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Research Article

Evaluation of a Landfill Site Using AHP and TOPSIS Models: A Case Study of Ardakan Landfill, Iran

Saba Zakerian [1]; Mehdi Mokhtari [2,*]; Sayed Ali Alhosseini Almodaresi [3]

[1]Department of Environment, Yazd Branch, Islamic Azad University, Yazd, IR Iran
[2]Department of Environmental Health, Shahid Sadoughi University of Medical Sciences, Yazd, IR Iran
[3]GIS and RS Department, Civil Engineering College, Yazd Branch, Islamic Azad University, Yazd, IR Iran

*Corresponding author: Mehdi Mokhtari, Department of Environmental Health, Shahid Sadoughi University of Medical Sciences, Yazd, IR Iran. E-mail: mokhtari@ssu.ac.ir

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Evaluating municipal landfills is vital due to the importance of health and environmental issues and the possibility of contravening environmental and engineering criteria and principles. The present research was conducted to evaluate Ardakans' municipal landfills using the analytical hierarchy process (AHP) and the technique for order of Preference by similarity to ideal solution (TOPSIS) models. The data were collected through library studies and organizational references, observations, and interviews with experts and authorities, especially those at Ardakan Municipality. Then, the evaluation criteria and sub-criteria and their options for running the TOPSIS model were chosen, and the AHP model and expert analysis as well as maps created in the geographic information systems (GIS) environment were used to weight them. Finally, the weights were inserted in the TOPSIS 2010, and the final ranking of the options and closeness coefficient were presented. The findings showed that from the options available for municipal landfill evaluation in Ardakan, appropriate and almost appropriate had the highest ranks with coefficients of 0.75 and 0.67, respectively. The results showed that the Ardakan municipal landfill is almost appropriate from the TOPSIS perspective and appropriate to very appropriate according to the evaluation criteria available.

Keywords: Municipal Solid Waste; Landfill Site Selection; TOPSIS; AHP

1. Introduction

Due to the cities' unplanned and unsystematic development and lack of a correct consumption pattern and the increasing growth of waste production and also the problems and the failure of the waste management system, presently the most common way of waste disposal method is landfill. Landfill is a solid waste disposal method whereby waste is disposed with the least sanitary and environmental risks. Some of its properties are the daily use of soil covers, the establishment of an impermeable layer to prevent leachate leakage into groundwater supplies, and the use of sand layers to control methane (1).

Thus, to have the least sanitary and environmental risks, these specifications are required. Landfill standards are comprised of checking the position of the landfill site, preparing the landfill, and checking the groundwater level, soil type, leachate, and gas, and odor seal (2). Measures such as the landfill's location not being in accordance with the prevailing wind direction (3), having a minimum distance of 8 km from the airports, and also not placing the landfill in precipitation areas are important in a landfill siting. Accordingly, given the importance of sanitary and environmental issues and the possibility of infringing engineering and environmental principles and criteria for waste disposal in many site selections as well as generating risks and environmental pollution, endangering future generations, etc., site selection and landfill site evaluation is of vital importance (2).

Locating landfills is among spatial analyses with a huge effect on reducing costs and launching various activities. That is why it is one of the most important and effective phases of a project. The first step in the design of the landfill is finding the suitable location. In locating the burial site, factors such as topography and local geology, regional hydrology, climate, land surface required, suitable soil for coating layers of waste, and groundwater level must be considered (4).

Several studies on the use of models and software for the site selection of a landfill have been conducted, and the analytical hierarchy process (AHP) and the technique for order of preference by similarity to ideal solution (TOPSIS) are among the popular models. The AHP is an analytical tool that enables experts to explicitly rank tangible and intangible criteria against each other for the purpose of selecting priorities. The TOPSIS is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion, and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. Various models have been utilized by several studies into landfill site selection. Farhoudi et al. employed fuzzy logic and the data integration of different models as well as the drawings of Sanandaj and managed to identify three different areas (5). Amini drew upon the Boolean and fuzzy method for landfill site selection in Sari (6). In 2002, Shrivastava and Nathawat used the geographic information systems (GIS) and related substances (RS) to located landfills around Ransi (7). In a study by Viliam, a suitable place for a sanitary landfill was determined in Vermont considering six variables, namely soil type, depth of rock, land use, distance from surface water, groundwater levels, and height levels (8). There is no research regarding Ardakan landfill evaluation; we, therefore, sought to evaluate the Ardakan landfill using the AHP and TOPSIS models.

2. Materials and Methods

The Ardakan landfill site was selected for this study. The city is situated at a mean altitude of 1234 meters above sea level and is located on the flat land of Yazd-Ardakan. The landfill site of Ardakan is located at a distance of 12 km from the Ardakan-Hamaneh Road in an area of about 100 hectares. It has a capacity of 240,000 tons of solid.

In the present descriptive-analytic study, data were collected via the GIS. Software was used to establish maps of the study area. Thereafter, field visits were done, and the landfill in Ardakan was evaluated using landfill evaluation criteria and the TOPSIS. To run TOPSIS, it is necessary to insert evaluation criteria weight to finalize the priority of options (9). To determine the weight of each of the criteria, including vegetation, groundwater table, distance of the four regions, distance from groundwater, distance from surface water, production of leachate, soil and water resources contamination, land use, distance of settlements, distance from the main road, slope, soil, distance from the waste production, and place, the two paired comparison, the AHP model, and expert choice software were used. Then the criteria, evaluation options for landfills, and the weights were inserted into the TOPSIS, and all the evaluation options of the Ardakan landfill were ranked and prioritized.

2.1. Analytical Hierarchy Process

One of the greatest methods of the multi-criteria decision making (MCDM) is the AHP, which first calculates the relation between the weights of criteria and then calculates the total value of each option based on the weight obtained. To that end, a hierarchical tree is created: the decision-making hierarchy tree represents the decision strategy graphically. The middle levels of the criteria affecting the final decision are decision-making choices. The most important section in this phase is choosing the criteria and factors affecting the decision (10).

2.2. Expert Choice Software

The Expert Choice software is designed for analyzing multi-criteria decision issues using analytic hierarchy process techniques and can run on personal computers. The software has a large number of abilities and in addition to the option of designing decision hierarchical graphs (Hierarchy) can also design questions, determine preferences, and calculate the net weight and decision sensitivity analysis to changes in the parameters of the problem. More importantly, in many cases, it presents appropriate diagrams and graphs to represent the outcome. Another advantage of this software is that it offers a simple interface (11). The procedure for weight measurement with the Expert Choice software includes the following steps:

To define the model's target:

- Enter the criteria and add a number of nodes equal to the number of criteria.
- Enter the sub-criteria into the main criteria and run the model.
- Compare the pairs of criteria in the software. (In this stage, in addition to the factors, proper criteria are selected for comparison.)
- Form a weight matrix for the comparison of the pairs.
- Calculate the weight (normalize and determine the priorities): for zoning and obtaining the effectiveness level of each of these elements, normalizing and weighted average are used. In other words, different options are compared based on the results of each criterion and then they are normalized with the average weight. Thus, the priority of each option is obtained.

2.3. Technique for Order of Preference by Similarity to Ideal Solution

The TOPSIS was proposed by Hwang and Yoon (1981) (12). This model is one of the best multi-criteria decision-making models and is used for a variety of purposes. In this method also, option m is evaluated by n parameters. The technique is based on the notion that the choices must at the minimum distance from the positive ideal solution (the best possibility) and at the maximum distance from the negative ideal solution (the worst possibility). Problem-solving with this method involves the following six steps: quantifying and deleting the scales of the decision matrix (N); obtaining the scale-less weighted matrix (V); determining the positive ideal solution and negative ideal solution (the best values for positive indicators are the biggest and for the negative indicators are the lowest, and the worst for positive indicators are the smallest of the values and for the negative ones, the biggest.); obtaining the distance of each option to the positive and negative ideals; determining the relative closeness of an option to the ideal solution; and rating the options. The TOPSIS is used in this research because it obviates the need to calculate all the above steps and obtains the expected results by calculating the weight through models such as the AHP.

3. Results and Discussion

Selection and presentation of options and criteria for evaluation:

According to the purpose of this study, first, the main criteria and evaluation options for weighting and ranking were indicated. The criteria and evaluation options for the landfill in Ardakan are depicted in Tables 2 and 3. The evaluation of landfills requires collecting and compiling criteria. Because the evaluation is not yet in compliance with the values, standards can be used to locate.

Converting qualitative indicators into quantitative ones and creating the decision matrix:

In this study, some of the indicators are quantitative and some qualitative. Using different methods, qualitative indicators can be converted into quantitative indicators. However, in the study of distance, the bipolar scale is used (13).

Table 1. Current Condition of the Ardakan Landfill Site

Variables	Values
Used area, ha	55
Depth of buried waste, m	Average 12
Total amount of waste buried from the beginning, t	24,000
Landfill age, y	2
Tonnage of waste transported to the landfill	An average of 30 (daily)
Landfill soil material, m	Trenching length: 12 - 20 and width: 4 - 8 and depth: 3 - 6
Landfill cover soil type	Native soil
Composition of waste buried, %	Recyclable waste: 42 Garbage: 58
landfill distance form, km Ardakan	8 - 12
Waste separation	Manual
Possibility of fire and explosion	Yes-limited fire in the summer
Utilities and facilities available in the landfill	Electricity powerhouse, restrooms and bathrooms, and water reservoir with rest rooms and temporary accommodation

Table 2. Suggested Options for the Evaluation of the Landfill in Ardakan

Variables	Description
Option 1	Landfill is appropriate
Option 2	Landfill is almost appropriate
Option 3	Landfill is inappropriate

Table 3. List of the Evaluation Criteria Affecting the Landfill Option Prioritization in Ardakan

Main Index (Effective evaluation criteria in prioritizing landfill options in Ardakan)	Factors	The Main and Effective Measure
Row		
1	Environmental	Vegetation
1	Environmental	Groundwater table
1	Environmental	Distance from the four regions
1	Environmental	Distance from groundwater
1	Environmental	Distance from surface waters
1	Environmental	Leachate production and water and soil contamination
2	Economic-social	Land
2	Economic-social	Distance from settlements (urban and rural)
2	Economic-social	Distance from the main road
3	Technical and operational	Slope
3	Technical and operational	Soil
3	Technical and operational	Distance from the waste production zone

Table 4 demonstrates the measurement type for indicators with a positive aspect. As the criterion increases, the utility rate rises too. Measures like distance from the surface, distance from settlements (urban and rural), distance from the underground waters, distance from the four regions, and the soil and the groundwater table are among the positive indicators.

Table 5 shows the measurement type for indicators with negative aspects such as slope, distance from the main road, leachate production, and contamination of water, soil, vegetation, and land are negative indices.

Since our goal in this study was to evaluate a landfill and the options were qualitative, a general framework quality of measures in accordance with Table 6 was defined to implement the TOPSIS model and close the decision matrix. Then, a pattern of rating the selected criteria in the scale (1 - 9) was developed in accordance with Table 8.

3.1. Suggested Scoring Pattern and Approach

Rating criteria for negative values is the opposite of the positive. In this approach, scoring and decision-making is based on the importance of the criterion for the choice. Moreover, experts must be perfectly aware of the evaluation criteria and measures to evaluate landfills and regional characteristics. Initial evaluation was based on expert opinions and criteria comparison.

Table 4. Type of Measuring for Criteria with a Positive Aspect

Range	Criteria
0 – 2	Very Low
2 – 4	Low
4 – 6	Average
6 – 8	A lot
8 – 10	So much

Table 5. Type of Measurement for Indicators with Negative Aspects

Range	Criteria
0 - 2	So much
2 - 4	A lot
4 - 6	Average
6 - 8	Low
8 - 10	Very low

Table 6. Model of Turning Quantitative Measures to Qualitative in Evaluating the Ardakan Landfill

Point	Criteria											
	Vegetation	Water table [a]	Distance from the protected areas	Distance from groundwater [b]	Leachate production and contamination of water and soil	Distance from stream and watercourse	Slope	Soil type	Distance from the waste production zone	Land use	Distance from settlements [b]	Distance from the main road [b]
1	Does not have	< 15	1 - 1.5 [b]	2 >	Low and no contamination	< 1	2 - 1	Clay, shale and rock with low permeability clay-potential low infection	2 [b]	Desert with no canal	25 <	1 - 10 [b]
5	Average	30 - 15	1.5 - 4 [b]	2 - 4	Leachate production in the medium and low risk of contamination	4 - 2	15 - 10	Clay and sand, semi-permeable with a medium potential	10 - 52 [b]	Rain-fed agricultural land	10 - 25	70 - 30
9	Rich	59 - 45	High-more than 2 [b]	10 - 15 km	Enormous and pollution	More than 2 [b]	15 <	High permeability sand with high potential for contamination	More than 50 [b]	Several, such as farmland, forests.	1 - 8 [b]	< 1; < 70

[a] Values are presented as meters.
[b] Values are presented as kilometers.

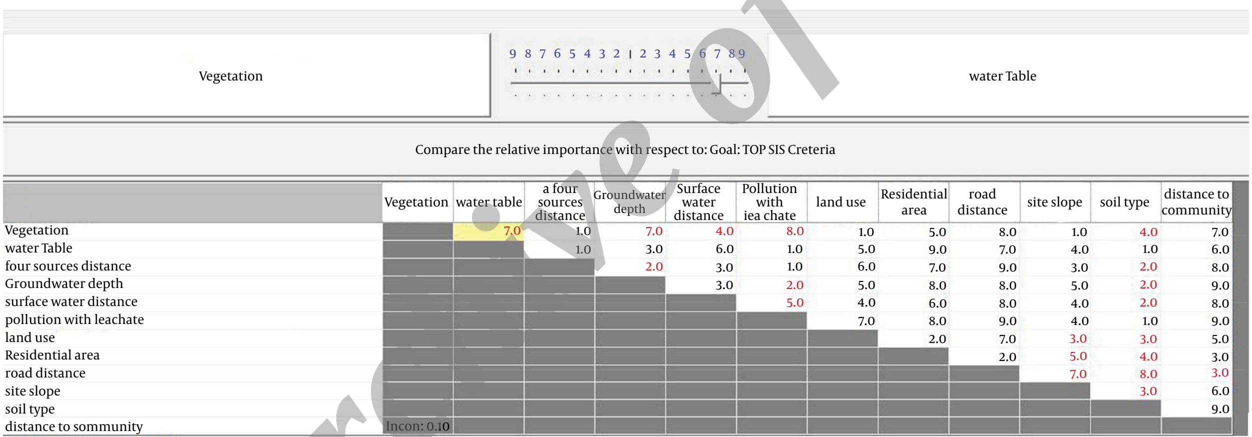
Table 7. Definition of the Scoring Pattern of the Options Based on the Purpose of the Research and Experts' Opinions

Points to the Importance of Each Option in Evaluation Options	1	3	5	7	9
Appropriate		3 - 5	7 - 5	7 - 9	10
Almost appropriate	1	2 - 1	3	5 - 4	9 - 7
Inappropriate	2 - 1	5 - 4	7 - 9		

Table 8. Decision Matrix for Ranking the Landfill Evaluation Options in Ardakan

Distance from main road	Vegetation	Water table [a]	Distance from the protected area	Distance from farms [b]	Leachate production and contamination of water and soil	Distance from stream and watercourse	Slope	Soil	Distance from the waste	Land	Accommodations distance [b]	Index switch
C 12	C 11	C 10	C 9	C 8	C 7	C 6	C 5	C 4	C 3	C 2	C 1	
3	2	9	9	8	4	3	1	5	3	1	5	Option 1
1	1	9	7	9	3	5	4	5	3	2	6	Option 2
5	3	5	4	5	3	4	8	4	4	7	3	Option 3

[a] Values are presented as meters.
[b] Values are presented as kilometers.



	Vegetation	water table	a four sources distance	Groundwater depth	Surface water distance	Pollution with iea chate	land use	Residential area	road distance	site slope	soil type	distance to community
Vegetation		7.0	1.0	7.0	4.0	8.0	1.0	5.0	8.0	1.0	4.0	7.0
water Table			1.0	3.0	6.0	1.0	5.0	9.0	7.0	4.0	1.0	6.0
four sources distance				2.0	3.0	1.0	6.0	7.0	9.0	3.0	2.0	8.0
Groundwater depth					3.0	2.0	5.0	8.0	8.0	5.0	2.0	9.0
surface water distance						5.0	4.0	6.0	8.0	4.0	2.0	8.0
pollution with leachate							7.0	8.0	9.0	4.0	1.0	9.0
land use								2.0	7.0	3.0	3.0	5.0
Residential area									2.0	5.0	4.0	3.0
road distance										7.0	8.0	3.0
site slope											3.0	6.0
soil type												9.0
distance to sommunity	Incon: 0.10											

Figure 1. Effective Criteria Matrix in Prioritizing the Evaluation Options of the Landfill in Ardakan

Finally, with regard to the criteria being negative and positive, a decision matrix was drawn according to Table 8 for ranking the landfill evaluation options. Weighting the criteria for the application of the AHP and Expert Choice:

After determining the criteria and sub-criteria and the formation of the hierarchical tree, weight was calculated using the pair comparison method. In the process of hierarchical analysis, the elements of each line were compared to the elements above them in a pair and the weight was calculated. This was called the relative weight. Afterward, by combining the relative weights, the final weight was specified, which was called absolute weight. All the comparisons in the hierarchical process were done in pairs (14). In these comparisons, decision-makers use oral judgments in a way that if element j is compared to i, the decision-maker says that the importance of i to j is one of the several cases (15). The results of the paired comparisons were inserted into the Expert Choice software and the results were given in the form of an effective measures matrix. Thus, it is evident that the criterion of groundwater tables with 0.183 of the total value of the weights is known as the most important sub-criterion.

For the selection of the option ranking, the software gave us the output with the scale of the matrix and the model phases and ranked the options. The results of the TOPSIS model indicated that the coefficient was 0.7532 for an almost appropriate landfill option and 0.671 for the appropriate landfill and that they ranked first and second.

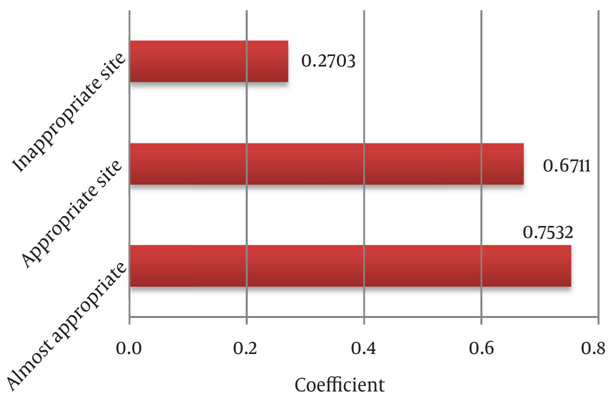


Figure 2. Final weight ranking of 3 Landfill site options in TOPSIS

The results of the criteria prioritization for the evaluation of the existing municipal waste landfills using the AHP and the Expert Choice software indicated that the maximum weight belonged to the groundwater table of 0.183, followed by leachate production and contamination of soil and water resources with 0.179. Additionally, the distance from groundwater, soil, slope, distance from protected areas, and vegetation criteria had weights of 0.139, 0.137, 0.115, 0.048, and 0.046, respectively.

Eskandary et al. (2011) also used the TOPSIS multi-attribute decision-making approach and the Expert Choice software to locate the hazardous waste landfills in central Iran (16). In the Onut and Soner study (17), the AHP was used for weighting measures (similar to the present study) and the TOPSIS for ranking the sites selected. The purpose of the present study was to evaluate the performance of a landfill. The TOPSIS was used in order to assess and rank the options from inappropriate to appropriate. The results of the evaluation conducted by a simple method compared to standard criteria determined that the results of the implementation of the TOPSIS model showed that the landfill of Ardakan had an almost appropriate to appropriate location.

4. Conclusions

In conclusion, our research findings are in line with other investigations utilizing the TOPSIS. The results showed that in site selection, the TOPSIS is a reliable model in comparison with other used models. The TOPSIS is dependent on the expert opinion; therefore, there is always the possibility of human error. It is recommended that for quality factor ranking of one landfill site, the TOPSIS model be used with caution.

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