Life Cycle Assessment, Optimization and Multi Criterions DM Models Facing Waste Management Problems Literature Review

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Abstract

Reviewing of numerous studies on waste management suggests that it is affected by a wide variety of economic, social and environmental factors which are themselves the source of the complexity of existing issues and a systemic look in this direction. For this purpose, existing researches has been investigated which here some are classified and enclosed in three areas of life cycle assessment models, multi-criteria optimization models and decision making. Additionally, reviewed articles in this areas are referred to the benefits and limitations of each. The results of current paper shows that in the reviewed models, there is no model that considers all three dimensions of environmental, economic, and social sustainability for waste management simultaneously, as well as combining and integrating two or more models and applying them simultaneously to a problem. It is possible that the shortcomings and limitations of each method alone will be eliminated by complementary methods and will usually be more accurate in judgments.

Keywords

Waste Management, Life Cycle Assessment, Optimization Models, Multi-Criteria Decision Making, Sustainable Development

Introduction

Literature Classification System

By reviewing the literature, the similarities and differences and the strengths and weaknesses of the various researches have been identified and the dominant research trend is revealed. Research gaps have also been revealed, and the problem can be defined with clear vision. Initially, as proposed by Chang et al. [1], we will consider two categories of decision-making techniques and decision making tools in this area:

(1) System engineering models; and (2) systems assessment systems;

The system's evaluation models assess and analyze the existing system and focus less on modeling details and optimizing the economic impacts of the waste management process. While the system engineering models focus on designing and delivering a solution for the waste management system. Methods such as multi-criteria decision making models, simulation models, forecasting models, cost-benefit analyzes, and optimization models are widely used in the system engineering approach. Life cycle assessment, risk analysis and material flow analysis are some of the system's evaluation models [1].Considering the above mentioned issues as well as the reviewed articles in the field of waste management, the proposed framework of Figure 2.1 is used to classify articles in this area. Of course, it should be noted that in this research, the areas that are shown with dashed lines are not discussed.

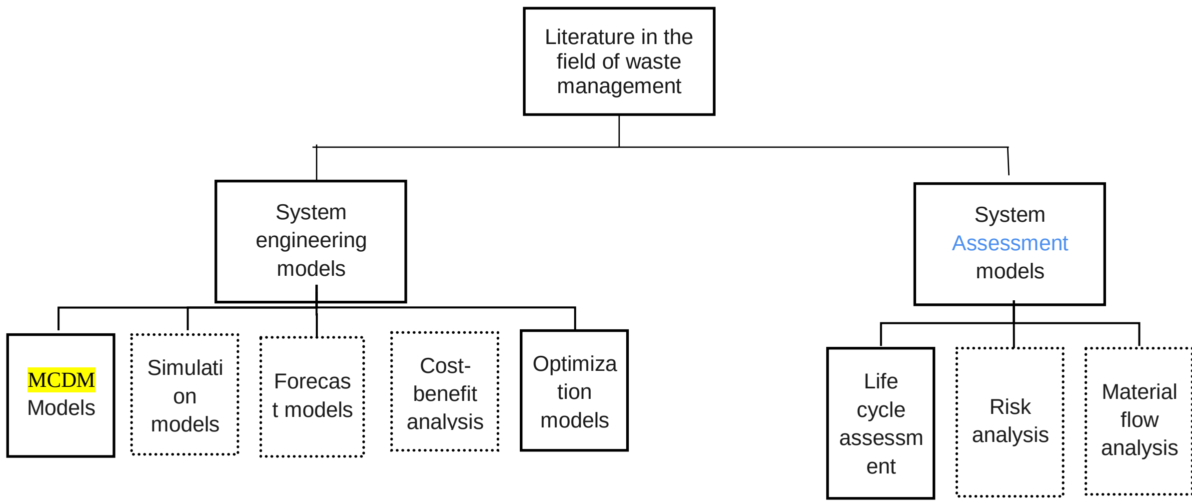

Figure 1. Literature framework for waste management

Research related to system evaluation models

As previously mentioned, solid urban waste contains dozens of different combinations that require proper management in all grades from storage and collection to disposal and burial. The SWM also includes complexities such as: the prediction of solid waste production, the selection of appropriate technologies, the selection of suitable locations, the estimation of the capacity of the facility, the management of the facilities, the planning of the system and the transportation of the waste. Systems analysis tools have been developed to support decision making on waste management since 1970, which SA models can be used to analyze the performance of an existing waste management system. [2] One of the best assessment methods in this area is the life cycle assessment method. From a logical point of view, the practical use of LCA in solid waste management dates back to the late 1990s. [3]

LCA Application in Urban Waste Management

LCA-based assessments due to being systematic, quantifying environmental qualitative parameters, and facilitating management decisions, have so far been taken into consideration by many researchers, especially in research related to municipal solid waste management. Looking at the history of the subject, it can be seen that in some studies, the researcher developed new models based on the LCA framework. Up to now, nearly 50 different LCA models have been developed in Europe. [1]. The purpose of this study is to review LCA's literature studies which has been used as an environmental tool for comparative evaluation, including comparing different waste management technologies and even comparing actual results and simulations in a real sample. Chen and Christensen, with the help of the LCA-EASEWASTE model, evaluated the environmental performance of the two waste incineration technologies in China [4], on the one hand, Rimaityte et al [5] compared the outputs of an LCA-IWM model and actual measured data on a waste incinerator, and found a large difference between model data and measured data. Since modeling assumptions and computational errors in the model may lead to different results, the identification of key criteria that could potentially have significant consequences in the results of the LCA model has a significant significance. Othman et al explores the LCA application to evaluate the comprehensive management of waste in several Asian countries. Their studies focused on assessing the environmental impacts of various waste management technologies. Eventually it was concluded that, recycling, anaerobic digestion and thermal processing are effective technologies for Asian countries [6]. Blengini Used LCA in Organic Waste Management in the northwestern Italy, and the purpose of this study was to get a proper understanding of the environmental components of organic waste management and concluded that the performance of aerobic and bio-aerobic plants plays a significant role in the management of these materials [7]. In another study by Cherubini et al., the various strategies for managing solid waste in Rome (Italy) were examined through the LCA method. Four sanitary landfill methods without biogas production, sanitary landfill with biogas production and electricity production, biogas production by anaerobic digestion and direct conversion of waste to ash were studied and the worst method of landfill was estimated and, and at best, with electricity generation, only 15% of needed energy was provided for the city of Rome[8].

In another study by Al-Salem and Lettiere [9], they used LCA to manage Kuwait's municipal waste, after reviewing three scenarios, the first scenario included three sections of collection, transfer and sanitary landfill, the second scenario included collecting, transferring, sanitary landfill and anaerobic digestion, and the third scenario, which included anaerobic digestion before the sanitary landfill, and this scenario was chosen as the best solution. LCA was used in a study by Zaman [10] on solid waste management technologies. And three purification methods were investigated. Finally, gasification and pyrolysis were selected as a nature-friendly approach. Sahib Mohammadi and Mahmoudkhani [11] have reviewed the role of waste management on greenhouse gas emissions in a valuable article. In this study, greenhouse gas emissions have been investigated in options such as recycling, waste incineration, composting and landfill. Rafiee et al [12] for the first time in Iran, the environmental assessment of the life cycle of urban waste management system (a case study of Mashhad) was carried out, and they used the LCA method to check the current status of the waste management system in Mashhad. In their research, they considered three scenarios: 1- direct transfer of waste; 2- composting; 3- indirect transmission through transfer stations. The results of this study showed that composting as one of the management options and the application of waste transmission stations at long distances plays an important role in reducing the amount of pollutants and energy consumption caused by the waste management system. Ganbarzadeh Lak and Sabour [13] evaluated the life cycle of urban solid waste disposal scenarios for greenhouse gas emissions and energy consumption (Case Study of Siri Island), and considered three scenarios for this purpose: 1) waste incineration with energy recovery and ash burial; 2- Sanitary landfill and garbage collection to extract energy from it. 3- Sanitary landfill without gas collection. Finally, the waste incineration method with energy extraction and ash burial in the island was proposed as a superior scenario. Therefore, if the option of waste incineration is chosen as the downstream item of Siri urban waste management, measures are also needed to reduce and differentiate from the origin of plastic dusts [4]. In general, a comprehensive look at the reviewed articles is presented in the literature of this field.

Research related to system engineering models

While SA models emphasize the measurement and analysis of existing systems, SE models build on the design and planning of a solution for a waste management system.

Optimization models

Optimization models consider designing a system based on a particular target function, and obtaining the best answer for the objective function. Various types of techniques are used as optimization models for waste management. Linear programming, mixed integer Linear Programming, Nonlinear Programming, Multi-objective Planning, Random Planning, Two-stage Planning, Fuzzy Programming, and Combined Models Including them. The first step in the developed SE model for solid waste management has put its emphasis on the cost-effective linear programming using an optimization program. LP is widely used with full forecast assumption [14]. For example, Münster and Meibom [15], in a paper using the energy analysis system called Balmorell, studied the use of waste in the future energy system. This study was conducted in Germany and Scandinavia and aims at analyzing WTE technologies for the recycling of various wastes in the medium-term energy system of the future and optimizing production and investment. The most economically viable way, including combined waste incineration, anaerobic digestion of organic wastes, and the conversion of the gas into a potential (RDF) gas to generate a combination of thermal and electric energy. While the remaining fraction is simultaneously flammable with coal. In power plants, combustion is associated with coal fuel, and it is possible to increase investment compared with the situation that investment in waste incineration takes place. Under existing assumptions, RDF can be used for combustion with coal in high- performance power plants.

The commonly used LP model is limited to a process that cannot support the evaluation and selection of multiple technologies. A more powerful modeling tool is needed to carry out modeling work for SWM, especially for real sample studies that include a wide range of uncertainties [16]. In this study, more complex methods of modeling are proposed, such as linear programming of complex integer, nonlinear programming, random programming, fuzzy logic, multi-criteria logic and AHP, as well as AHP-Topsis Integrated Model. The linear programming of complex integer is relatively simple and can be used for complex scenarios associated with uncertainty. Using the binary selection function, this model enables the selection of different technologies and the dynamic design of the resource network for the waste management system. Badran and El-Haggar [17] Noting that there has been no research on the optimization of waste management systems using the methodology of operations research in Egypt, the issue of the location of waste collection stations in Port Said, Egypt Studied.

In order to model the problem from the MILP with the objective function, they used minimization of transportation costs and waste collection costs and finally, it was concluded that the optimal mode for the problem was to include 27 collecting stations with a capacity of 15 tons and two stations with a capacity of 10 tons. In addition, the choice of the best location for the stations from among the candidate locations is another model output. Research by Dai et al [18] has been a new attempt to improve the accuracy of analysis on waste management systems optimization problems, which is achieved by combining the regression model of support vector and linear programming of a complex integer with interval parameters. With this combination, a two-stage backup vector regression model for municipal waste management has been proposed to solve the waste allocation problem and increase the capacity of waste processing facilities in China's Bijing. The support vector regression model is used to predict the production rate of waste generated from the optimization model inputs, while IMILP has been used to plan allocation of waste stream and increase the capacity of processing facilities under uncertainty conditions. Sie et al. [2] used a mixed-integer linear programming model to optimize the MSWM system of the Iskandar City in Malaysia. This model is able to predict the best combinations of waste treatment technologies and product production from waste purification process and estimation of greenhouse gases emitted from the system, which ultimately leads to the creation of an optimal and affordable solution in terms of economic and environmental for managing solid urban waste. The indicators of this research are the integration of an MSWM processing network for energy production and value added products to achieve economic and social competitiveness. There are four scenarios in this article. 1. Business as usual (as a sustainable study); 2. Production to energy; 3. Recycling waste; 4. Mixed technology. Finally, the model with the MIXTECH scenario, which emphasizes an economical waste processing network and leads to a maximum net profit of 101.85 USD, is accepted as a desirable scenario, which is able to achieve renewable energy as well as recycling targets and promote composting [14]. One of the problems with this model could be the limited availability of land in a country. In addition, waste transportation costs to recycling factories and the types of waste and product operations technologies, environmental factors and waste disposal sites should be considered.

Shekar riz fard et al. In an article [19], investigated a new method based on nonlinear zero and one planning with the aim of determining a model that, in addition to locating suitable stations in the city of Shiraz, simultaneously determines the best route to carry waste to these stations.

For this purpose, the study area was divided into equal size cells and road maps were prepared in GIS software. To solve a problem with such dimensions, a nonlinear zero and one program was considered. In this research, the goal is to minimize the cost of transportation and the location of the construction of a waste transmission station. The model presented in this study is an applied model, due to the modeling structure (zero and one planning), as well as the simultaneous optimization of the location of the transfer station and the route of transportation of waste as well as the use of cells to reduce the dimensions of optimization and Increased flexibility. The model also has the ability to accept new factors for future studies. For example, we can mention the possibility of entering the route traffic. Chang et al. [20] Presents a model for assessing sustainable urban waste management strategies, with taking into account uncertainty. In the proposed model, the economic and environmental aspects are considered and in the fuzzy objective function, in addition to economic issues, environmental aspects such as noise control, air pollution control and traffic constraints have been considered. Guo and Huang [21] have introduced a Fuzzy randomized mixed integer programming model for long-term planning of the waste management system in Regina, Canada, with taking into account multiple uncertainties. The researchers aimed at minimizing the costs of increasing capacity and waste stream costs from collecting areas to waste processing facilities. A general summary of the optimization models according to the categories mentioned above is presented in Table 1.

Multi-criteria decision making

The developed models in the multi-criteria decision framework include multi-stage processes that can be implemented by decision-makers in order to evaluate possible options for an issue. In the environmental literature, various MCDM models have been proposed, including models such as Multi- index Utility Theory, Analytical hierarchy process, and Network Analysis Process, Prometheus Model, and Electro Model [22].Choosing the right option for waste management is a multi-criteria and complex issue that needs to be considered biologically, socially, technologically and economically. The use of multi-criteria decision-making models is one of the solutions that researchers have used to overcome these complexities, which, with multiple criteria, facilitates the selection of the most appropriate option among available options. Over the years, these models have been widely used in issues related to waste management systems.

In addition to using multi-criteria decision-making techniques to prioritize and evaluate different waste processing technologies, some studies have used these techniques to select the most suitable place for waste processing. Feo and Gisi [23] used Analytical hierarchy process to prioritize selected sites with the aim of choosing the location for the composting plantin the state of Campania in southern Italy. Researchers also pointed out that existing conflicts among various stakeholders in the waste management system (government officials, municipal officials and citizens), selecting the right place for waste dumping or even waste processing has become one of the most difficult issues in the world. Therefore, they have proposed a new weighting technique called "Priority Scale" to follow the technical objectives (Choose the best place) and the social (Effective Participation of the Participants), which easily identifies the non-discriminatory criteria accepted by different decision-makers. Wang and colleagues [24] in a research, tried to find a suitable location for Landfill in Beijing, China. In this research, the AHP method and the geographic information system are used. Indicators of this research are the combination of economic and environmental criteria in landfill location selection. Finally, 15 layers of maps were prepared and entered GIS software, which can be used to manage and analyze layers for optimal management of urban wastes. Since GIS software is not responsive to qualitative factors, only for the first phase and the choice of the site initial options were used, and for the definitive opinion, the AHP method was used, which was weighted from 1 to 5 for each criterion. In the end, three options were selected for the 50-year period. Assadi [25] has conducted a research with the aim of determining and evaluating Ahwaz municipal waste landfills using the Fuzzy Analytical Hierarchy Process. Also Bahrani and Ebadi [26] studied the methods of landfill locating of solid municipal waste based on decision making methods including Analytical Hierarchy Process, linear weight composition method and arranged weighted average method. Amiri et al. [27] Used multi-criteria decision making and Analytical Hierarchy Process to compare different waste management scenarios in Karaj city. In this study, three different scenarios including segregation from source, mechanical and biological processing, waste-derived fuel, waste incineration, anaerobic digestion and Sanitary landfill have been compared. These scenarios are based on various criteria: 1. Required land, 2. The amount of delivered energy and the cost of each scenario, 3. Environmental effects, 4. The amount of recycling of materials, 5. The complexity and acceptability of each scenario are valued and scored, and then scenarios are prioritized according to the AHP method. The results show that the second scenario from different perspectives, including environmental impacts, costs associated with the implementation of the plan, and public acceptance of the best scenario for waste management in Karaj. This scenario includes separation from source, compost production, mechanical and biological processing, RDF, sanitary landfill.

The AHP method alone has been criticized for having unbalanced decision scales and inability to decide on uncertain and vague data in the binary comparison process. To overcome these shortcomings, the AHP fusion method was established. Hung et al. [28], with a combination of multi-criteria decision-making and consensus analysis models, have presented a new sustainable decision-making model to prioritize food waste recycling technologies in Taipei, Taiwan. Using Fuzzy Analytical Hierarchy Process, researchers have prioritized technologies such as burning, burial, composting, and converted into animal feed and anaerobic digestion. The result shows that the anaerobic digestion technology is preferred to other options, and burning technology is the worst option. The consensus analysis model, in addition to contributing to decision making, identifies the degree of stakeholder consensus on options, and helps resolve conflicts among stakeholders during decision-making stages.

Yeh and Xu [29] have developed a new approach to planning for the sustainable recovery of electronic waste, and developed a fuzzy multicriteria decision-making algorithm to assess the various options for electronic waste recycling. Also, different dimensions of sustainable development have been considered in the selection of evaluation criteria, and several optimum weighting models have been developed to determine the optimum weight of the dimensions of stability and the corresponding sub-criteria. Dehghani Kazemi et al. [22] in the study presented a combination model of multi-criteria decision making techniques and fuzzy logic to identify the optimal waste disposal method in Tehran. In this paper, firstly, by reviewing internal and external sources and interviewing experts, the criteria for decision making were identified. Since all the criteria are not equally important, the Analytical hierarchy process was conducted to determine the relative weight of the criteria. After determining the weight of the criteria, the final method of disposal of waste was identified by combining fuzzy logic and TOPSIS

Table 1. Researches Related

Disadvantages	Advantages	Goals	Reviewed Articles	Modeling method
Using LCA models in waste management systems tends to produce very divergent and even conflicting results. ♣ Real complex issues may not be included in the LCA waste management models ♣ There are assumptions in the LCA model, for example, assumptions about boundary conditions, data sources, criteria for assessing effects, and even weights, may be mental or even tastes, which is very influential on the results. ♣ Data aggregation and access to required information are the most difficult stages of the LCA	Quantify environmental quality parameters and facilitate management decisions ♣ An LCA model considers environmental improvement and economic benefits simultaneously ♣ All effects of the release of harmful substances on humans and ecosystems are estimated and evaluated. ♣ In order to identify the most appropriate scenario, alternative scenarios identify an existing waste management strategy and compare it with the existing scenario.	Evaluating Environmental Performance of Two Waste Incineration Technology in China with the LCA-EASEWASTE Model	Chen and Christensen (2010)	LCA
		Comparison of outputs of a LCA-IWM model and actual measured data for a waste incineration plant	Rimaityte et al. (2007)	
		Examining the application of LCA to assess the comprehensive management of waste in several Asian countries	Othman et al. (2013)	
		Getting an understanding of the environmental components of Organic Waste Management in the Northwest of Italy	Blengini (2008)	
		Review of various waste management strategies in Rome (Italy)	Cherubini et al. (2009)	
		Use of LCA in Kuwait municipal waste management	Al-salem and Lettiere (2009)	
		Comparison of Solid Waste Management Technologies	Zaman (2010)	
		Study of the role of waste management on greenhouse gas emissions	Sahib Mohammadi and Mahmoudkhani (2007)	
		Study of present status of waste management system in Mashhad	Rafiei et al (2009)	
		Determine greenhouse gas emissions and energy consumption	Ghanbarzadeh Lak and Sabour (2010)	
It is limited to a process that can not support the evaluation and selection of multiple technologies ♣ Simultaneously does not consider all three dimensions of sustainable development in modeling. ♣ The social dimension of sustainable development has not been considered in any research.	Focus on the modeling of WTE technologies ♣ Integrate waste management system and energy system in relation to waste transmission problem	Increasing economic profitability in energy consumption (Balmor) and Emphasizing Process for Residual Management to Focus on Fertilizer	Münster ,Meibom(2010)	LP
	Relatively simple, usable in complex scenarios	Location of waste collection stations in Port Said, Egypt	Badran and El-Haggar (2006)	MILP
		Upgrading the analysis accuracy in waste management system optimization problems by combining the regression vector model of support and linear	Dai et al. (2011)	

♣ Equivalent value of input factors if the value of waste management criteria is different.		programming of a complex integer with interval parameters		
		Integrating a MSWM Processing Network to Generate Energy and Value Added Products to Achieve Economic and Social Competitiveness	Sie et al.(2014)	
	Use cells to reduce the dimensions of optimization and increase flexibility	The evaluation of sustainable urban waste management strategies has been presented. The proposed model includes economic and environmental aspects.	Chang et al. (1997)	NLIP
		Simultaneous optimization of the location of the transfer station and the route of transportation of waste	shekar riz fard et al (2009)	
	Accepting new factors	The goal of this research is to minimize the cost of increasing capacity and waste stream costs from collecting areas to Regina Conda waste processing facilities.	Guo and Huang (2009)	Random Planning
MCDM does not consider the risk effects that might be posed in the options. ♣ In the field of waste management, the MCDM models only evaluate different options and do not provide any information on minimizing waste and preventing waste generation. ♣ By changing the criteria or the weight of the criteria used, the evaluation results can change. ♣ There may be an interdependence between the selected criteria, which makes it possible to achieve a double weighting criterion.	Various criteria can be considered in the decision-making model. ♣ Not only can quantitative criteria be used in the model, but qualitative criteria can also be used for evaluation. ♣ In most cases, MCDM models are flexible and can use criteria of different kinds.	Choose a location for a composting plant in Campania, southern Italy,	Feo and Gisi (2010)	MCDM (AHP)
		Combining Economic and Environmental Standards in Selecting Landfil Place	Wang et al. (2009)	
		Determination and Evaluation of Urban Waste Landfill locations in Ahvaz	Asadi (1391)	
		Investigation of Landfill Placement Methods of Urban Solid Waste	bohrani and Ebadi (1392)	
		Comparison of different waste management scenarios in Karaj city	Amiri et al. (2010)	
The expert should summarize all his experience in relation to the topic of research only in a number or verbal equivalent.	Extracting criteria to below criteria leads to greater freedom of action ♣ Use of fuzzy logic compensates existing ambiguities and facilitates judgments.	New sustainable decision making model to prioritize food waste recycling technologies in Taipei, Taiwan	Hung et al. (2007)	AHP - Fuzzy
		Provide a new approach to planning for the sustainable recycling of electronic waste	Yeh and Xu (2013)	
		A compilation model for identifying the optimal waste disposal method in Tehran	Kazemi et al. (1391)	

technique. The results show that the option of material recovery and burial of residues in land is an optimal method. Production of compost, RDF production, landfill, and burning without extraction of energy are the next priorities, respectively. According to the results of this study, as well as the benefits of recycling of materials, including access to raw materials, reduction of waste volume, less environmental impact, compensation of waste management costs with the sale of recycled materials, employment in the operator sector, sales and marketing of products, etc., it is suggested that urban managers focus and pay more attention to recycling. Table 2-3 summarizes multi-criteria decision making models in urban waste management.

Conclusion

This article examines some existing studies in the field of waste management, and researches in literature have been investigated according to the type of problem modeling. Examined articles are categorized in four areas of LCA models, optimization models, and MCDM models. Studies conducted in the LCA area can be categorized into several categories. In some studies, the researcher developed new models based on the LCA framework. Another category of studies in the literature of researchers is merely to evaluate and compare some of the different models in the LCA field of waste. Using LCA as a comparative environmental tool is another class of studies that is sometimes used to compare different waste processing technologies. In this research, just a review of these LCA models has been made. A review of optimization studies showed that comprehensive research in this field, both in terms of sustainability and in terms of technology, has not been carried out. Therefore, the research vacuum that is considered in the sustainable development environment while simultaneously considering all three dimensions of the economic, environmental, and social aspects of designing, modeling and optimizing waste recycling systems is felt. In addition to the comprehensive proposal vacuum, the lack of appropriate research for deciding on the optimal and sustainable use of solid urban waste in Iran is another significant point of this section. Studies in the framework of multi-criteria decision-making techniques have contributed to prioritizing and evaluating different waste processing technologies, as well as prioritizing and evaluating waste disposal sites for decision makers, as well as combining and combining AHP and fuzzy techniques and applying them together in the context of the AHP shortcomings and limitations, the fuzzy complement method is eliminated and usually results in more accuracy in judgments.

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