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RESEARCH PAPER

Evaluation and prioritization of municipal waste disposal methods; case study: Karaj municipality waste management organization

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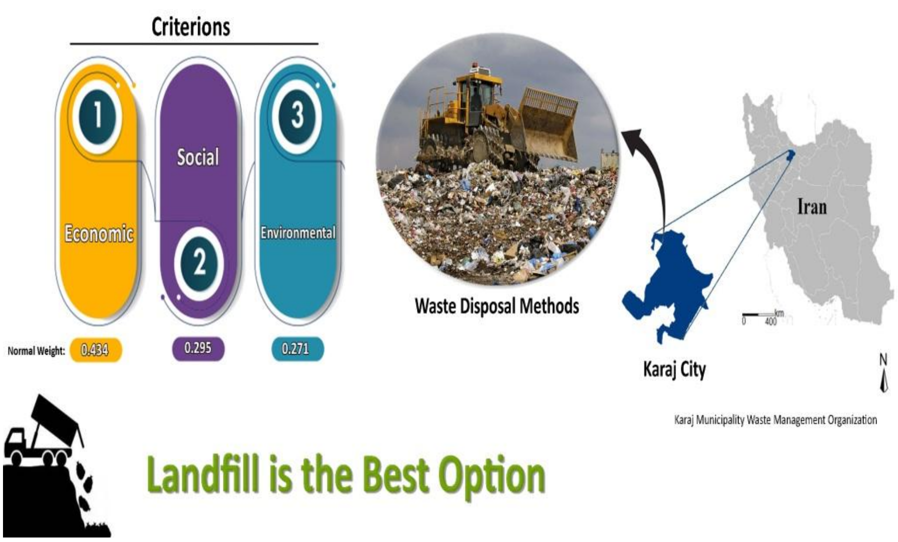
Highlights

- Constructing a sustainable evaluation index system from multiple dimensionsand Selection of the most appropriate waste disposal method to energy technologies is performed.
- Articulating evaluation criteria by mathematical models and Proposing a weighting model to improve efficiency and handle correlations among criteria respectively : Economic>Social> Environmental criterion based on AHP and ANP.
- TOPSIS technique with Entropy weighted method is applied and Introduced to rank Waste Disposal Methods : landfill was the best and RDF was the lowest score.
- Providing managerial insights for investors and the government to manage solid waste.

Graphical Abstract



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Abstract

Urban waste management has always been one of the problems of urban planners and its management in a principled and environmental manner is one of the most important issues in urban management. The purpose of the present study is to resolve the dilemmas related to municipal waste management in Karaj and to transform the threat of municipal waste into an opportunity to generate energy and convert waste into useful products. This study was designed and implemented in 5 steps. Firstly, the literature review and performance indicators were identified and then evaluated by a group of experts in the Delphi panel. Ranked from hierarchical literature and technique, the next step was to classify the waste disposal methods with the TOPSIS technique. Economic criterion with normal weight of 0.434 in priority, social criterion with normal weight of 0.295 in second priority and environmental criterion with normal weight of 0.271 is in third priority. Also, the inconsistency rate of the comparisons is 0.006. Finally, the best technology, landfill technology with 0.567 points, compost technology with 0.557 points, biogas with 0.519 points, waste incinerator with 0.337 points, gas fuel with 0.438 points and RDF with 0.428 points are ranked first to sixth, respectively. It can be concluded that the Landfill is the best option and economy is the most important criterion with the sub-criterion of construction cost

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1. Introduction

Municipal waste is one of the unavoidable productions of any city and waste management is one of the main needs of that city. Therefore, the establishment of a waste management system is a necessity that concerning the amount of waste generation and composition, there are various options for its management and in addition to economic costs, there are various environmental and social burdens (Ibáñez-Forés et al., 2018). Therefore, the collection and disposal of waste in an appropriate way that can directly and indirectly reduce the risks to human health and damage to the environment, is of great importance (Lu et al., 2012). Therefore, technical solutions for municipal solid waste management should take into account health, environmental and economic and social aspects (Magrinho et al., 2006; Yildiz et al., 2021).

In solid waste management, there are different disposal and destruction methods that we try to prioritize in terms of appropriate criteria. In this case, Okkacha showed that the problem of waste management in the city of Micheria was related to geographical and urban issues and that an efficient waste management system could not be achieved without considering them (Abderrahmane and Hassiba, 2014). Themelis and Mussche also said that China pays less for waste management than the US and Japan (Themelis and Mussche, 2013). In their research in New Delhi, they examined municipal waste management and recycling and landfill constraints. The results indicated that all capacities of landfills should not be utilized and that these sites need to be stopped from time to time (Agarwal et al., 2005).

Bala also presented a model of a solid waste management system in Dhaka, Bangladesh. He also stated that most of the waste generated from human activities is solid and unusable (Bala et al., 2017). Waste management is a set of regulations related to the control of production, storage, collection, transportation, processing and disposal of waste in accordance with the best principles of public health, economics, engineering science, environmental protection, aesthetics and other environmental considerations and also, the public attitude that they should be disposed of as soon as possible based on the principles of health, safety and environmental remediation otherwise they will have severe environmental consequences. In solid waste management, there are various disposal and disposal methods, including landfill technology, composting technology, biogas, waste incineration, gaseous fuel, and conversion to RDF. In this regard, the present study is rated identify waste disposal indicators based on economic, social and environmental criteria and is done based on smart criteria.

2. Materials and Methods

2.1. Study area

Waste management organization of Karaj municipality in 1997 in the name of waste recycling and conversion organization has started its activities in the field of applying scientific and specialized waste management which has so far utilized its scientific capacity and executed its personnel in the departments. With the approval of the ministry of interior in 2009, the organization was renamed from the waste recycling and conversion organization to waste management organization. The organization was established following article 84 of municipal law and clause 15 of article 71 of the organization, duties and elections of the islamic councils of iran, the election of the municipalities approved on may 3, 1996, and article 10 of the waste management law approved in 2004 and is related to the municipality of Karaj.

2.2. Methods

This study was conducted in five general phases as below:

2.2.1. Phase 1: Identification of indicators for the selection of waste disposal methods

By examining existing literature, library studies, reviewing existing waste management standards, waste management practices in organizations, existing documentation and in-depth interviews with relevant experts and experts, 41 indices and 6 general methods were extracted.

2.2.2. Phase 2: Establishing the expert panel to select the top indicators and their validation

Delphi method was used to obtain the correct selection of indices, which is the result of consultations with experts and three sessions with 15 experts in the field of waste and environment, and questionnaire number 1 was provided to them and they were weighted for three important indicators: being non-repetitive, understandable, and measurable. As a result, the number of indicators was reduced to 18, followed by validity and reliability editing, reaching the third stage, which eventually decreased to 15. Kendall's coefficient of the agreement was used to calculate the coordination of the experts' point of view (Table 1).

Table 1. Kendall's coefficient of agreement.

	Number of items	Number of Experts	Kendall's coefficient	Degree of freedom	Significance value
1st Round	41	15	0.249	19	0.0015
2nd Round	18	15	0.350	17	0.001
3rd Round	15	15	0.391	14	0.000

2.2.3. Phase 3: Ranking of Indicators Identified by the Smart Method

Once the indices are identified, they will be benchmarked in addition to the essential attributes by the SMART technique, meaning that the indices must be: specific, measurable, achievable, realistic, and time frame. So at this stage, the indicators were weighted two by two against the criteria of the smart method.

2.2.4. Phase 4: Criterion Ranking Using the AHP Technique

In this study, the main criteria and then the sub-criteria were compared two by two.

2.2.5. Phase 5: The main disposal methods were classified by the TOPSIS method

This phase consists of six steps that in the first step, the options were coded and ranked with the Likert spectrum. In the second step, the decision matrix was scaled down to Norm. If each dot denotes the scaled matrix with N and each dot withn_{ij}, each n_{ij} is calculated by dividing the corresponding dot in the original matrix by the sum of the squares of the corresponding column elements, as follows.

$$n_{ij} = \frac{a_{ij}}{\sqrt{\sum_1^m a_{ij}^2}} \quad (1)$$

Step three, provide an incomparably balanced matri that is, the non-scalar matrix (N) is converted to the scalar matrix (V) which must have the weights of the indices. The weights of each index were calculated using the hierarchical analysis technique (AHP) (Fig. 2). We multiply the scalar matrix into a square matrix (Wnxn) whose main diameter elements are index weights and other elements are zero.

$$V = N \times W_{nxn} \quad (2)$$

Step four, calculating the positive and negative ideals that for each index, a positive ideal (V+) and a negative ideal (V-) are calculated.

Step five, calculate the distance of each option from positive and negative ideals that the square of the difference of each cell is calculated with the ideal positive value. To do this, we use the following formula:

$$CL^*i = di- /(di- + di+) \quad (3)$$

The CL value is between zero and one. The closer this value is to the target, the closer it is to the ideal answer and the better the target.

3. Results and Discussion

Results of the AHP Method: In the first step, the main benchmarks were compared. The results were reported in Table 2 and Fig. 1.

Table 2. Paired comparison matrix of main criteria.

Criterion	Economical	Social	Environmental	Geometric mean	Eigenvector
Economical	1	1.356	1.732	1.329	0.434
Social	0.738	1	1.008	0.906	0.295
Environmental	0.577	0.992	1	0.831	0.271

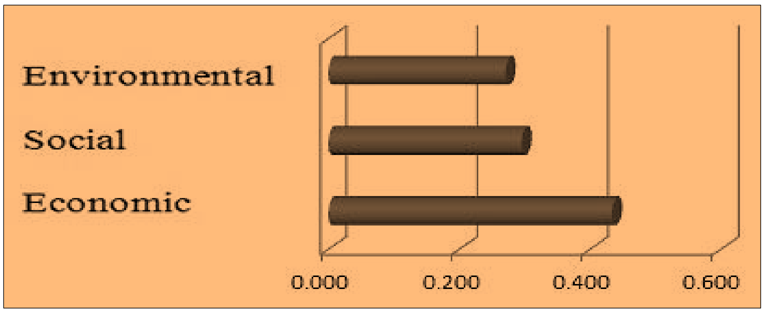

Fig. 1. Prioritization of the main criteria by research purpose.

In the second step of the AHP technique, the sub-criteria for each criterion were compared in pairs. The first priority of each criterion is as follows:

Economic Criterion, that is the sub-criterion of cost of construction and equipment with special vector 0.323. Social Criteria, that is the sub-Criterion of Landscape Beauty with Special Vector 0.392. Environmental criterion, that is the sub-criterion of water pollution with special vector 0.287.

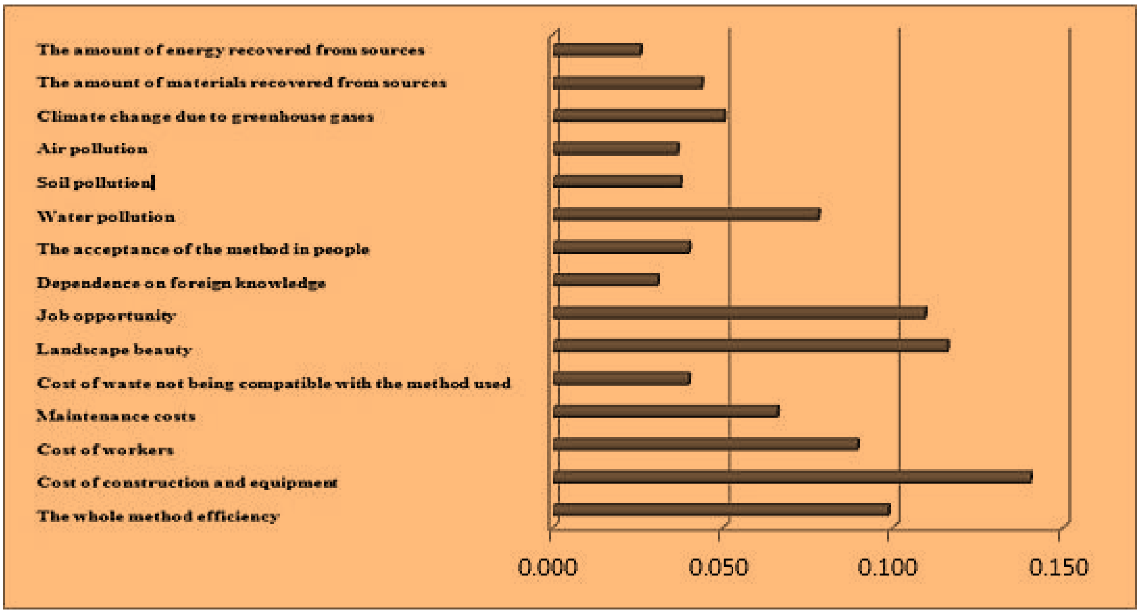

Fig. 2. Weighting Sub-Criteria.

According to the calculations performed for all the criteria, the following three criteria had the highest weight (Fig. 2).

The sub-criterion of construction cost with a final weight of 0.140 is a top priority. The sub-criterion of landscape beauty with a final weight of 0.116 is a top priority. The job opportunity sub-criterion with a final weight of 0.109 is the second priority.

3.1. Topsis technique ranking of waste disposal options

Select the option that has the most distance from the negative factors and the least distance from the positive factors. In the first step, the scoring matrix of waste disposal technologies was developed based on the sub-criteria, and then the second power matrix was computed and the decision matrix elements were calculated and then the non-scalable decision matrix was calculated. Next, the scalar matrix was weighted and presented. Next, a positive ideal (V+) and a negative ideal (V-) were defined for each indicator (Table 3).

Table 3. Ideally positive and negative reviews for each indicator.

V-	0.015	0.037	0.056	0.034	0.018	0.043	0.038	0.015	0.015	0.034	0.017	0.016	0.022	0.015	0.009
V+	0.060	0.037	0.015	0.013	0.014	0.049	0.051	0.010	0.019	0.029	0.013	0.013	0.019	0.020	0.011

Table 4. Sum of distance rows from positive and negative ideals.

Sum of distance rows from positive ideals	Sum of distance rows from negative ideals
0.001	0.002
0.002	0.003
0.004	0.002
0.002	0.001
0.002	0.001
0.002	0.004

Table 5. d + and d- calculations.

	+d	-d
A1	0.036	0.044
A2	0.047	0.051
A3	0.059	0.044
A4	0.047	0.037
A5	0.044	0.035
A6	0.046	0.060

Finally, waste disposal methods were prioritized through TOPSIS analysis so that the relative proximity of each option (waste disposal method) to the indicators' ideal, respectively indicates that the landfill method was ranked 0.567 (Table 6).

Table 6. Ranking of waste disposal methods by TOPSIS analysis.

Methods	Code	+d	-d	CL	Final Ranking
Composting technology	A1	0.036	0.044	0.550	2
Biogas	A2	0.047	0.051	0.519	3
Convert to RDF	A3	0.059	0.044	0.428	6
Production of gas fuel	A4	0.047	0.037	0.438	5
Waste incineration	A5	0.044	0.035	0.445	4
Landfill	A6	0.046	0.060	0.567	1

The purpose of this study was to identify and rank new solid waste disposal technologies using the multi-criteria decision making method in Karaj municipal waste management organization as a case study. In the other study, was showed that traditional approaches to municipal waste need to be replaced by new approaches in order to achieve the goals of municipal waste recycling (Alygizakis et al., 2020; Wang et al., 2019). Regarding the purpose, the present study is aimed at the field of applied research. On the other hand, since library research methods and field methods such as questionnaires have been used in this study, it can be stated that this research is a descriptive survey based on nature and methodology. Data collection methods were divided into two categories: library and field. Library methods were used to collect information on the subject literature and research background and the field method was used to collect information to answer the research questions. In this study, interview and questionnaire tools were used for data collection.

The study population consisted of experts of Karaj municipal waste management. Three types of questionnaires were used in this study and each questionnaire had different sections. In the first questionnaire for screening and identifying sub-criteria, the second questionnaire was used to prioritize criteria related to waste disposal. The opinions of 15 experts in the field were used for pairwise comparisons and then sub-criteria for each criterion were compared in pairs. In the third questionnaire, new technologies for waste disposal were evaluated based on sub-criteria. In this regard, used the screening method to promote the level of culture of waste separation (Khoshand et al., 2019)(Fig. 3).

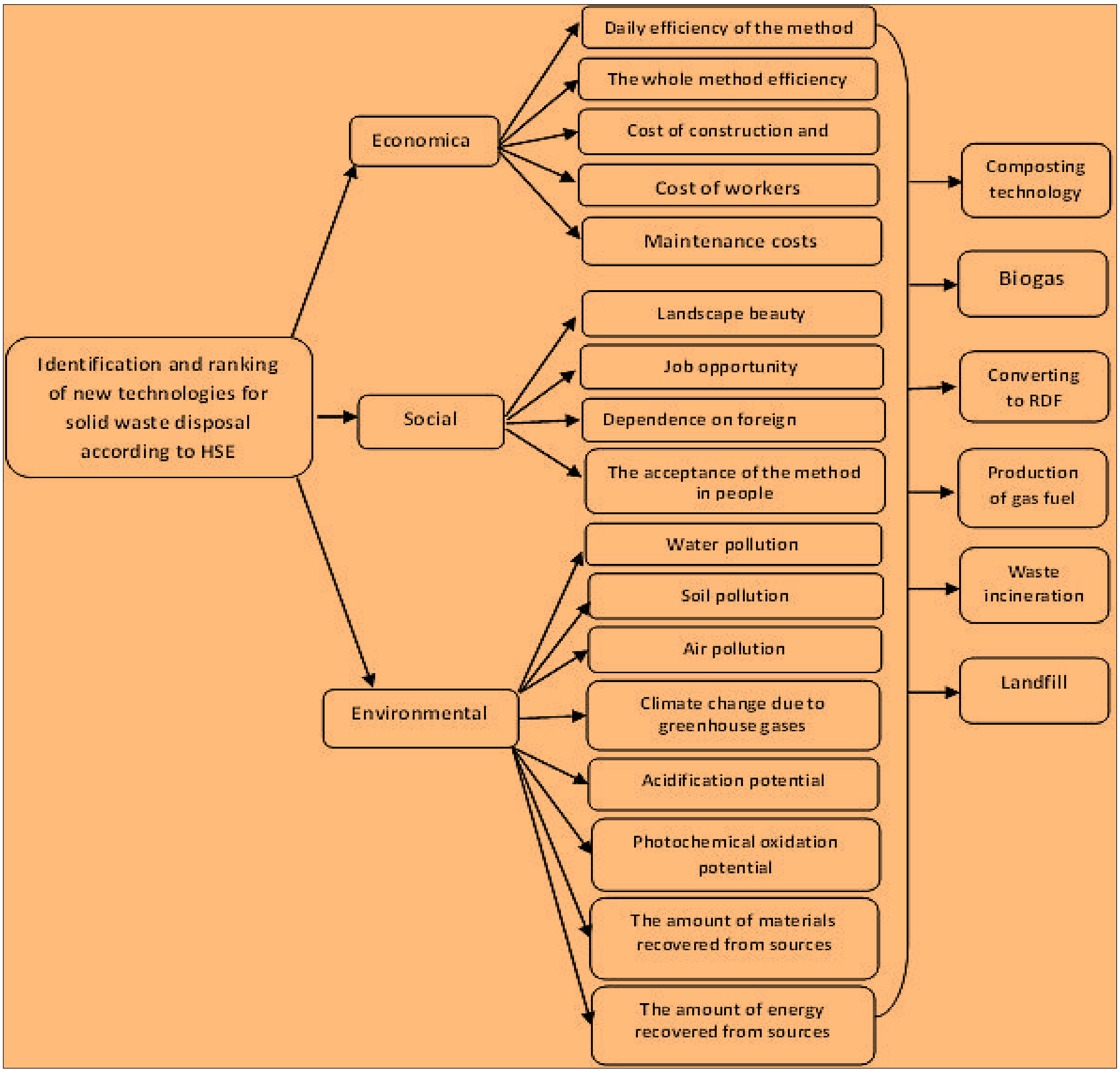

Fig. 3. Conceptual research method.

Also, in the other study, evaluated the waste disposal criteria in 2017 and developed a strategic management system (Pujadas et al., 2017). The priority obtained in this study is the economic criterion which means that no method of waste management will be chosen unless it has economic justification. In this regard, Nazari et al., (2014), in their research, addressed the economic factor as an important part of waste treatment in Qom (Nazari et al., 2014). In this regard, the most expensive part relates to construction and basic equipment costs. No matter how cheap it is, but with no good visual aesthetic, it does not have the social support and public participation it deserves. Therefore, the social criterion was considered as the second main criterion in this study. In the other study, Taelman et al., (2018) realized that the problem of waste management in the city of Mijria was related to social issues and that an efficient waste management system could not be achieved without considering them (Taelman et al., 2018). On the other hand, economic justification and social acceptance without environmental considerations is not a sustainable system, so the third criterion for research is the environmental criterion and because water is the most important factor in life, its sub-criterion is water pollution. In this regard, Taghvaii et al., (2012), in their research stated that the waste industry is like a double-edged sword and if we don't identify and manage challenges such as environmental pollution when they arise, can be devastating (Taghvaii et al., 2012). Therefore, evaluating the effectiveness of the correct waste disposal method is a hierarchical process that helps researchers achieve multi-criteria decision-making.

4. Conclusion

One of the most notable issues in maintaining and enhancing the health index of the individual and society is the proper, informed and consistent approach to new technologies efficient in waste and waste management which unfortunately are sometimes endangered due to inadequate management and the use of adverse community and environmental health practices. The role of safety, health and the environment cannot be ignored. Therefore, in this research, we sought to answer the question of what new technologies for solid waste disposal exist in the Karaj Waste Management Organization survey and how to rank them.

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