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Landfill Site Selection Using Fuzzy Logic & AHP & WLC (Case study: Razan city - Iran)

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Abstract

The landfill has the potential impacts of environmental pollution if not properly selected, which can be irreparable because the environment and health components are human and other creatures. The ultimate goal Locating the most appropriate place to achieve the fewest adverse effects to the environment and natural resources and economically the most cost and engineering perspective to have the best features. This study aims to locate a place for a landfill in the city of Razan. The ARC GIS 9.3 software and the Analytical Hierarchy Process (AHP) are used. The data layers such as elevation, slope, aspect, soil, climate, and vegetation were determined and collected. Then by using the analytical hierarchy process (AHP), weight parameters were given. Then parameters were standard in the GIS environment. The layers obtained the value by multiplying the analytic hierarchy process and data layers together with (WLC) method, and this is the final layer that can be extracted. The final plan was presented to construct a landfill.

Keywords: *Landfill - Locating – AHP – GIS –Fuzzy logic, Razan city*

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I. INTRODUCTION

Population development and urbanization have resulted in large volumes of municipal solid waste generation, creating a challenge for the urban environment [1]. While there is a movement toward minimizing solid waste at the source through reuse and recycling, landfills remain the final disposal alternative [2]. Municipal solid waste (MSW) is a significant problem for city planners and officials. A significant factor that complicates the decision-making process is the global, political, and environmental crisis [3]. The literature on MSW landfill site selection methodologies [4, 5, 6, 7, 8, 9, 10, 11,12] is conceptually rich.

The landfill method consists of loading, spreading, and covering waste material with soil in a sanitary way. Furthermore, the landfill should mitigate negative environmental impacts and costs associated with its site. As a result, any potential landfill site should be evaluated for protection, sanitary aspects, natural environment, and socioeconomic factors, with the best site chosen from a range of options [13]. As a consequence, since there are too many requirements to address when considering a landfill site, the use of GIS is advantageous due to the potential to accommodate a vast amount of unique data management. GIS allows for the storage, study, and presentation of data in compliance with the applicant's requirements [14]. Many landfill site selection experiments have been done in a GIS setting [2,5,15,4], with the AHP approach being used in some of them [14,10,1,16]. Similarly, separate requirements were used in some studies in Iran for choosing urban solid waste landfill sites [17,18]. For landfill site selection in Sari city, Khorasani et al. (2004) used Boolean logic and fuzzy methods [19].

In the Polog Area of Macedonia, Donevska et al. (2011) used two fuzzy logic approaches, AHP and GIS, to pick a site for a toxic landfill. The parameters were unified using various fuzzy membership features, and the relative value of the criteria was determined using AHP. When environmental and economic targets were regarded similarly, their analyses found that the least desirable area for a landfill occupied 1.0 percent of the overall area. When economic targets were given a higher priority, the most suitable landfill site was 1.8 percent [20, 21,22,23].

According to the literature, countries all over the world have effectively incorporated GIS in their municipal waste

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management planning systems. Furthermore, the use of advanced GIS techniques is a first in the landfill siting process, taking some work to interpret the effects, highlighting the significance of GIS and spatial statistics tools.

The key difference between previous research and this one is that there has never been a systematic analysis in Razan that involved the implementation and assessment of different spatial models using GIS. As a result, Boolean, AHP, and WLC models in Razan with strong decision-making capacity for locating landfill sites have generated a substantial market for landfill siting.

A GIS multiple criteria assessment (MCE) for a new landfill site in Razan city is defined in this article. MCE's spatial judgment for the current sanitary landfill issue was overcome by AHP. The relative weights of the decision criteria were calculated using the pair-wise comparison formula, which was then combined with the GIS Boolean and FUZZY logic model to generate suitable landfill siting sites in the study area.

II. MATERIALS AND METHODS

A. Study area

Razan city (fig 1) is the Razan town center in the Hamedan province with geographic coordinates 35.3750 ° latitude and 49.0425 longitudes of east northeast of Hamadan Province the mainstream Hamedan-Qazvin located. The city's population is 13,711 people, according to the 2011 census results that by taking 800 mg per day of waste produced for each person according to what is equivalent to 11 tons of waste per capita country in the day produced. Due to inadequate separation of wet and dry waste at source and not the other way and the amount of waste recycled, Directed straight to landfill.

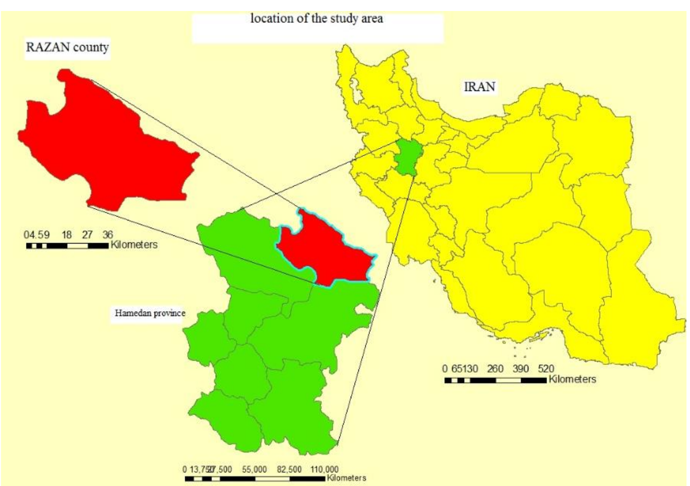


Fig. 1. The location map of the study area

B. Methods

This research was performed based on the below diagram (fig 2).

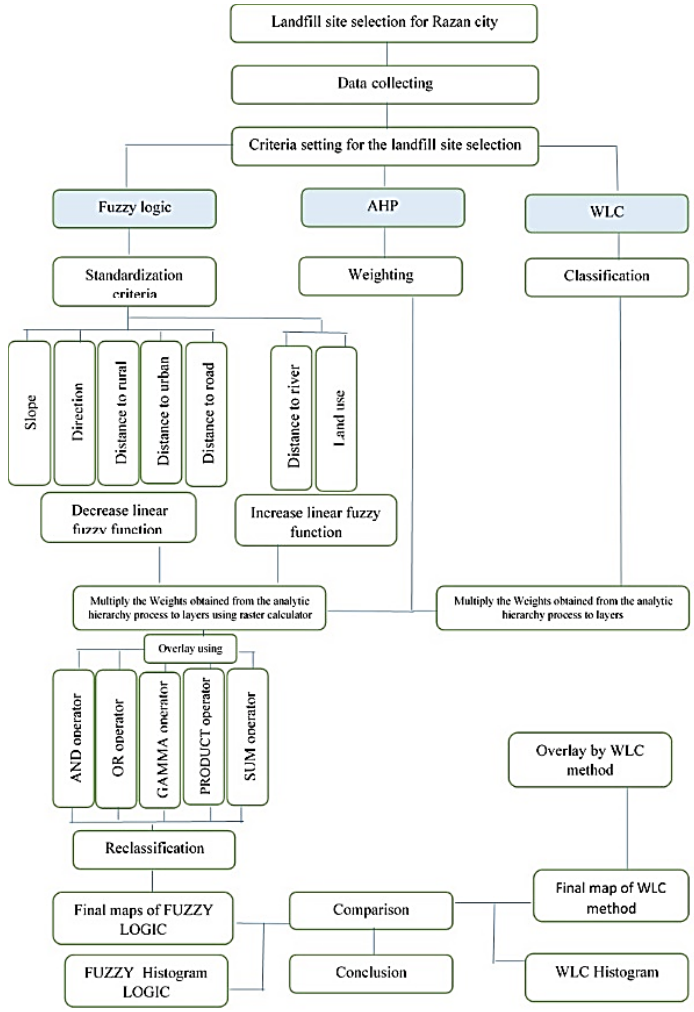


Fig. 2. Stages of implementation of Landfill site selection in study area

C. AHP

Saaty presented the analytic hierarchy process (AHP). It is based on three guiding principles: refraction, comparative judgement, and priority synthesis. To structure decision-making problems into hierarchical forms, the theory of refraction is necessary. By considering their roots in higher levels, each element in the resulting hierarchical systems is put in extraordinary levels. The synthesis theory created a compound collection of priorities for items at the lower levels of a hierarchy by representing each site's priorities using a determined proportion scale for the various levels of a hierarchy (i.e., options).

The defining principle consists of the following stages [24,25,26,27]:

1. Create a binary matrix with comparisons:

(a) To assess the magnitude of the relative priorities of two parameters, this approach generates a simple scale of values varying from 1 to 9. (Table 1).

TABLE I. AHP PAIR-WISE COMPARISON SCALE FOR NINE IMPORTANCE

Extent of importance	Definition
1	Equal importance
2	Equal to average importance
3	Average importance
4	Average to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very strong or super-strong importance
9	Super strong importance

2. Calculating criteria weight: the following measures are included in this stage: (a) In the comparative binary matrix, the sum of the values for each column. Divide the sum of each matrix column by the component's component's component's component's component's component's component' A "Normalized comparative binary matrix" is the resulting matrix.

(b) In the normalized binary comparative matrix, find the mean of the elements in each row.

3. Measuring the compromise ratio

4. The following phases are included in this stage:

(a) Multiply the weight of the first scale in the first column of the main binary comparative matrix, then multiply the second scale in the second column, the third scale in the third column, and finally find the sum of these weights to get the complete weighted vector.

(b) Evaluate the agreement vector by dividing the weight vector by the previously defined scale weights.

D. *Weighted linear combination method (WLC)*

The most popular technique for evaluating multi-scale evaluations is the weighted linear combination approach (WLC). This form is also regarded as a "scoring method." This approach is based on the weighted average's content. The analyzer or decision-maker is focused on the weighted "relative value" scales. For each choice, a final measure can be obtained by multiplying the relative weight by the function value (such as picture element in spatial analysis). Alternatives with higher values would be the better choice for the desired reason after determining each option's final value [28,29,30,31].A desirable objective is calculating the proportion for a particular activity or estimating the likelihood of a specific event. In this method, decision-making concepts used Eq. (1) to measure the worth of each Ai option:

$$Ai = \sum_{j=1}^{n} \mathrm{Wj} \times \mathrm{Xij}$$

Wj is the j criterion weight in this equation, and Xij is a value that is agreed I put in relation to the j criterion. In other words, this value will reflect the degree to which the I position satisfies the j criterion; n is the total number of parameters, and Ai is a value that will be correlated with the I location. The total weight should be 1 in this method; otherwise, Ai should be divided by the number of all weights in the previous level. As a consequence, the Ai output will range from 0 to 1. Weight normalization may be skipped, resulting in higher or lower levels of output due to an acceptable or incorrect choice. In the end, the option with the most Ai [31] would be the better option.

E. *Fuzzy Logic*

All variables are combined in one step in this process, which can employ a purposeful pattern of map integration. The principle of fuzzy logic takes into account spatial artifacts on a diagram, such as the members of a set. Membership will take any value between 0 and 1 that represents a degree of membership in fuzzy set theory, and there is no realistic limit to the number of fuzzy membership values. The Fuzzy Logic approach provides more compact weighted map compositions and is easy to apply with a GIS modeling language. To display the set's membership degree, values are chosen based on discretionary judgement (figure 2). There are two ways to define fuzzy membership functions: type and shape.

S-shaped (Sigmoidal), J-shaped, and other forms are available (J-shaped), Monotonically increasing, monotonically decreasing, and symmetric are examples of linear and forms. Taking into account the user-defined criteria, a total of ten membership roles can be described. Four points or Inflection Points are used to detect various types of membership features. Two types of functions were used in this study: increasing linear and user defined. The minimum and maximum values are used as scaling points in the linear function standardization process (Figures 3 and 4). The following is a schematic of the linear scaling method: Rmin

$$X_i = \frac{(R_i - R_{min})}{(R_{max} - R_{min})} * \mathrm{standardized\_range}$$

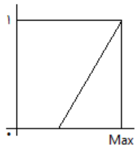
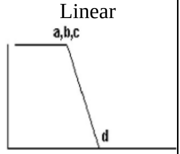
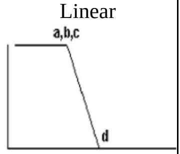
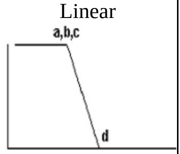
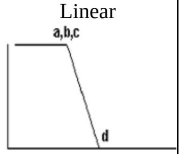
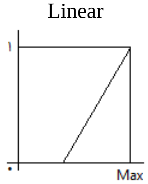
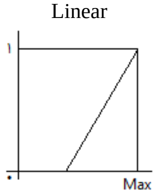
Xi represents the cell value after standardization, while Ri represents the cell value before standardization. R min is the factor's minimum value; Rmax is the factor's maximum value. The set of standardization differences is referred to as the standardized range.

In general, there are two types of standardization variations: 0-1 (actual numerical scale) and 0-255. (byte scale). A higher score means that the cells are more suited for making a decision. User control points are described by the user in the user Defined process, and then very different shapes of this type of feature are generated. The fuzzy logic model will construct factor maps, combine them, and standardize the values in their groups. OR, AND, Number, PRODUCT, and GAMMA are five fuzzy operators used to combine a series of GIS data seen in Table II.

F. *Evaluated criteria*

The environmental and legal requirements in a given area are taken into consideration when selecting a landfill site. In this respect, the parameters and values that should be taken into account in this analysis are split into two categories: physical and socioeconomic criteria. These requirements were chosen in compliance with Iran's environment organization's and municipality's standards and regulations.

TABLE II. TYPES OF FUZZY OPERATORS

Criteria	Control point		Shape	Type	Layer weight	Criteria score
Direction	A	B	Linear 	Increase	0.060	7
	0	360				
	Plain without aspect is the best and east, north, west and finally south.					
Slope	89.4 degree	0	Linear 	Decrease	0.080	6
Distance to road	31850	0	Linear 	Decrease	0.106	5
Distance to rural	9500	0	Linear 	Decrease	0.177	3
Distance to urban	37500	0	Linear 	Decrease	0.215	2
Land use	1	5	Linear 	Increase	0.244	1
Distance to river	0	7500	Linear 	Increase	0.120	4

Environmental criteria

Slope: When it comes to landfill building, ground morphology is key. Slope gradation, which is assessed in percent or degrees, is used to determine land morphology [5]. Steep slopes are unsuitable for landfill development because the expense of excavation increases as the slope rises [16]. The sufficient slope of the ground surface is important in stopping leachate from flowing [17]. Based on pixel scale in percentage, the slope layer map was generated from the research region DEM map. Lands with a slope of more than 30% and a value of 0 is found unsuitable.

Direction:

Radius from the river: Hazardous waste dumping sites must be kept separate from bodies of water (streams, rivers). A 500-meter buffer zone should be preserved around major water sources, according to EU directives [5]. The bulk of the surface water in the study region is in the form of streams that emerged during the winter season's heavy rains.

Socio economic criteria

The dump site should be far away from the city's residential areas. Otherwise, it degrades the beauty, emits foul odors, and decreases the property value of the local city (Chang et al., 2008). The landfill site should not be impacted by the city's growth plans because there is ample landfill space for the city's long-term needs [32].

Road network: Building roads for landfill access, especially over long distances, necessitates considerable upfront costs. As a result, the chosen position should be near highways and major thoroughfares [32].

Land use: This criteria is not prescriptive and can vary depending on the research region [5]. It is preferable to choose bare land that can be used or leased after the landfill site is finished [32]. Residential fields, semi-compact and low compact pastures, agricultural lands and orchards, bare plains, and rocks are among the established uses in the study area.

Residential areas (comprising the distance between the urban and rural areas): The landfill should be situated further from the city's most heavily inhabited neighborhoods. Otherwise, it impacts the local area's aesthetics, odors, and land valuation [15]. The landfill site should not be impacted by the city's growth plans because there is ample landfill space for the city's long-term needs [32]. Be guided by the city's growth plans [32].

III. RESULT & DISCUSSION

We followed the below model in this research (fig 2). First, we specified and studied site selection and landfill, and then, the necessary criteria for this research exported and evaluated. Then we collected the data that we need to import to the GIS environment for valuation, classification, standardization, and overlay. We used the AHP technique to criteria valuation and fuzzification function memberships to deferent layer standardization in a GIS environment. To overlaying standardized layer used of deferent fuzzy operators. We use different GAMMA levels for logical use of these operators, AND, PRODUCT, SUM, OR operators. Restriction map created with union deferent restrict element layers and finally overlay the final capability map exported from three levels of operators and restriction map for specifying the areas with landfill capable.

The pair-wise contrast matrix of physical and socio-economic parameters is seen in Table 3. After accounting for sub-criteria (factors) in each of the two physical and socioeconomic categories, the final weight is determined by multiplying the obtained sub-criteria weight by the weight of the relevant criteria.

TABLE III. FINAL WEIGHTS ASSIGNED TO CRITERIA IN THE EVALUATION PHASE

criterion	Relative importance weight
Land use	0.244
Distance to urban	0.215
Distance to rural	0.177
Distance to river	0.120
Distance to road	0.106
Slope	0.080
Direction	0.060
Sum	1

Also, Table III shows the criteria used – classification and coefficients of each of them. In this table, we classify criteria into five classes, then give the coefficient for each criterion. Class 1 shows unsuitable class, class 2, relative unsuitable, class 3, moderately capability, class 4, suitable, and class 5 refer to a very appropriate area for landfill site selection.

TABLE IV. THE CRITERIA USED – CLASSIFICATION AND COEFFICIENTS OF EACH OF THEM

Criteria	Class 1 (Unsuitable)	Class 2 (Relative unsuitable)	Class 3 (Moderately capability)	Class 4 (Suitable)	Class 5 (Very suitable)	Coefficient
Land use	Urban & Rocks	Orchards	Agriculture & mixed lands	Pastures	Bare lands	24
Distance to urban	0-2000	7000≥ X	5000-7000	3000-5000	2000-3000	22
Distance to rural	0-2000	7000≥ X	5000-7000	3000-5000	2000-3000	18
Distance to river	0-100	100-500	1000-5000	500-1000	5000≥ X	12
Distance to road	0-200	5000≥ X	1000-5000	500-1000	200-500	10
Slope	30%-100%	15%-30%	10%-15%	5%-10%	0%-5%	8
Direction	South	West	North	East	P	6

In this study's case of fuzzy logic, we measure the slope, aspect, distance from town, away from the rural area, and distance to the road, using decrease linearly and measures the distance to the river and land use using increasing linear (fig. 3).

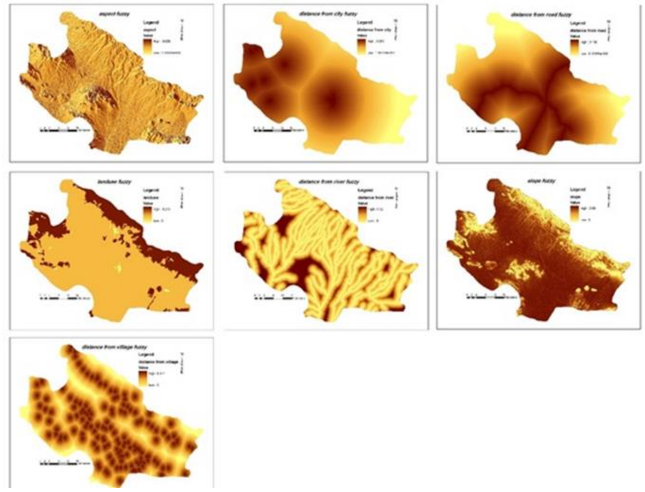


Fig. 3. Fuzzy maps of used layers

This stage's output was multiplied by the weight obtained from AHP and Overlay by GAMMA, OR, and PRODUCT and SUM operators (fig. 4).

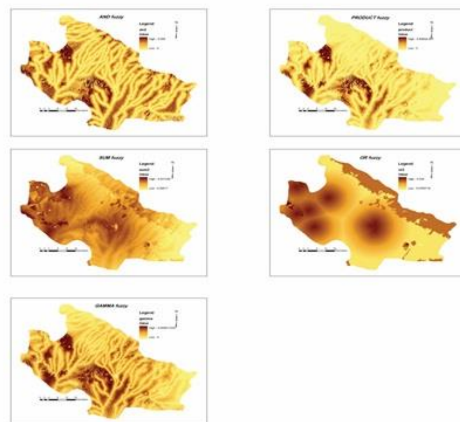


Fig. 4. Fuzzy operators

The results were classified and final maps of fuzzy logic generated (Fig. 5).

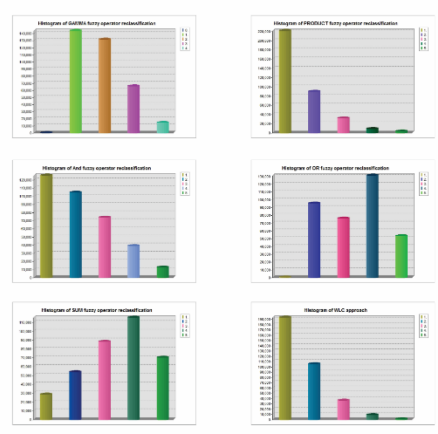


Fig. 5. histogram of output map, exported from fuzzy logic operators and WLC on GIS software

The WLC method maps were also classified and were multiplied by the weights obtains AHP, then classified. Results and coefficients from table 2 performed the Overly by WLC method.

IV. Conclusion

The current research explains how GIS, fuzzy logic, and multi-criteria assessment methods can be used to assess the suitability and collection of solid waste landfill sites. Seven criteria were used to assess the suitability of the site. The obtained results from expert opinions indicate that among physical sub-criteria, direction, distance to river, and slope are important in order, whereas among socio-economic sub-criteria, residential areas (consisting of distance to urban area and distance to rural area), land use, and access roads are important in order. Since the length of certain appropriate regions exceeds the necessary landfill site, it is possible to set up bio compost and recycling equipment alongside it to help handle solid waste while lowering transition costs.

In site selection challenges, it is beneficial to use GIS and multi-criteria decision analysis. GIS has a lot of variety when it comes to requirements, so it's possible to extend this approach by incorporating more useful criteria. Furthermore, the ability to use GIS in a fuzzy system, as well as the extensive value ranges of each choice (0 to 255) and the availability of cell details, allows the study area's characteristics to be examined precisely at small cell sizes. Fuzzy logic is more fluid than Boolean logic because it accepts various degrees of membership (0 and 1). Multi-criteria decision analysis also offers the requisite requirements for weighing multiple criteria within the site selection assessment issue, aiding decision-makers in making the right choice. As an effective method, GIS combined with decision analysis as a supporting decision framework can assist decision-makers in each site selection problem. The AHP approach simplifies decision-making by breaking down difficult problems into simpler ones. Pair-wise comparison for weight recognition is used to compare decision components, which decreases the difficulty of the decision problem. It's also worth mentioning that the final findings for specific fields which vary due to the varying parameters prioritization given by different experts. In addition to the other costs and political concerns, a field investigation of the existing landfill sites should be proposed before reaching a definitive decision. Managers will benefit from the proposed approach when it comes to disposal and solid waste management.

The results of fuzzy operators and WLC maps and their histograms were compared with another and field observation. The most logical way for landfill site selection in Razan city was to introduce the WLC map and the final fuzzy map by PRODUCT & GAMMA operators.

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