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LANDFILL SITE SELECTION BY USING PAIRWISE COMPARISON, RATING, RANKING AND TRADE-OFF METHODS FOR CRITERIA WEIGHTING

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ABSTRACT

Any multi criteria decision analysis process need to weigh the criteria and to know any weighting method the best to use according the nature and degree of complexity of the problem. There are four method for criteria weighting Rank, Rating, Pairwise and Trade-off methods. In this study, which was done in Najaf – Iraq used this methods to weigh the seventeen criteria used to select landfill site within integration of (GIS -MCDA) in Najaf governorate. There is no difference between the results within Pairwise or Ranking method only in size of landfill in west part of study area (five sites were selected in each try). Within trade-off and rating methods, there are more than five site were selected.

Keys words: Rating, Ranking, Pairwise Comparison, Trade-Off Method

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1. INTRODUCTION AND RESEARCH OBJECTIVE

Historically countries disposed waste on land and covering it up. In many cases uncontrolled burning of waste would precede or follow dumping activity. Landfills are the final depository of a waste after all other waste management options have been carried out. Landfills can be categorized according to open dumps, controlled dumps or sanitary landfills (or secured landfill or engineered landfill).

Sanitary landfill facilities are generally located in areas where the potential for degradation of the quality of air, land, and water is minimal. Similarly, a sanitary landfill should be located away from an airport to avoid air accidents between birds and aeroplanes. The location should preferably be outside 100-year floodplain and should not be located in the close proximity of wild life sanctuaries, monuments and other important places which is ecologically important. Location of sanitary land fill should also consider seismic sensitivity of the area to avoid environmental damage during earthquake [1].

All potential locations need to be considered in the light of site-specific characteristics, which may result in some parameters being given a greater weighting than others. There are four methods for criteria weight which Rating, Ranking, Pairwise comparison and Trade-off methods[2].

The objective of this study is to compare the selected sites within Al-Najaf governorate by using the approach based in integration of Geographic Information Systems (GIS) and Multicriteria Decision Analysis (MCDA)with each one of criteria weight method.

For this purpose, 17 input digital map layers Urban centers, Cemetery, Airports, Electrical power lines, Oil Pipes, Railways, Roads, slope, Historical sites, Main rivers, Industrial areas, Religion sites, Wells, Military area, Electrical power plants, Nature reserves and National borders were prepared and multi criteria analysis was implemented with geographic information system.

2. MATERIALS AND METHODS

2.1. Study area

Najaf is located between Anbar and Muthanna governorates on Iraq's southern border with Saudi Arabia. Its landscape is dominated by desert, particularly towards the border with Saudi Arabia. Najaf city hosts the shrine of Ali Ibn Abi Talib, who is regarded by Shi'a Muslims the first Imam and by Sunni Muslims the fourth Caliph. The city is therefore one of the most holy sites in Shi'a Islam, attracting high numbers of religious tourists from within Iraq and abroad, and a centre for religious scholarship. Other religious sites in the governorate include Wadi A-Salaam (Valley of Peace), and Kufa Mosque[3].

Najaf governorate lies between coordinates of latitudes (32° 21′ N and 29° 50 ′ N), coordinates of longitudes(44°44 ′E and 42°50 ′ E) with total area 28,824 sq km (6.6% of Iraq) as shown in figure (1).

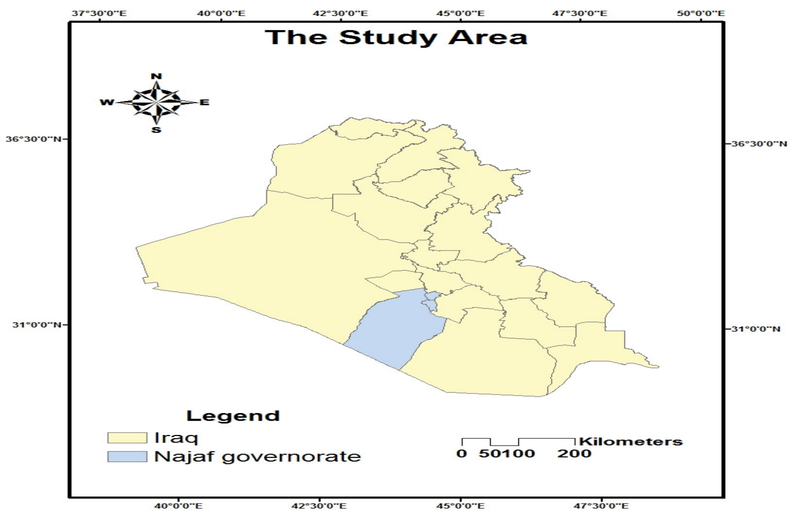

Figure (1) Map of study area

2.2. Methodology

This study include four tries for landfill site selection depend on using of geographic information system (GIS) for data input, data storage and management, data manipulation and analysis and data output as suitability map in last step of this aim. Multi Criteria decision analysis methods was used for weighting the criteria and using (SAW) integrated with GIS to find suitability index. In each try used different method (Rating, Ranking, Pairwise comparison and Trade-off methods) for criteria weight.

Seventeen criteria (Urban centers, Cemetery, Airports, Electrical power lines, Oil Pipes, Railways, Roads, slope, Historical sites, Main rivers, Industrial areas, Religion sites, Wells, Military area, Electrical power plants, Nature reserves and National borders) were used to identify the best landfill site for Al-Najaf in the GIS and MCDA. The geographical information systems is commonly organized the data by separate thematic maps or sets of data, referred to as a map layer. suitability maps generated by used spatial analysis as highlighting “suitable” geographic areas execrated from weighted and combined map layers based on previous established criteria for study area. (MCDA) was used to measure the relative importance weight for individual evaluation criteria. MCDA is to divide the decision problems into smaller understandable parts, analyze each part separately, and then integrate the parts in a logical manner[4]. Figure (2) show methodology framework.

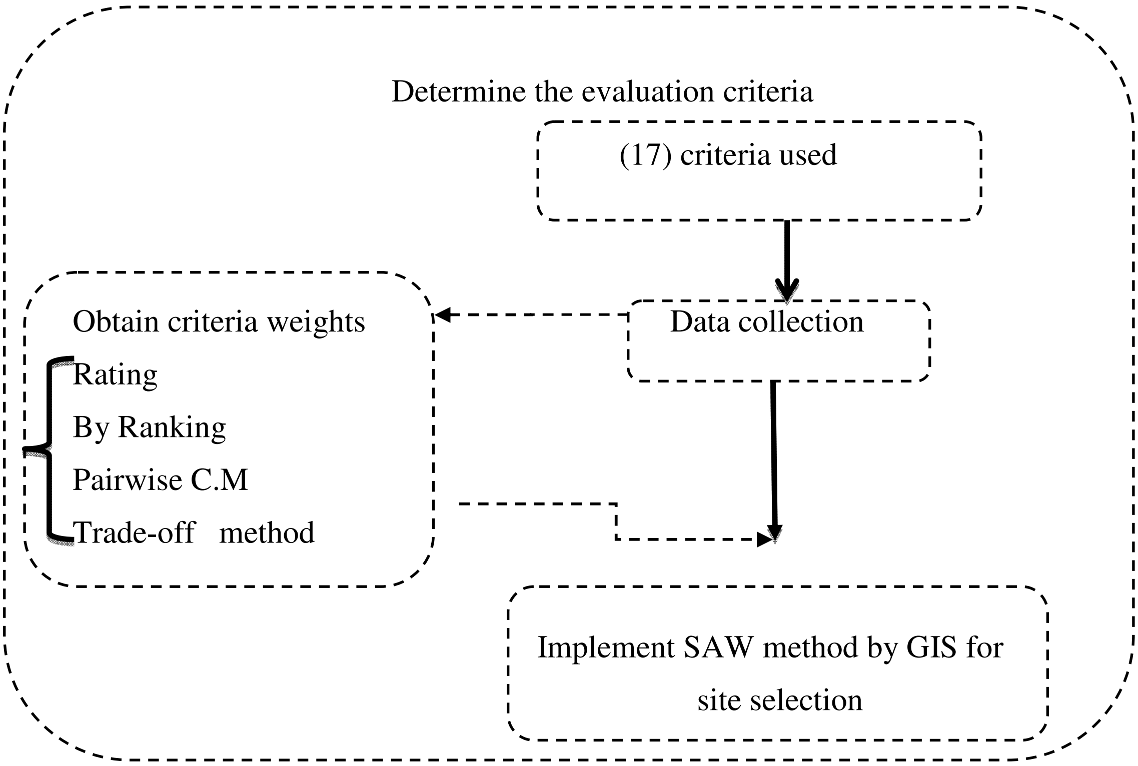

Figure (2) show methodology framework for landfill site selection

2.3. Criteria Analysis

For study area, the criteria decision tree developed for the landfill site selection problem is illustrated in Figure(3).

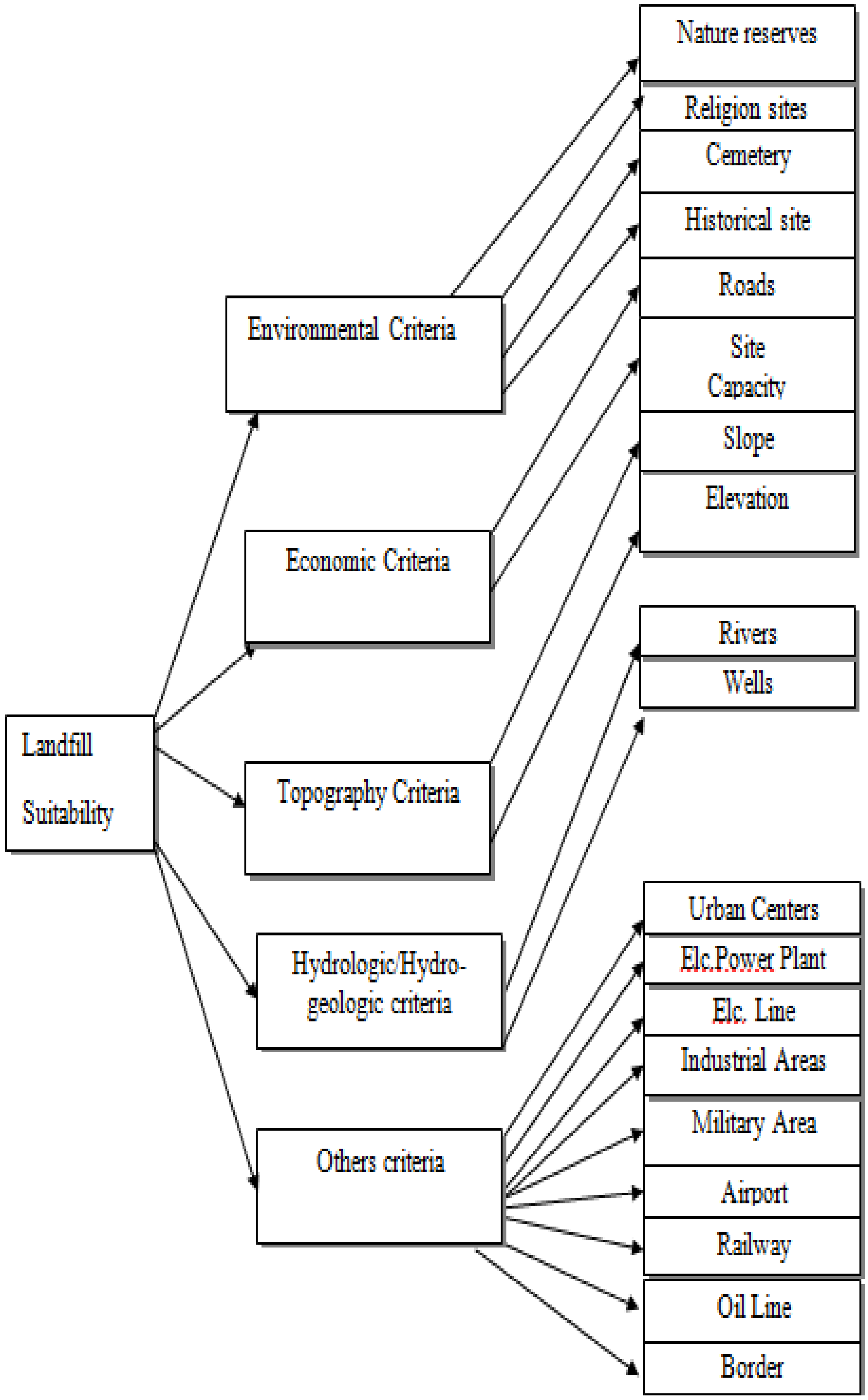

Figure (3) criteria decision tree developed for the landfill site selection problem in study area.

2.4. Criteria Weights

A weight is a measure of the relative importance of a criterion as judged by the decision maker. Assigning weights it's important process to evaluation criteria accounts for many reasons (i) the changes in the range of variation for each evaluation criterion, and (ii) the different degrees of importance being attached to these ranges of variation[5].There are four different techniques when assigning the weights: Ranking, Rating, Pairwise Comparison and Trade of Analysis Method [6]**.**In this study, Calculating weight for the criteria done by using each one of previous four method as every method methodology and mathematical basics. The resulting weights are given in table (4), table (5), table (6) and table (7).

2.4.1 Ranking Methods

The simplest method for assessing the single weight for each criteria in a set of criteria to arrange them in rank order[7]. Either straight ranking (The most important equal 1, second important equal 2, etc.) or inverse ranking (the last important equal 1, second last important equal 2, etc.) can be used [8]. There are many approach for generating numerical weights for ranking criteria are available :rank sum, rank reciprocal and rank exponent.

2.4.1.1 Ranking Sum Methods

Rank sum weights are arrived at via the formula:

$$w_i = \frac{n - r_j + 1}{\Sigma\,(n - r_k + 1)}$$

Where (**wi**) is the normalized weight for the criterion, (**n**) is the number of criteria under consideration (k = 1 ,2 ,...,n), and (**rj**), is the rank position of the criterion. Every criterion is weighted (n – rj + 1) and then normalized by the sum of all weights, that is, ∑ (n – rk + 1). Criteria weights by this method in table (1).

Table (1) Criteria weights by Ranking Sum method

Straight rank (rj)	Criteria (n)	Weight (n – rj + 1)	Normalized weight (wi)
1	Urban centers	17	0.111
2	Main river	16	0.105
3	Roads	15	0.098
4	Historical site	14	0.092
5	Power lines	13	0.085
6	Oil pipes	12	0.078
7	Electrical p. plant	11	0.072
8	Cemetery	10	0.065
9	Military Site	9	0.059
10	Religion site	8	0.052
11	Slope	7	0.046
12	Airports	6	0.039
13	Industrial site	5	0.033
14	Border	4	0.026
15	Nature reserves	3	0.020
16	Railways	2	0.013
17	Wells	1	0.007
SUM		153	1.000

2.4.1.2. Ranking Reciprocal Method

Weights are generated from the normalized reciprocals of a criterion's rank. The following formula is used to calculate the weights:

$$w_i = \frac{1/r_j}{\sum_{j=1}^{n} \quad (1/r_j)}$$

where **(wi)** is the normalized weight for attribute i, **(ri)** is the rank for the ith attribute, **(n)** is number of criteria. Criteria weights by this method in table (2).

Table (2) Criteria weights by Rank Reciprocal Method

Straight rank (rj)	Criteria (n)	Reciprocal weight (1/rj)	normalized weight (wi)
1	Urban centers	1	0.2907
2	Main river	0.5	0.1454
3	Roads	0.333	0.0969
4	Historical site	0.25	0.0727
5	Power lines	0.2	0.0581
6	Oil pipes	0.166	0.0485
7	Electrical p. plant	0.142	0.0415
8	Cemetery	0.125	0.0363
9	Military Site	0.111	0.0323
10	Religion site	0.1	0.0291
11	Slope	0.090	0.0264
12	Airports	0.083	0.0242
13	Industrial site	0.076	0.0224
14	Border	0.071	0.0208
15	Nature reserves	0.066	0.0194
16	Railways	0.062	0.0182
17	Wells	0.058	0.0171
SUM		3.439	1.0000

2.4.1.3. Ranking Exponent Method

This method needs an additional piece of information. The decision maker is required to specify the weight of the most important criterion on a (0-1) scale. This weight is generated from the formula:

$$w_i = \frac{(n - r_j + 1)^p}{(\sum_{j=1}^{n} \quad (n - r_j + 1)^p)}$$

For (p = 0) previous equation assigns equal weights to the evaluation criteria. For(p = 1) the method results in rank sum weights. As (p) increases, normalized weights gets steeper and steeper. Criteria weights by this method in table (3).

Table (3) Criteria weights by Rank exponent Method

straight rank (ri)	Criteria (n)	Reciprocal weight (n- ri+1)	squire reciprocal weight $(n - r_i + 1)^2$	normalized weight (wi)
1	Urban centers	17	289	0.1774
2	Main river	15	225	0.1381
3	Roads	14	196	0.1203
4	Historical site	13	169	0.1037
5	Power lines	12	144	0.0884
6	Oil pipes	11	121	0.0743
7	Electrical .P. plant	10	100	0.0614
8	Cemetery	10	100	0.0614
9	Military Site	9	81	0.0497
10	Religion site	8	64	0.0393
11	Slope	7	49	0.0301
12	Airports	6	36	0.0221
13	Industrial site	5	25	0.0153
14	Border	4	16	0.0098
15	Nature reserves	3	9	0.0055
16	Railways	2	4	0.0025
17	Wells	1	1	0.0006
SUM			1629	1.0000

Finally, the average values for the three methods:

Table (4) Average Criteria weights by Rank method

Criteria	Rank Sum	Rank Reciprocal	Rank exponent	Average
Urban centers	0.111	0.2907	0.1774	0.193
Main river	0.105	0.1454	0.1381	0.127
Roads	0.098	0.0969	0.1203	0.103
Historical site	0.092	0.0727	0.1037	0.087
Power lines	0.085	0.0581	0.0884	0.075
Oil pipes	0.078	0.0485	0.0743	0.067
Electrical .P. plant	0.072	0.0415	0.0614	0.058
Cemetery	0.065	0.0363	0.0614	0.054
Military Site	0.059	0.0323	0.0497	0.047
Religion site	0.052	0.0291	0.0393	0.040
Slope	0.046	0.0264	0.0301	0.034
Airports	0.039	0.0242	0.0221	0.028
Industrial site	0.033	0.0224	0.0153	0.026
Border	0.026	0.0208	0.0098	0.021
Nature reserves	0.020	0.0194	0.0055	0.017
Railways	0.013	0.0182	0.0025	0.014
Wells	0.007	0.0171	0.0006	0.008

2.4.2 Rating Method

The rating methods require from the decision maker estimation the weights on the basis of a predetermined scale; for example, a scale of (0 to 100) can be used [7]. The simplest approach of this method is (point allocation). The value of (0) refer that criteria can be ignore where the value (100) represented that only one criteria must be adapted [8]. This method does not constrain the decision maker's responses. It is can to change the any weight of one criterion without affecting the weight of another criteria. Criteria weights by this method in table (5).

Table (5) Criteria weights by Rating Method

Ratio scale (100 - 0) Original weight = (Ratio scale / lowest ratio scale) Normalized weight = (Each Original weight / Sum of original weight)				
straight rank(ri)	**Criteria (n)**	**Ratio Scale**	**Original Weight**	**Normalized Weight (wi)**
1	Urban centers	100	20	0.1364
2	Main river	80	16	0.1091
3	Roads	75	15	0.1023
4	Historical site	70	14	0.0955
5	Power lines	65	13	0.0887
6	Oil pipes	60	12	0.0819
7	Electrical power plant	55	11	0.0750
8	Cemetery	50	10	0.0682
9	Military Site	40	8	0.0546
10	Religion site	35	7	0.0477
11	Slope	25	5	0.0341
12	Airports	22	4.4	0.0300
13	Industrial site	17	3.4	0.0232
14	Border	15	3	0.0205
15	Nature reserves	10	2	0.0136
16	Railways	9	1.8	0.0123
17	Wells	5	1	0.0068
			146.6	1.0000

2.4.3 Trade-off Analysis Method (swing weights approach)

Decision maker in this method is required to make comparison of two alternatives with respect to two criteria at a time and make an assessment which alternative is preferred. The trade-offs define a unique set of weights that will allow all of the equally preferred alternatives in the trade-offs to get the same overall value/utility[8]. Swings weights approach which is one of Trade-off Analysis Methods generates the weights in way of asking the decision maker (DM) to make comparison between a change from the least-preferred to the most-preferred value on one attribute to a similar change in another attribute[7].Criteria weights by this method in table (6).

Table (6) Criteria weights by Trade-off Analysis Method

Criteria (n)	Code	Weight comparing with (W1)	Weights (wi)
Urban centers	W1	1	* 0.1088
Main river	W2	0.9	0.0979
Roads	W3	0.85	0.0925
Historical site	W4	0.8	0.0871
Power lines	W5	0.77	0.0838
Oil pipes	W6	0.7	0.0762
Electrical power plant	W7	0.65	0.0707
Cemetery	W8	0.6	0.0653
Military Site	W9	0.55	0.0598
Religion site	W10	0.5	0.0544
Slope	W11	0.44	0.0479
Airports	W12	0.38	0.0413
Industrial site	W13	0.35	0.0381
Border	W14	0.25	0.0272
Nature reserves	W15	0.2	0.0218
Railways	W16	0.15	0.0163
Wells	W17	0.1	0.0109
		9.19	1.00

* W1=(1/9.19)

2.4.4. Pairwise Comparison Method

This method was developed by professor Saaty (1980), in the context of the analytic hierarchy process. This method includes pairwise comparisons to generate a ratio matrix. This method involve taken pairwise comparisons as input and produced relative weights as output[9].Criteria weights by this method in figure (3)and table (7).

	UC	CE	MR	HS	IS	NR	WE	OP	EP	SL	AP	PL	RO	RW	MS	BO	RS
UC	1	6	4	5	5	6	9	7	5	6	6	6	6	6	6	8	9
CE	1/6	1	1	1	1/2	1	2	2	2	2	1	1	2	2	2	2	6
MR	1/4	1	1	5	3	4	7	5	5	3	5	5	6	7	4	5	6
HS	1/5	1	1/5	1	2	2	3	1/2	2	2	1	1	1/3	2	1	3	2
IS	1/5	2	1/3	1/2	1	1	2	2	1	2	3	1/5	1/2	1	1/2	1	1/2
NR	1/6	1	1/4	1/2	1	1	2	1	1/2	1	1/2	1	1/2	1/2	1	1	1
WE	1/9	1/2	1/7	1/3	1/2	1/2	1	1/2	1/3	1/4	1/4	1/2	1/5	1	1/4	1/3	1/2
OP	1/7	1/2	1/5	2	1/2	1	2	1	2	1	2	1	2	3	1/2	1/2	1/3
EP	1/5	1/2	1/5	1/2	1	2	3	1/2	1	2	1	2	2	3	1	2	1
SL	1/6	1/2	1/3	1/2	1/2	1	4	1	1/2	1	2	2	2	3	1/2	3	2
AP	1/6	1	1/5	1	1/3	2	4	1/2	1	1/2	1	1	1	2	1	3	1
PL	1/6	1	1/5	1	5	1	2	1	1/2	1/2	1	1	1/4	2	1	2	2
RO	1/6	1/2	1/6	3	2	2	5	1/2	1/2	1/2	1	4	1	5	3	4	3
RW	1/6	1/2	1/7	1/2	1	2	1	1/3	1/3	1/3	1/2	1/2	1/5	1	2	2	1/2
MS	1/6	1/2	1/4	1	2	1	4	2	1	2	1	1	1/3	1/2	1	2	2
BO	1/8	1/2	1/5	1/3	1	1	3	2	1/2	1/3	1/3	1/2	1/4	1/2	1/2	1	1
RS	1/9	1/6	1/6	1/2	2	1	2	3	1	1/2	1	1/2	1/3	2	1/2	1	1

Figure (3) comparison matrix.

*UC: Urban centers, CE: Cemetery, AP: Airports, MR: main river, HS: historical site, IS: Industrial site, NR: nature reserves, Sl: slope, WE: Wells, OP: Oil pipes, EP:Electrical power plant Industrial areas, PL: Power lines, RO: roads, RS: Religion site, BO: border, MS: Military Site, RW: Railways

$\lambda max = 19.525$, CI = 0.1578, RI = 1.71 and CR = 0.09228< 0.1

Table (7) Criteria final weights by Pairwise Comparison method

Urban Centers	**0.233**	**Military Sites**	**0.044**
Main Rivers	0.148	Regional Sites	0.033
Roads	0.067	Slope	0.046
Historical sites	0.050	Airports	0.041
Electrical Power lines	0.044	Industrial sites	0.043
Oil Pipes	0.042	Borders	0.026
Electrical Power Plant	0.047	Nature Reserves	0.031
Cemetery	0.062	Railways	0.028
Wells	0.016		

2.4.5 Comparing the methods

Table (8), summarizes the main features of the all methods for assessing criterion weights [7]:

Table (8) shows the Comparison of the methods used in estimating weights

Method features	Ranking Method	Rating Method	Pairwise Comparison	Trade-off Analysis
Hierarchical	Possible	Possible	Yes	Yes
Underlying theory	None	None	Statistical/ heuristic	Axiomatic/ deductive
Ease of use	Very easy	Very easy	Easy	Difficult
Trustworthiness	Low	High	High	Medium
Precision	Approximations	Not precise	Quit precise	Quit precise
Software availability	Spreadsheets	Spreadsheets	Expert choice	Logical decision
Use in a GIS environment	Weights can be imported from a spreadsheet	Weights can be imported from a spreadsheet	Components of IDRISI	Weights can be imported from LD

2.5 Criteria Reclasses

Each map layer is to be ranked by how suitable it is as a location for a new landfill. However, in order to be able to combine them, a common scale (for example, 1-10) giving higher values (scores) to more suitable attributes. It is usually assigned to each class, using "Reclassify" option in ARC GIS 9.3 software as in figure below.

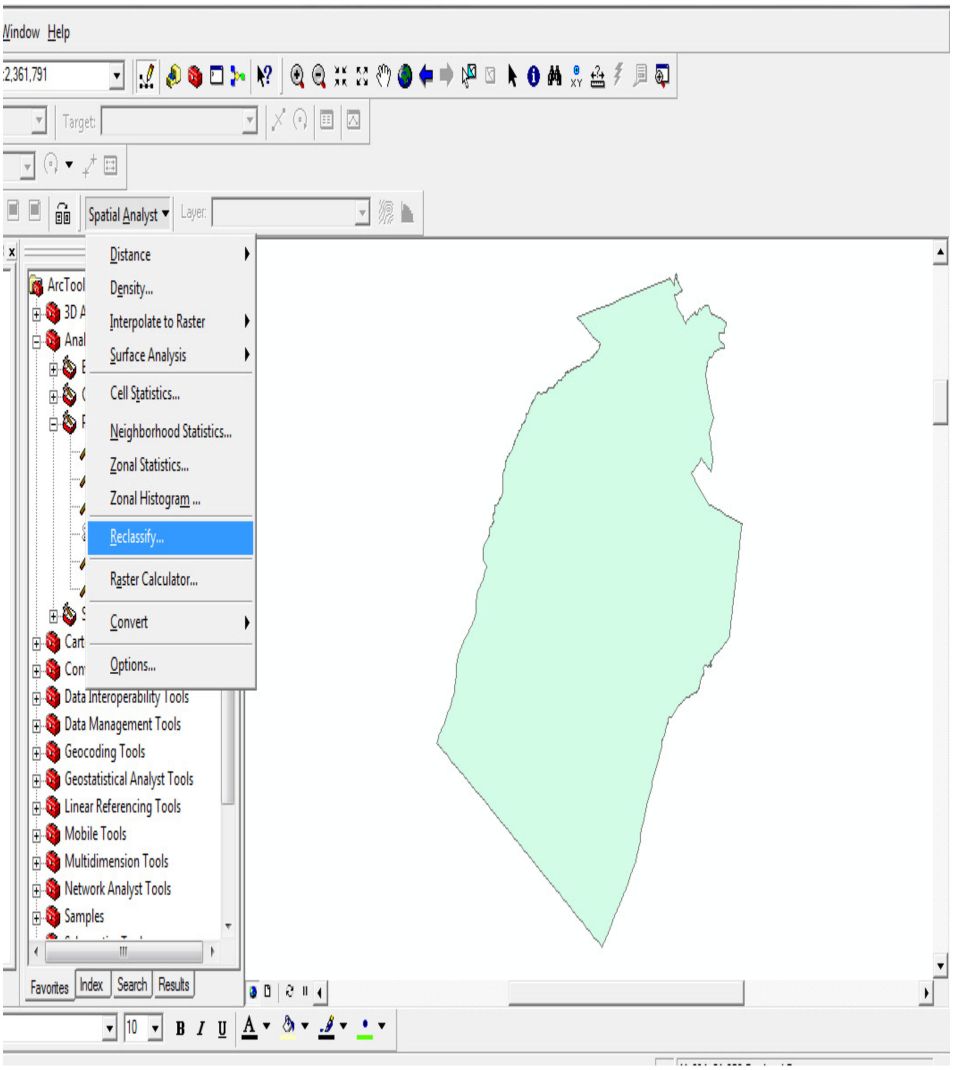

Figure (4) show the "Spatial Analyst – Reclasses" option in ARC GIS 9.3 software.

Table (1) show the summary of the Input Layers classesused in Analyzing.

Table (9) the summary of the Input Layers used in Analyzing.

Criteria	Buffer Zone	score
Urban Center	0 m - 5000 m	0
	5000m-10000m	5
	10000m-15000m	4
	15000m-20000m	3
	> 20000 m	1
Surface Water	0- 250 m	0
	250 - 500 m	1
	500 - 750 m	3

Criteria	Buffer Zone	score
	750 - 1000 m	4
	> 1000 m	5
Main Roads	(0m - 500m)	0
	500m-1000m	5
	1000m-1500m	4
	1500m-2000m	3
	> 2000 m	1
Airport	0- 3000 m	0
	3000- 6000 m	1
	6000- 9000 m	3
	9000- 12000 m	4
	> 12000 m	5
Historical areas	0 - 1500 m	0
	> 1500 m	5
High Voltage powerlines	0- 30 m	0
	> 30 m	5
Oil pipes lines	0 - 75 m	0
	> 75 m	5
Military Area	0-500	0
	> 500 m	5
Rail Way	(0m - 500m)	0
	>500 m	5
industrial investment zones	0 - 250 m	0
	> 250 m	5
The cemetery	0 - 1500 m	0
	> 1500 m	5
Religious areas	0 - 1500 m	0
	> 1500 m	5
Wells	0- 400 m	0
	> 400 m	5
Nature reserves	0- 400 m	0
	> 400 m	5
Electrical power plant	0 - 250 m	0
	> 250 m	5
Border	0-1000 m	0
	> 1000 m	5
slope	0- 15 %	5
	> 15 %	0

2.6. Results

After of all input data layers preparation, one method is selected among the decision rules to analyze the data of digital environment maps for landfill site selection by using Geographic Information Systems (GIS). The selected method is Simple

Additive Weighting (SAW) method. The output digital environmental maps produced by the method include the multiplication of data layers, weights and constraints. The simple additive weighting method evaluates each alternative, by the following formula [10]:

$A_i = \sum w_j . x_{ij}$

Where (xij) is the score of the (ith) alternative with respect to the(jth) criteria, (wj) is the weighted criteria.(wj) in this formula used from different criteria weighting method. The score value of this resultant map is evaluated and it between (1.88 to 9.28), the output values are divided into seven classes. The white color refer to most suitable area for landfill sitting. Figure (5) continue the four suitability index maps by using four criteria weighting methods.

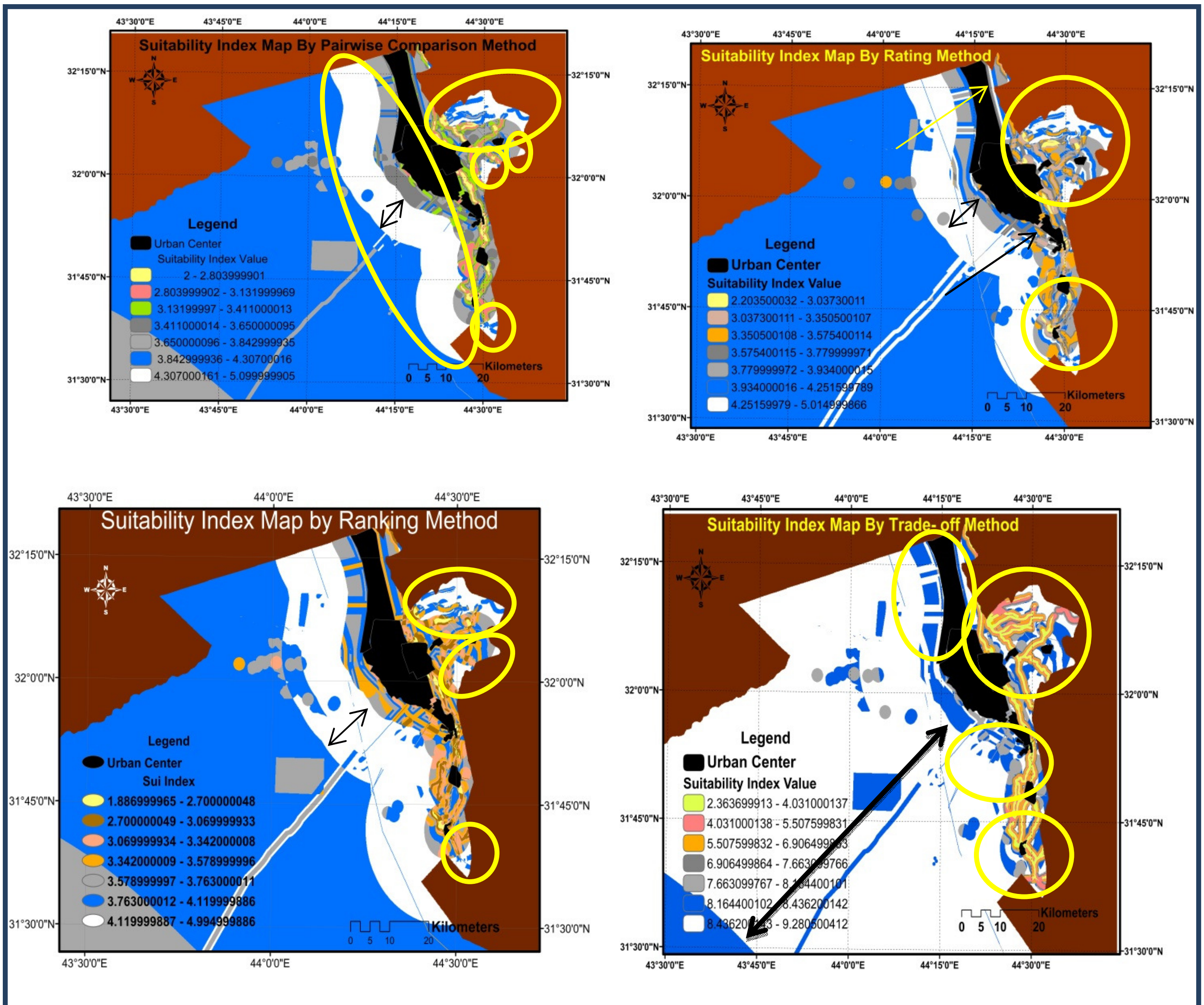

Figure (5) suitability index maps by using four criteria weighting methods.

2.7. Conclusions & Recommendations

Based on results from applied the models by for different methods for criteria weighting, some conclusions and recommendations can be noted:

- When the factors like the ease-of-use feature , time and cost included in generating a set of criteria weights are the major concerns, you must choose the ranking, rating or (trade-off analysis)methods to be applied. On the other hand, when the accuracy and theoretical foundations are the major concerns, you should take (pairwise comparison) to be applied.
- Criteria weights calculated by Rating and Trade-off methods, often to be closed together and no large variation on value (from 0.136 to 0.006 and from 0.1 to 0.01). But there is large variation by ranking and pairwise comparison (from 0.233 to 0.016 and from 0.193 to 0.008).
- Number of selected landfill sites by Ranking, or Pairwise comparison criteria weighting method remain the same (five sites), but there are different in the volume of landfill site in west of study area (site with strip shape). But with (trade-off analysis)or Rating method there is a lot of other sites selected beside the urban center therefore, this methods not valid to criteria weighting for site selection process.
- It recommended to use pairwise comparison method for weighting criteria at any site selection process or any process based on accuracy and theoretical foundations.

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