Following this, the Generalized Multiplicative Choquet Integral (GMCR) method will be implemented to identify the most suitable option (Nassereddine et al., 2021). The selection will prioritize scenarios closely aligned with implementation while considering the political, economic, and environmental

realities in Lebanon pertaining to the final disposal of solid waste.

2.3. Multimethodology intervention

[Paucar-Caceres \(2010\)](#) posits that employing diverse approaches in Operations Research/Management Science (OR/MS) research signifies a notable advancement. [Kotiadis and Mingers \(2006\)](#) contends that adopting multiple methodologies is a beneficial strategy for problem-solving and decision-making. This approach involves the integration of various OR/MS techniques along with the concurrent utilization of various problem-structuring techniques (PSM) ([Zhu, 2011](#); [Ormerod, 2014](#)). However, [Howick and Ackermann \(2011\)](#) caution that amalgamating methodologies in case studies may result in a lack of generalizable lessons within literature. [Ormerod 2014](#)) underscores that the selection of intervention design is contingent upon the specific problem, emphasizing that there is no singular "best way" to combine approaches. Despite the ongoing interest in integrating multiple PSM models, recent literature explores the amalgamation of PSM with non-PSM methodologies, such as hard-OR and decision analysis ([Ackermann, 2012](#)).

2.4. Research gap

The identified research lacuna in solid waste management in Lebanon revolves around the absence of comprehensive studies delving into the social, political, and behavioral dimensions of waste management practices. While there has been research on the technical and environmental facets of waste management, there is a notable dearth of attention to comprehending the attitudes, perceptions, and behaviors of diverse stakeholders, encompassing households, businesses, and local communities.

The formulation of effective and sustainable waste management strategies stands to gain significant benefits from an in-depth understanding of the Lebanese political landscape, which encompasses diverse political parties, sects, and currents, along with the ongoing economic crisis. Additionally, sociocultural factors influencing waste generation, disposal practices, and recycling behaviors should not be overlooked.

To obtain a more holistic comprehension of the challenges and opportunities in addressing the waste crisis and achieving sustainable waste management in the nation, there is a call for research that scrutinizes the political, social, and behavioral aspects alongside the existing technical and economic studies. In pursuit of this objective, researchers have adopted a multi-methodological approach, integrating journey-making (JM) and game theory. Initially, the

distribution of questionnaires to experts and researchers in the fields of environment, economics, and politics, all with an interest in the issue of solid waste in Lebanon, facilitated a comprehensive understanding of the problem from diverse dimensions and identified both direct and indirect influential players. Subsequently, applying the Generalized Multiplicative Choquet Integral (GMCR+) software allowed researchers to determine options for direct players, laying the groundwork for presenting and discussing feasible consensus states with the principal decision-makers.

3. Research methodology

A notable deficiency exists in the remodeling and modeling process, a gap that Journey Making (JM) proves capable of bridging. While JM effectively addresses this weakness, its applicability in analyzing social interventions, such as conflict resolution, is particularly fruitful for comprehending the situation, developing options, and predicting scenarios. However, it is imperative to note that JM encounters limitations in handling complex scenarios as the number of players, options, and scenarios increases, making it less suitable as a negotiation method.

In summary, this paper concentrates on developing and implementing multimethodological intervention, capitalizing on the merits of soft Operational Research (OR) and game theory to navigate the intricate nature of real-world problems.

The five fundamental steps of this research involve delineating the circle of impact on Lebanon's solid waste issue through the Journey Making (JM) approach. Subsequently, primary participants are selected and distinguished from secondary players. The second stage employs a SWOT analysis to contrast centralization and decentralization in waste management. The third step proposes a synthesis of centralization and decentralization as a recommended solution, aligning with the political, demographic, and economic circumstances in Lebanon. The GMCR program is then employed to select the most optimal options for the main actors identified in the initial phase. The conclusion involves the players endorsing the proposed strategy.

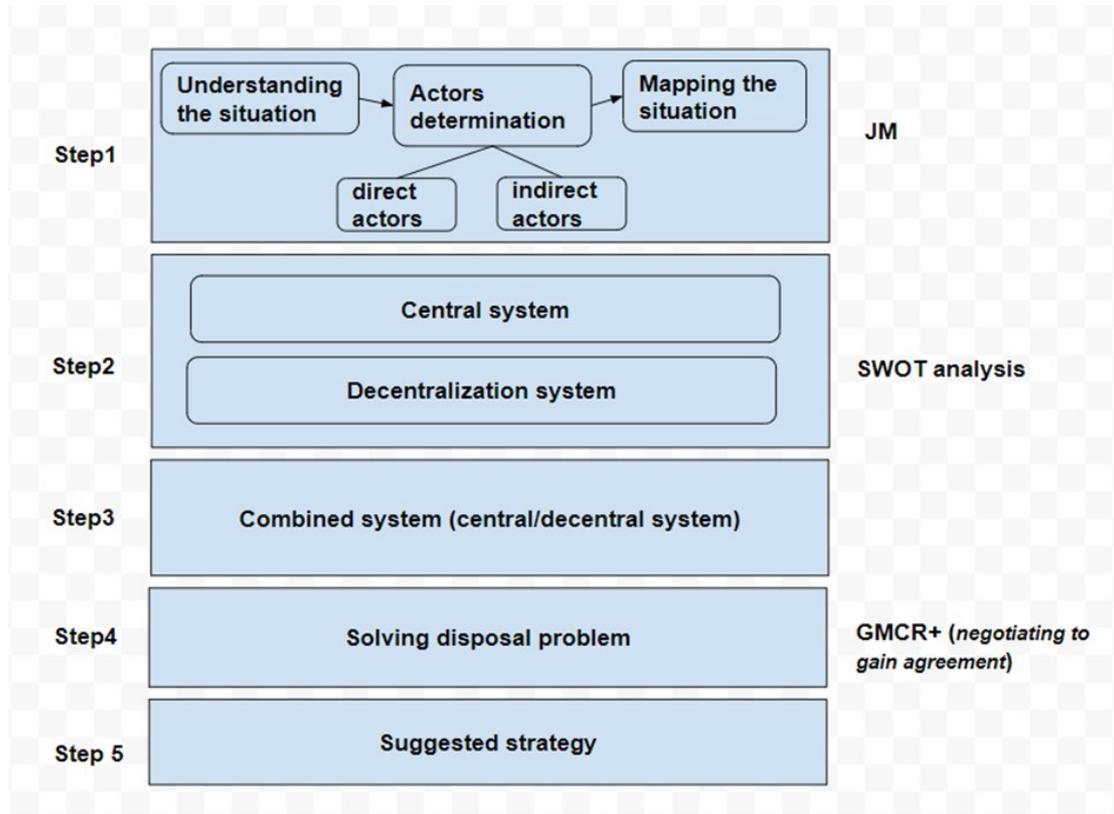


Figure 1. The study framework

3.1. Actors classification

The conflict in solid waste management (SWM) in Lebanon involves multiple parties, both directly and indirectly. The research initiation encompassed a survey targeting experts in the field. A decision team was assembled comprising ten experts representing influential political parties, municipal members, academic researchers, and officials from environmental associations and non-governmental organizations.

The preliminary phase involved a comprehensive examination of the historical context of SWM, coupled with the collection of experts' opinions. Based on this information, nine actors were initially selected. In the subsequent round, the most pivotal actors were identified.

Despite utilizing a causal map structure that primarily centers on individual players in this conflict, experts incorporate an assessment of the underlying causes of the conflict when choosing decision-makers (players), determining their available options, assigning participant roles, and mapping the overall situation. In consideration of the initial phase, which involves becoming acquainted with the situation in the Journey Making (JM) process, the table below outlines the involvement of nine players.

Table 1. Lebanon’s SWM conflict actors

1	Relevant ministries	MoE ¹ , MoIM ² , MoA ³ , MoPH ⁴ , MoPWT ⁵ , MoET ⁶ , MoF ⁷ , MoEW ⁸ , MoI ⁹)
2	Municipal councils	Independent or union municipalities
3	Lebanese parties	Each party influences its affiliates or supporters
4	NGOs, CBOs	Organizations concerned mainly with the environment, Health, and Social awareness sectors
5	Private sector	Recycling industry, Agriculture sector, Energy sectors, Street scavengers, Companies
6	Academics	Universities, Research institutions, Professors, and Published articles.
7	Service users	Households, Companies, Hospitals...
8	Financing organizations	International and National institutions, Regional funds, Donors
9	Lobby	Media, Influential politicians...

MOE¹ Ministry of Environment, MOIM² Ministry of Interior and Municipalities, MoA³ Ministry of Agriculture, MOPH⁴ Ministry of Public Health, MOPWT⁵ Ministry of Public Works and Transport, MOET⁶ Ministry of Economy and Trade, MoEW⁷ Ministry of Energy and Water, MoF⁸ Ministry of Finance, MoI⁹ Ministry of Industry.

In the context of solid waste management (SWM) in Lebanon, there exist numerous direct players or decision-makers alongside indirect players whose role is integral to the success of any developed strategy aimed at resolving the waste predicament. The distinction between direct and indirect players hinges on their capacity as active individuals or institutions to either accept or reject any proposed strategy. In negotiations involving multiple parties, whether internal or international, attaining a specific agreement that satisfies all parties necessitates maximal support and endorsement from entities not directly engaged in decision-making. This is particularly noteworthy in the intricate case of Lebanon, characterized by sectarian distribution and cultural differences. Pressure groups assume a pivotal role in influencing public opinion to accept decisions emanating from the central authority. Beyond that, pressure groups, or lobbies, play a crucial role in shaping a coherent narrative and enhancing the understanding of a scientific and practical foundation for politicians who may not have reached decision-making positions based on specialized scientific backgrounds.

Table 2. Power/interest

No	Actors	Power	Interest
1	Relevant ministries	3.2	2.7
2	Lebanese parties	3.5	2.8
3	Municipal councils	3	3.5
4	NGOs, CBOs	1.5	3.7
5	Private sector	1.4	3.2
6	Academics	1.3	4
7	Financing organizations	2	2.4
8	Service users	1.5	2
9	Lobby	2.2	3

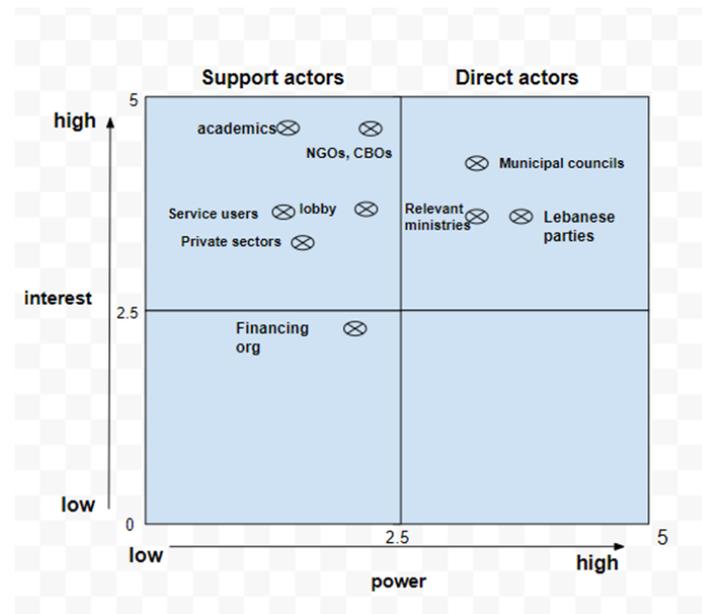


Figure 2. The Power/interest grid of the actors

As illustrated in Figure 2, three primary actors will progress to the subsequent phase, namely the GMCR+ program, to examine the available options for resolving the conflict and formulating a strategy that garners acceptance from all involved parties.

4. SWOT analysis (centralization vs decentralization)

Certain individuals may posit that solid waste management (SWM) in a nation like Lebanon should be straightforward, given the predominantly organic nature of the waste, the modest size of its territory, and the geographical diversity enabling the establishment of sanitary landfills across various locations. However, the intricate sectarian structure of Lebanon, which significantly influences political dynamics and decision-making processes, stands as the nation's fundamental challenge.

The collection and disposal of waste from a centralized location, such as a landfill or incinerator, falls under the purview of centralized waste management. In contrast, decentralized waste management involves waste collection and processing at smaller, more regional facilities, including composting or recycling facilities. The following outlines key distinctions between centralized and decentralized waste management systems in Lebanon:

1. Cost: Centralized waste management systems, requiring extensive infrastructure and incurring higher operating costs, may be more expensive to establish and maintain compared to decentralized systems. Decentralized systems, particularly those leveraging local labor and resources, could present a more cost-effective alternative.

2. Effectiveness: Centralized systems, capable of processing larger quantities of waste simultaneously, may excel in terms of waste collection and disposal. Conversely, decentralized systems tailored to specific waste streams and regional conditions may exhibit superior efficiency in resource recovery and recycling.

3. Environmental Impact: The environmental repercussions of both centralized and decentralized waste management systems depend on the technology and procedures employed. Decentralized systems often embody greater sustainability, promoting the principles of the circular economy. In contrast, centralized systems may contribute to increased greenhouse gas emissions, air pollution, and soil contamination.

4. Community Involvement: Decentralized waste management systems, often operated by local businesses or cooperatives, offer opportunities for community engagement in waste reduction and recycling efforts. In contrast, centralized systems managed by larger governmental or commercial entities may be less responsive to community demands and preferences.

In summary, there is no singular approach to waste management in Lebanon. Depending on priorities and environmental considerations, a combination of centralized and decentralized systems may constitute a viable and effective strategy.

<u>Central system</u>	
Strengths: <ul style="list-style-type: none"> - Long distance collection and controlled landfilling - Ease of assigning responsibilities 	Weaknesses <ul style="list-style-type: none"> - persistence corruption - weaken the role of society - Low treatment quality
Opportunities <ul style="list-style-type: none"> - Reduce the cost to the government - Direct monitoring 	Threats <ul style="list-style-type: none"> - Repetition of crisis - Direct influence on political changes - Lack of change
<u>Decentralized system</u>	
Strengths <ul style="list-style-type: none"> - Participation of non-governmental organizations - Increase the sense of responsibility of the households - Quality treatment 	Weaknesses <ul style="list-style-type: none"> - less government monitoring - Poor experience and training - Difficulty assigning responsibilities framework
Opportunities <ul style="list-style-type: none"> - Activating the industrial sector - Flexibility in treatment solutions - Local jobs 	Threats <ul style="list-style-type: none"> - Inequalities of service - Handling and disposal of residual and toxic wastes

Figure 3. SWOT analysis of the centralized vs decentralized system

4.1. Combined system

According to a SWOT analysis, the optimal approach for managing solid waste in Lebanon involves integrating both centralized and decentralized systems. The centralized system would entail the implementation of legislation, establishing precise regulations for solid waste disposal, and overseeing the activities of municipalities and nongovernmental organizations. To avert potential environmental crises, an imperative for Lebanon given its existing challenges, the ultimate waste disposal option, whether it be incineration, landfilling, exporting, or a combination, must be subjected to explicit and stringent environmental restrictions. Facilitated by nongovernmental organizations, the decentralized system, represented by governorates and municipalities, is empowered to engage in waste collection, sorting, operation of recycling plants, or the licensing of specialized facilities under its supervision. This fosters community involvement in diverse environmental initiatives by enhancing public awareness. The decentralized system is capable of receiving support and grants from amicable municipalities and donor nations in various forms, encompassing financial assistance, administrative training, public awareness campaigns, and specialized waste sorting and pressing machinery.

5. Decision-makers and their options

As previously elucidated, in accordance with the outcomes derived from the application of the JM method for player identification, the principal actors in this context are the Lebanese government, municipal councils, and Lebanese political entities. Each entity harbors distinct rationales guiding its preference for a particular waste disposal methodology over another. Given the prevailing financial crisis in Lebanon, the government endeavors to ascertain an economically viable solution that is both cost-effective and expeditious in implementation. This pursuit is motivated by the imperative of securing public support, especially amidst the time-sensitive scenario posed by the impending saturation of existing waste disposal sites. Moreover, the relatively transient tenures of Lebanese governments foster a proclivity for expeditious, albeit less enduring, accomplishments, as opposed to the formulation of long-term strategic resolutions.

Municipal councils, being most directly impacted by the environmental consequences within their purview, exhibit a heightened aspiration for expeditious waste elimination. The immediacy of this concern stems from the direct repercussions on residents' perceptions and evaluations of municipal councils should a failure to address the crisis transpire. Consequently, there exists a

pressing need for a rational and verifiable solution. Municipal councils, located in close proximity to residents, grapple with mounting pressures arising from the escalating waste disposal predicament and a concomitant dearth of financial support from the central government. Concurrently, these councils contend with external pressures from civil society groups, non-governmental organizations, and academic institutions, all actively engaging with them to influence their perspectives and proffer solutions for crisis mitigation. Given the often-representative nature of municipal councils vis-à-vis political parties, even with changes in membership, the councils consistently revert to representing the dominant parties in their regions. This temporal advantage empowers them to formulate strategic programs for waste crisis resolution alongside expeditious measures for waste removal.

Lebanese political entities exhibit substantial convergence in their perspectives with municipal councils. Each party, whether confined to a specific region or spanning multiple regions, nominates candidates from its adherents to contest municipal council elections, resulting in alignment between municipal decisions and the positions of dominant parties in a given locale (Parreira, 2020). In this instance, the competitive atmosphere among Lebanese political entities may act as a positive catalyst, prompting the provision of optimal solutions to the waste disposal predicament. Consequently, political entities actively seek consultations with experts in the field, alongside engagement with non-governmental organizations and donors for the financing of waste disposal initiatives. Furthermore, it is noteworthy that political entities, within their spheres of influence, place emphasis on generating employment opportunities for loyal citizens, thereby stimulating contemplation on productive projects achievable through waste recycling.

The Lebanese government possesses several alternatives for addressing the waste issue in Lebanon, as indicated by Verdeil (2018). One avenue involves substantial investments in enhancing the existing waste management infrastructure, encompassing the establishment of new landfills and waste treatment facilities. Another approach entails the implementation of programs aimed at waste reduction and recycling, such as composting and plastic recycling, to diminish the volume of generated waste and mitigate its environmental impact. Furthermore, the government may contemplate waste-to-energy solutions, including incineration and gasification, as mechanisms for generating electricity from waste. Additionally, there exists the possibility of importing waste for processing and disposal within Lebanon or exporting waste from Lebanon to other nations under specific conditions. However, this latter option is frequently contentious and may encounter resistance from local communities. Ultimately, a comprehensive and sustainable resolution to the waste predicament in Lebanon may necessitate

a synergistic application of these alternatives, coupled with effective governance and public involvement.

It is imperative to acknowledge that the interplay among the government, political parties, and municipalities is characterized by a dynamic and cyclical nature rather than a linear progression. Within the framework of the Lebanese political landscape, decision-making in the government is intricate and may involve voting on proposed resolutions that ministers scrutinize and subsequently vote on following consultations with their affiliated political parties. Conversely, proposed legislation may emanate from the requests of municipalities and political parties, which submit these propositions to ministers for endorsement and voting, thereby facilitating their transformation into enforceable laws. This elucidation underscores the primary objective of this article, which aims to formulate solutions attaining a relative or complete consensus among diverse political entities, even those espousing disparate political ideologies. This is because political accord and consensus represent the sole avenue for devising sustainable environmental and technological solutions to the quandary of waste and environmental pollution in Lebanon.

From a technical perspective, the stakeholders are confronted with three viable alternatives that necessitate judicious decision-making, each entailing environmental and financial advantages and disadvantages.

5.1. Incineration

Waste incineration is a process wherein waste materials undergo combustion, resulting in the conversion of these materials into ash, gas, and heat. This method is frequently employed for the management of waste that proves challenging to recycle, compost, or dispose of in a landfill (Zhuang et al., 2022).

The incineration process entails loading waste into a furnace or incinerator, typically equipped with a high-temperature burner and air pollution control devices. Subsequently, the waste is subjected to combustion at elevated temperatures, typically within the range of 800 to 1000 degrees Celsius. This process serves to reduce the volume of waste and transform it into ash and gases. Gases generated during incineration are typically subjected to treatment to eliminate pollutants before their release into the atmosphere.

The utilization of waste incineration as a waste management strategy carries both advantages and disadvantages. On the positive side, it can diminish the quantity of waste destined for landfills, generate heat or power, and offer a secure means of disposing of hazardous waste.

Conversely, potential drawbacks include the emission of air pollutants during incineration, with consequent adverse effects on the environment and human health. In comparison to alternative waste management strategies, the construction and operation of incinerators can be costly, and there exists a risk of producing harmful ash residue during the combustion process. In sum, while waste incineration can prove effective in certain scenarios, meticulous management and regulation are imperative to mitigate its adverse impacts on human health and the environment.

In the context of Lebanon, waste management has persistently presented challenges, prompting the consideration of waste incineration as a prospective solution to the nation's waste crisis. Nevertheless, this proposal has encountered substantial controversy and opposition within Lebanon, primarily stemming from apprehensions regarding its environmental and health implications.

The closure of Lebanon's largest landfill in Naameh in 2015 led to a significant waste management crisis, with refuse accumulating in the streets of Beirut and other major cities. In response, the Lebanese government advocated for waste incineration as a resolution to the crisis but encountered substantial resistance from local communities and environmental activists.

Opponents of waste incineration in Lebanon have voiced concerns regarding the potential release of toxic pollutants into the air and its impact on public health. Moreover, there have been reservations about the perceived lack of transparency and public consultation in the decision-making process (Chalhoub, 2018).

Despite these concerns, there have been endeavors to advance waste incineration in Lebanon. In 2018, a waste-to-energy plant was proposed in the city of Sidon, although it encountered significant opposition from residents and environmental groups. As of 2021, the future trajectory of waste incineration in Lebanon remains uncertain, with ongoing debates and controversies surrounding the issue.

5.2. Landfilling

The United States Environmental Protection Agency (U.S. EPA) recognizes that the integrity of all landfill liners tends to degrade within a span of 20 years, if not sooner, thereby warranting a nominal lifespan guarantee of approximately two decades (Barlaz et al., 2002). Furthermore, the detection of leakage, whether subterranean or airborne, poses a non-trivial challenge, often exacerbated by inadequacies in testing methodologies.

Landfilling represents a waste management approach entailing the burial of waste in a demarcated land area (Singh, 2019). Typically, the waste is enveloped in layers of soil or

alternative materials, serving the dual purpose of mitigating odors, preventing disease dissemination, and minimizing contamination risks.

Various landfilling methods are deployed contingent upon the nature of the waste and its geographical location. Noteworthy examples encompass:

1. Sanitary landfills: These facilities are engineered for the management of municipal solid waste (MSW) and are conventionally equipped with impermeable linings to forestall the dissemination of contaminants into the contiguous soil and groundwater (Nanda & Berruti, 2021).

2. Industrial landfills: These sites are configured for the disposal of waste generated through industrial processes and may be subject to distinct regulatory frameworks and requisites compared to sanitary landfills.

3. Hazardous waste landfills: Tailored for the management of hazardous waste materials, such as chemicals, solvents, and medical waste, these landfills adhere to stringent regulations ensuring the safety of both workers and the environment.

4. Bioreactor landfills: Crafted to augment the natural decomposition of waste, bioreactor landfills introduce liquid or air into the landfill environment to foster the proliferation of microorganisms facilitating waste breakdown.

The selection of a landfilling method hinges on the characteristics, composition, and location of the waste in question. While landfilling is generally regarded as a less favored waste management strategy compared to recycling, composting, or waste-to-energy alternatives, as it does not align with resource conservation or energy recovery principles, it nonetheless persists as a prevalent method due to its cost-effectiveness and straightforward implementation.

5.3. Waste exportation

Waste exportation denotes the practice of conveying waste materials from one country to another for disposal or recycling purposes (Marbury, 1995). This practice has been the subject of extensive debate due to its potential adverse effects on the environment, public health, and social justice. On the one hand, countries exporting waste may derive benefits from diminished waste disposal costs and increased revenue through recycling. Conversely, importing nations may encounter heightened environmental pollution, health hazards, social disparities, and the risk of illicit dumping and trafficking.

In recent years, the matter of waste exportation has garnered heightened attention in academic research, policy formulation, and public discourse. Scholars have scrutinized diverse facets of

waste exportation, encompassing its economic, environmental, and social ramifications, the legal and regulatory frameworks governing the practice, and the determinants influencing waste trade flows and patterns.

In its entirety, the issue of waste exportation remains intricate and contentious, necessitating a judicious examination of myriad factors and perspectives. Consequently, further research and dialogue are imperative to formulate effective and equitable policies and practices that can ensure sustainable waste management and mitigate the adverse impact of waste on the environment and public health.

In the context of Lebanon, one proposed solution involves exporting waste to other countries for treatment and disposal, a strategy successfully implemented in countries facing comparable waste management challenges, such as Sweden and Denmark, where waste is exported to Germany for treatment (Behzad et al., 2020). However, the viability of waste exportation as a solution for Lebanon is not devoid of challenges. Considerations include logistical and financial factors such as transportation costs, customs fees, and the expenses associated with treatment and disposal in the receiving country. Additionally, it is recognized that waste exportation may not constitute a sustainable long-term solution, as it fails to address the root causes of the waste management crisis in Lebanon, such as deficient infrastructure and a lack of political will to implement effective waste management policies.

5.4. DMs' preference ranking over the feasible states

Inferences regarding players' preferences regarding the states are drawn from the conflict background and expert opinions, as outlined in Table 3. Divergence in preference among decision-makers (DMs) was noted concerning experts. Consequently, the Borda count method was employed to delineate the ultimate preference. Further details on the Borda Count method can be found in Zahid and De Swart (2015).

Ordered	Decimal	Filter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1 - lebanese parties	incineration	-	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	
	export abroad	-	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	
	building new landfill	-	N	N	Y	Y	N	Y	N	N	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	Y	Y	Y	
	Expansion existing I	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
2 - municipalities	incineration	-	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	Y	N	
	export abroad	-	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	
	building new landfill	-	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	
	expansion existing I	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
3 - relevant ministr	incineration	-	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	
	export abroad	-	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	
	building new landfill	-	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	
	expansion existing I	-	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Payoff For:	lebanese parties	-	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Payoff For:	municipalities	-	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
Payoff For:	relevant ministries	-	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	
	Nash	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
	GMR	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
	SEQ	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
	SIM	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
	SEQ & SIM	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
	SMR	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	

Figure 4. Feasible states

lebanese parties:	[[22, 20, 21, 23, 24, 19, 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18]]
municipalities:	[[22, 23, 20, 21, 24, 19, 1, 2, 3, 4, 5, 6, 13, 14, 15, 16, 17, 18, 7, 9, 8, 11, 10, 12]]
relevant ministries:	[[12, 9, 7, 8, 11, 10, 1, 2, 5, 13, 6, 14, 17, 3, 4, 15, 16, 18, 22, 20, 21, 19, 23, 24]]
No Errors. Preference rankings are valid.	

Figure 5. Preferences vector of the players

5.5. Stability analysis

If a player does not exhibit a tendency to transition from a specific state, that state is deemed the stable state for that player. When a state is stable for all players involved, it is termed "equilibrium." As previously delineated, diverse methodologies exist for ascertaining the equilibrium states of a conflict, contingent upon the players' attitudes and their decision-making horizon. In the context of Nash equilibria, players contemplate only one future state. A player characterized by Nash stability will abstain from making any moves if the prospective state fails to confer advantages surpassing those of the current state. In the overarching frameworks of general meta-rationality (GMR) and sequential stability (SEQ), a player's decision to move is contingent upon the consideration of the two ensuing steps.

The concordance among political parties and municipalities will reflect an internal consensus within the government, whose ministers are affiliated with these parties, as evidenced by GMCR+ outputs. Consequently, the practicable options (24 in total) outlined in the table are predominantly contingent upon political agreement, a characteristic uncommon in conflict research and analysis. Nevertheless, surveys and expert interviews posit that the optimal course of action involves formulating an environmental emergency plan encompassing the expansion

of existing temporary landfills in mutually agreed-upon locations by the parties and the establishment of new sanitary landfills adhering to safety requirements.

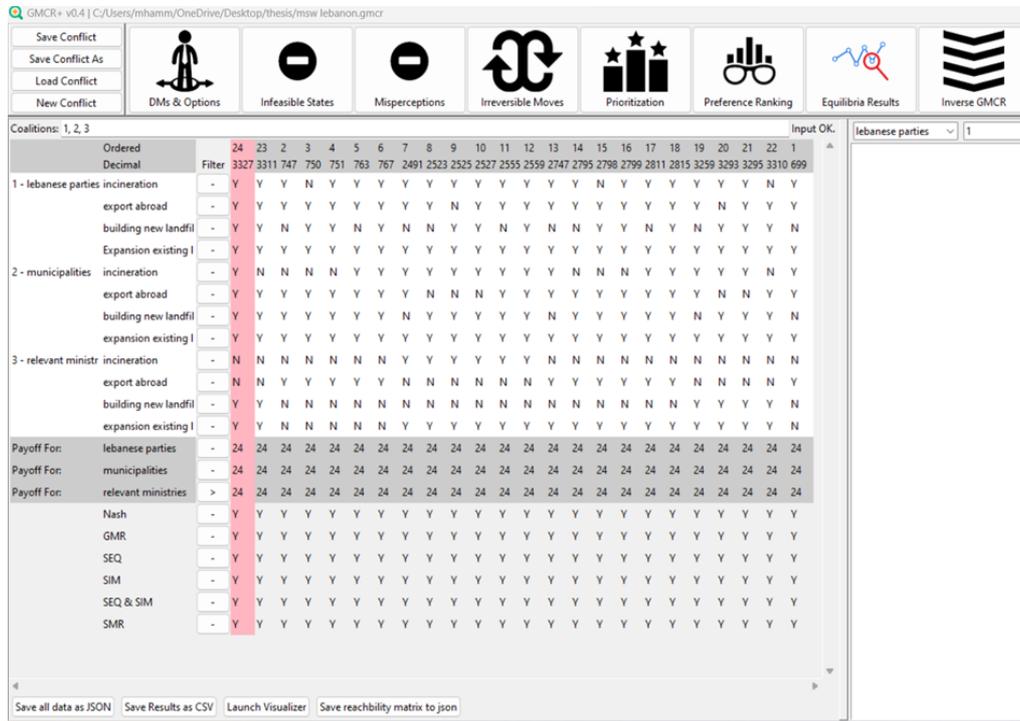


Figure 6. Equilibrium states

5.6. Equilibria

Throughout the GMCR+ outputs, it has been observed that the "payoffs" associated with all options (24 in total) are equivalent. This indicates that each option or decision in a conflict resolution scenario result in identical outcomes in terms of benefits or costs. In other words, there is no discernible variation in the consequences or rewards linked to each choice. This implies that all the options carry comparable environmental and financial impacts, and none of them offers a distinct advantage or disadvantage over the others.

Option No. 24 is regarded as the most favorable solution for the concerned ministries, as it secures technical agreement from municipalities and involved parties. This enables the government to broaden the range of technical options available for discussion. The state opts to avoid incineration due to its considerable environmental and health risks, particularly given Lebanon's lack of transparency in standards. Furthermore, incineration involves high operational and maintenance costs that the state is unable to afford amidst the current crisis.

6. Discussion and conclusion

Lebanon's waste predicament transcends mere technical concerns, fundamentally manifesting as a political issue. While the imperative for effective physical and technological waste

management solutions remains undeniable, the root challenges in Lebanon revolve around administrative inefficiencies, decision-making processes, and the absence of streamlined legislative frameworks. The dearth of a coherent waste management policy, coupled with political instability and pervasive corruption, collectively underpin the garbage crisis afflicting Lebanon. These political dynamics have impeded the implementation of efficient and sustainable waste management practices. Consequently, addressing Lebanon's waste crisis necessitates not only technical interventions but also a confluence of political resolve, transparent governance, and the establishment of effective regulations and laws.

Upon achieving a political consensus among influential factions and aligning with Lebanon's intricate political, sectarian, cultural, and economic context, a judicious initiation of the amalgamation of centralization and decentralization in Lebanon's solid waste management becomes imperative. The researchers underscore the exigency for decentralization owing to Lebanon's diverse cultural and social norms, as well as the prevalent socioeconomic disparities.

Waste incineration significantly reduces the volume of waste, reducing the need for landfill space. It is also possible to generate electricity or heat through waste-to-energy processes. However, due to concerns about air pollution, emissions of dioxins, furans, and other pollutants, and high initial investment and operating costs, this solution, although it may be acceptable to parties and municipalities, will not be accepted by the government as a solution.

Exporting waste can be a quick solution to the problem of waste accumulation, or it can be a temporary solution with the development of long-term waste management strategies, but the main problem lies in the unwillingness of any parties or countries to import solid waste from Lebanon, especially with the absence of a solid waste sorting policy.

Therefore, the Lebanese government remains faced with the option of landfilling waste, which is characterized by low initial investment compared to incineration and can be implemented relatively quickly. In addition, work must be done to build sanitary landfills on various Lebanese lands following the principle of decentralization in solid waste management, because Lebanon lacks such landfills that take appropriate environmental conditions into account. The proposed strategy advocates for the establishment of both decentralized sorting and recycling facilities managed by local cooperatives alongside centralized waste management facilities to handle substantial waste volumes efficiently. Public-private collaborations, educational initiatives, and active engagement of the business sector emerge as pivotal components of this approach. The formulation of a comprehensive waste management strategy is recommended, encompassing objectives related to waste minimization, recycling targets,

collection, sorting, treatment, and sanitary landfilling. To ensure progress tracking and adherence to environmental standards, continuous monitoring and evaluation are deemed indispensable.

The articulated strategy places significant emphasis on fostering a societal ethos that champions waste reduction, reuse, recycling, and composting while simultaneously endorsing industries rooted in recycling. The formulation of unequivocal policies delineating the roles of the state, municipalities, civil society organizations, and households is imperative. The integration of centralization and decentralization must unfold within the framework of an encompassing strategy garnering support across diverse regions, thereby averting the pitfalls encountered by previous initiatives.

6.1. Limitations

Given the intricate nature of the conflict, the research may encounter challenges pertaining to the accessibility and reliability of data concerning waste management in Lebanon. The findings and proposed strategy may exhibit specificity to the Lebanese context and may not readily lend themselves to broader application in regions or countries characterized by distinct socio-economic and political circumstances. The intricacies of waste management in Lebanon, entwined with political and social nuances, may pose difficulties in engaging a diverse array of stakeholders for the study. Furthermore, constraints related to time and finances may impede the practical implementation of the envisaged solution. A comprehensive evaluation of the technological viability of waste treatment methods is imperative, as certain technologies may prove nonviable or unsustainable within the framework of Lebanon's infrastructure.

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References

- Abou Jaoude, L., Nassif, N., Garau, G., Darwish, T. and Castaldi, P., 2022. Biochar Addition Decreases the Mobility, Bioavailability, and Phytotoxicity of Potentially Toxic Elements in an Agricultural Contaminated Soil. *Communications in Soil Science and Plant Analysis*, 53(13), pp.1655-1671. <https://doi.org/10.1080/00103624.2022.2063313>.
- Ackermann, F., 2012. Problem structuring methods 'in the Dock': Arguing the case for Soft OR. *European Journal of Operational Research*, 219(3), pp.652-658. <https://doi.org/10.1016/j.ejor.2011.11.014>.
- Zhu, Z., 2011. After paradim: why mixing-methodology theorising fails and how to make it work again. *Journal of the Operational Research Society*, 62, pp.784-798. <https://doi.org/10.1057/jors.2010.31>.

- Aghmashhadi, A.H., Zahedi, S., Kazemi, A., Fürst, C. and Cirella, G.T., 2022. Conflict Analysis of Physical Industrial Land Development Policy Using Game Theory and Graph Model for Conflict Resolution in Markazi Province. *Land*, 11(4), p.501. <https://doi.org/10.3390/land11040501>.
- Ajeeb, R.J., 2017. *The health effects of burning wastes on newborns in Lebanon* (Doctoral dissertation).
- Awasthi, S.K., Sarsaiya, S., Kumar, V., Chaturvedi, P., Sindhu, R., Binod, P., Zhang, Z., Pandey, A. and Awasthi, M.K., 2022. Processing of municipal solid waste resources for a circular economy in China: An overview. *Fuel*, 317, p.123478. <https://doi.org/10.1016/j.fuel.2022.123478>.
- Barlaz, M.A., Rooker, A.P., Kjeldsen, P., Gabr, M.A. and Borden, R.C., 2002. Critical evaluation of factors required to terminate the postclosure monitoring period at solid waste landfills. <https://doi.org/10.1021/es011245u>
- Baumann, H., 2023. Bringing the state and political economy back in: Consociationalism and crisis in Lebanon. *Nationalism and Ethnic Politics*, pp.1-18. <https://doi.org/10.1080/13537113.2023.2188655>.
- Behzad, M., Zolfani, S.H., Pamucar, D. and Behzad, M., 2020. A comparative assessment of solid waste management performance in the Nordic countries based on BWM-EDAS. *Journal of Cleaner Production*, 266, p.122008. <https://doi.org/10.1016/j.jclepro.2020.122008>.
- Boswall, J., 2019. Lebanon: the state of waste.
- Chalhoub, M.S., 2018. Public policy and technology choices for municipal solid waste management a recent case in Lebanon. *Cogent Environmental Science*, 4(1), p.1529853. <https://doi.org/10.1080/23311843.2018.1529853>.
- Eden, C. and Ackermann, F., 2018. Theory into practice, practice to theory: Action research in method development. *European Journal of Operational Research*, 271(3), pp.1145-1155. <https://doi.org/10.1016/j.ejor.2018.05.061>.
- Menhall, E. and Joseph, N., 2017. *Decentralization as a policy option in Lebanon: the case of the waste management crisis and local level solutions* (Doctoral dissertation).
- El Richani, D., 2017. *This is Not a Revolution: The Sectarian Subject's Alternative in Postwar Lebanon* (Doctoral dissertation, Université d'Ottawa/University of Ottawa). <https://doi.org/10.20381/ruor-20295>.
- Hipel, K.W. and Fang, L., 2020. The graph model for conflict resolution and decision support. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, 51(1), pp.131-141. <https://doi.org/10.1109/TSMC.2020.3041462>.
- Howick, S. and Ackermann, F., 2011. Mixing OR methods in practice: Past, present and future directions. *European Journal of Operational Research*, 215(3), pp.503-511. <https://doi.org/10.1016/j.ejor.2011.03.013>.
- Khalil, S., 2022. *Impacting Policies: Waste Management and Advocacy in Lebanon*.
- Kinsara, R.A., Petersons, O., Hipel, K.W. and Kilgour, D.M., 2015. Advanced decision support for the graph model for conflict resolution. *Journal of decision systems*, 24(2), pp.117-145. <https://doi.org/10.1080/12460125.2015.1046682>.

- Marbury, H.J., 1995. Hazardous waste exportation: The global manifestation of environmental racism. *Vand. J. Transnat'l L.*, 28, p.251. Available at: <https://scholarship.law.vanderbilt.edu/vjtl/vol28/iss2/3>.
- Kotiadis, K. and Mingers, J., 2006. Combining PSMs with hard OR methods: the philosophical and practical challenges. *Journal of the Operational Research Society*, 57, pp.856-867. <https://doi.org/10.1057/palgrave.jors.2602147>.
- Nanda, S. and Berruti, F., 2021. Municipal solid waste management and landfilling technologies: a review. *Environmental Chemistry Letters*, 19, pp.1433-1456. <https://doi.org/10.1007/s10311-020-01100-y>.
- Nassereddine, M., Ellakkis, M.A., Azar, A. and Nayeri, M.D., 2021. Developing a multi-methodology for conflict resolution: Case of Yemen's humanitarian crisis. *Group Decision and Negotiation*, 30, pp.301-320. <https://doi.org/10.1007/s10726-020-09695-x>.
- Ormerod, R.J., 2014. OR competences: the demands of problem structuring methods. *EURO Journal on Decision Processes*, 2(3-4), pp.313-340. <https://doi.org/10.1007/s40070-013-0021-6>.
- Parreira, C., 2020. *The Art of Not Governing: Local Politics in Postwar Lebanon*. Stanford University.
- Paucar-Caceres, A., 2010. Mapping the changes in management science: A review of 'soft'OR/MS articles published in Omega (1973–2008). *Omega*, 38(1-2), pp.46-56. <https://doi.org/10.1016/j.omega.2009.04.001>.
- Sbeih, R., 2023. *The Case Study of Transitioning Centralized Solid Waste Management in Lebanon: The Devolution and its Limitations* (Doctoral dissertation).URL: <https://frw.studenttheses.ub.rug.nl/id/eprint/4162>.
- Singh, A., 2019. Remote sensing and GIS applications for municipal waste management. *Journal of environmental management*, 243, pp.22-29. <https://doi.org/10.1016/j.jenvman.2019.05.017>.
- Smith, C.M. and Shaw, D., 2019. The characteristics of problem structuring methods: A literature review. *European Journal of Operational Research*, 274(2), pp.403-416. <https://doi.org/10.1016/j.ejor.2018.05.003>.
- Swaid, K., 2021. The Political Economy of Patronage in Lebanon-The Case of the Council of Development and Reconstruction.URL: <http://hdl.handle.net/10725/12898>.
- Verdeil, É., 2018. Infrastructure crises in Beirut and the struggle to (not) reform the Lebanese State. *The Arab Studies Journal*, 26(1), pp.84-113.URL: <https://www.jstor.org/stable/26528992>.
- Xu, H., Hipel, K.W., Kilgour, D.M. and Fang, L., 2018. *Conflict resolution using the graph model: strategic interactions in competition and cooperation* (Vol. 153). Cham: Springer International Publishing. <https://doi.org/10.1007/978-3-319-77670-5>.
- Zahid, M.A. and De Swart, H., 2015. The borda majority count. *Information Sciences*, 295, pp.429-440. <https://doi.org/10.1016/j.ins.2014.10.044>.
- Zhuang, J., Tang, J. and Aljerf, L., 2022. Comprehensive review on mechanism analysis and numerical simulation of municipal solid waste incineration process based on mechanical grate. *Fuel*, 320, p.123826. <https://doi.org/10.1016/j.fuel.2022.123826>.