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Presenter Information

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An application of MCDA method to evaluate and select the most suitable landfill sites for urban waste. A project case study for Berat County. Albania.

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Abstract. Waste management system needs a clear and strict management policy. They also need a process of evaluating and selecting the most appropriate landfill sites that respect the restrictions and constraints dictated by the presence of the population in that area, with respect to ecological ecosystems and other factors. In addition to the geographical and geological criteria and other specifications that are defined by traditional selection procedures, there are new factors adding to the old constraints and limitations. Urban waste is produced in large quantities in our cities, every year. As a result, the number of sites should increase with the population growth as well as the increase in urban waste products. On the other hand, the eligibility criteria and adding constraints and limitations make it more difficult to choose suitable sites. Environmental and local and state regulations limit the number of choices as well as areas and volume of sites making their selection more difficult, posing a real challenge for specialists. Specialists need to use the Geographic Information System (GIS) as well as the method of Multiple Critical Decision Analysis (MCDA) to select the most optimal location. Our study aims to apply MCDA integrated with GIS to select potential sites for urban waste deposition. The method of hierarchy analysis (AHP) will be used to weight and rank the constraints and criteria. This article is part of a potential project we are working to propose to Berat County, Albania.

Keywords: site, landfill, mcda, criteria, AHP

1. Introduction

The problem of waste and urban waste is a growing concern all over the world, especially in poor and developing countries. However, it is a major problem for countries that do not have a clear policy on urban waste management that includes and respect all social, economic, political and environmental factors.

Reducing waste production, increasing the amount or percentage of recycling, processing, waste transformation are widely used methods by countries that have achieved an efficient management of the problem. Beyond the methods of recycling waste, incineration or dumping, the method of underground deposition is referred to landfilling. The process of choosing the suitable landfill is a difficult task because it requires many criteria, policies and restrictions to be respected, and it depends on different factors and regulators, whether these political, social, economic, etc.

Increasing populations and population density, increasing public health concerns, increasing new urban centres, roads and water pipes will make the construction of landfills very difficult, but not impossible.

Pollution of surface and groundwater are the main long- term problems that are closely related to the environment and the health of the population because there is a great risk of the possibility of contamination of surface water and underground waste from urban waste deposits. These are main concerns a team of specialist should consider before they start looking for the landfill sites.

2. Methods and Methodology

MCDA and AHP.

The process of selecting the most suitable sites for depositing urban waste is a process that needs to take into account several factors that are of geological, social, ecological, economical, etc.

From a geological point of view, sites suitable for landfill projects are subject to serious criteria to make sure that the effects of pollution, particularly groundwater pollution, are minimized, [1]. Factors that determine the suitability of geological and hydrogeological sites are:

1. Layer lithology (rock type, stone size characteristics, texture, bed characteristics), geology (rock thickness, homogeneity), hydrology (porosity, permeability), geological structure, (bedding, folding, defects), hydrogeology (groundwater levels, water distribution, water flow), surface (size and discharge of passages passing through the site), topography (steep slope, wind, visual impact, etc.).

The technical decision for the most appropriate landfill assessment needs specialists of different fields to work together, using multiple criteria analysis method (MCDA) as well as geographic information system (GIS).

For this purpose, six sites are selected, including the present site. From the first selection, two sites are excluded due to the failure of geological criteria.

To estimate the sites, 12 inputs or criteria are used. They are urban centres, land use, pipes, power lines, roads, surface water, slope, streams, surface water, industrial areas, liquid gas pipes, soil types. AHP will be used to weight all the factors in order to evaluate the sites. AHP uses the pairwise comparison to ranking all the factors.

2.2 Multi-criteria decision analysis techniques. AHP.

Multi-criteria decision analysis, (MCDA) is a sub- discipline of operations research, [2]. AHP method, (Saaty 1977, 1980 & Saaty and Vargas, 1991) is a well-known method in MCDA, [3]. In this method, both quantitative and qualitative information about decision-making problems can be organized. AHP is a flexible, quantitative method for selecting among alternatives which are based on their relative performance to more than one interest criteria. Criteria weight can be defined as a value assigned to each factor which indicates its relative importance to other factors under consideration, fig. 1. There are four different techniques when assigning the weights: ranking, rating, pairwise comparison and trade of analysis methods. Pairwise comparison method has advantages. For each comparison, we decide which of the two criteria is more important and assign a score which shows how much more important to other criteria, table 1. MCDA applications have been very useful in strategic planning and choices, industrial project assessments such as investment

priorities, technology choices, tourism development priorities, technological services estimates, etc. Some of its most popular applications are;

- Choosing a Cooler System for a Power Plant- France,
- Localization of Wind Farm Project- France,
- Personal Financial Planning- Germany,
- Bank Rating- Greece,
- Cost Evaluation of Nuclear Fuel Repository- Belgium
- Composite Web Site Selection- France.

Fig.1

Table 1.

Scale for the comparison (Saaty and Vargas), 1991	
Scale	Degree of preference

1	Equal importance
3	Moderate importance
5	Strong importance of one factor over another
7	Very strong importance
9	Extreme importance
2,4,6,8	Values for inverse comparison

2.3 Buffer Zones.

1) Residential Areas.

According to Allen, et al. [4], the distance from the residential areas should be at least 5 km and from isolated houses 500 m to find a landfill.

The buffer zone for a population of more than 500 people was defined as 1000 m. For other centres is 500 m, for private residences, businesses, community and social buildings is 250 m.

2) Industrial Areas.

The minimum distance, [5], to the study area was defined as 5 km for residential areas and 250 m for industrial areas. The industrial zone layer is classified as appropriate or inappropriate by defining values 1 and 0 respectively.

3) Roads

The minimum distance from the urban or urban transport network is 100 m on both sides, [6]. All roads involving main, middle, regional and third class roads should be avoided at least 30 m from both sides. A distance greater than 1 km from main roads and highways should be provided.

4) Airports.

A distance of 10 to 13 km should be called a safe distance from the flight zone. Taking into account these estimates, it is designated as safe distance from the airport at a distance of 3000 m. Areas were rated as appropriate for value 1 and not worth 0.

5) Surface waters.

The required protection zone for swamp areas is defined as 250 m.

6) Pipelines.

Pipelines taken into account are those of the water supply of the population. The security zone is up to a distance of 250 m on both sides. The area is called appropriate or inappropriate by giving values of 1 or 0.

7) Energy lines.

The security zone is 30 m on both sides of the line. The power line layer is classified as appropriate for the site by setting values 1 and 0 respectively.

8) Water currents, streams, rivers.

The necessary water currents area is 300 m on both sides, [7]. The surface water layer has been classified as appropriate for a waste disposal site with values of 0 and 1.

9) Liquid gas tubes.

The indispensable buffer zone for liquid gas pipes is defined as 300 m.

10) Use of land.

Types of land use are grouped and evaluated according to their suitability for a site of urban waste deposition giving values 0, 5 and 10.

3. Study Area.

Berat County is located in southwest of Albania, the coordinates are:
 North 40 degrees 52'24 " ; South 40 degrees 29'30 "
 East 20 degrees 10'51 " ; West 19 degrees 44'30 ".
 County covers an area of 1.6 square km city), fig. 2, 3.

Berat is one of the oldest cities in Albania, more than 2400 years ago. The first archaeological finds date back to 400 BC. This makes it a very important city from the tourist and cultural point of view, and a very popular destination for foreign tourists.

Fig. 2
 Fig. 3.

The population has been reduced due to internal or external emigration, during the years 2003- 2018. However, urban waste production has been increased because of higher standart of living, consumption, construction, tourism, urban development, etc, table 2, fig. 4.

Table 2.

Fig. 4.

According to the experience and scientific literature, safe distances and buffer zones are created for urban centres, roads, industrial areas, villages, water pipes, gas pipelines, for the purpose of respecting landfill assessment criteria, [8].

During the selection process, two sites have been excluded for geological reasons. The remaining four sites are further studied for all the criterias. From all the known criterias, railways and oil pipelines are excluded. The remainings are;

2010	45367	81,743
2011	47898	129,641
2012	48240	177,881
2013	48353	226,234
2014	49230	275,464
2015	50410	325,874

Urban centres, main and secondary streets, industrial areas, land use, drinking water pipelines, power lines, water and river streams, water surfaces, gas pipelines, land type, land slope, etc.

Four sites are selected to fulfil the geology criteria, and the present site. They are less than

30 km of distance from the city, the main production of urban waste. They have been selected out of the buffer zones for urban areas, industrial areas, pipes, roads, streams, waters. The sites are useless for crops or any other agriculture productivity, making suitable for further evaluation, fig. 5.

Fig. 5.

3. Mathematical model

As a math model, MCDA model is defined by a set of alternatives, denoted by $A = \{A1, A2, \dots, Am\}$, and a set of criteria, denoted by $C = \{C1, C2, \dots, Cn\}$.

$$\begin{matrix} & \text{Matrix} \\ \left[\begin{array}{ccccc} \text{ALT} & C1 & C1 \dots & Cn \\ A1 & a11 & a12 & \dots & a1n \\ A2 & a21 & a22 & \dots & a2n \\ A3 & a31 & a23 & \dots & a3n \\ \dots & \dots & \dots & \dots & \dots \\ AM & am1 & am2 & \dots & amn \end{array} \right] \end{matrix} \quad (1)$$

Test of consistency: The aim of this is to determine if the comparisons are consistent or not. It involves following operations:

- Determine the weighted sum vector by multiplying the weight for the first criterion times the first column of the original pairwise comparison matrix, then multiply the second weight times the second column, the third criterion times the third column of the original matrix, finally sum these values over the rows,
- Determine the consistenct vector by dividing the weighted sum vector by the criterion weights determined previously.
- Compute lanmda (λ) which is the average value of the consistenct vector and consistency index (CI) and has the formula below:

$$CI = \frac{\lambda - n}{n - 1} \quad (2)$$

- Calculation of the consistency ratio (CR) which is defined as follow:

$$CR = \frac{CI}{RI} \quad (3)$$

Where RI is the random index and depends on the number of elements being compared.

If $CR < 0.10$, the ratio indicates a reasonable level of consistency in the pairwise comparison, if $CR > 0.10$ tha values indicates incosistent judgement.

Performance matrix is constructed $D = a_{i,j}(mxn)$, fig. 6.

The criterias are;

UR = urban centre, IN = industrial areas, ST = streams, WP = water pipes,

SW= surface water, LU = land use, AE- airport, ST = soil types, PL = power lines,

RO = roads, LG = liquid gas pipes, SL = slope.

As a result of AHP application method of pair wise comparison, we have the criteria weights and the matrix, fig. 6.

Fig. 6. Matrix and the criteria weights.

The final ranking of the landfill sites is calculated by estimating and calculating safe distances from the factors, (buffer zones), table 3.

Table 3. Ranking values calculations.

Category	Priority	Rank		1	2	3	4	5	6	7	8	9	10	11	12
1	UR	24.5%	1	1	1.00	5.00	6.00	5.00	4.00	4.00	4.00	6.00	6.00	5.00	7.00
2	IN	19.0%	2	1.00	1	1.00	5.00	4.00	4.00	5.00	6.00	5.00	6.00	5.00	7.00
3	ST	17.0%	3	0.20	1.00	1	4.00	4.00	5.00	5.00	5.00	6.00	5.00	5.00	6.00
4	WP	6.4%	5	0.17	0.20	0.25	1	0.25	1.00	3.00	3.00	4.00	3.00	4.00	3.00
5	SW	9.4%	4	0.20	0.25	0.25	4.00	1	3.00	3.00	4.00	3.00	3.00	4.00	3.00
6	LU	5.7%	6	0.25	0.25	0.20	1.00	0.33	1	3.00	1.00	3.00	3.00	3.00	3.00
7	AE	4.5%	7	0.25	0.20	0.20	0.33	0.33	0.33	1	3.00	2.00	3.00	2.00	3.00
8	ST	4.0%	8	0.25	0.17	0.20	0.33	0.25	1.00	0.33	1	3.00	2.00	3.00	3.00
9	PL	2.6%	10	0.17	0.20	0.17	0.25	0.33	0.33	0.50	0.33	1	1.00	2.00	2.00
10	RO	2.9%	9	0.17	0.17	0.20	0.33	0.33	0.33	0.33	0.50	1.00	1	3.00	3.00
11	LG	2.2%	11	0.20	0.20	0.20	0.25	0.25	0.33	0.50	0.33	0.50	0.33	1	2.00
12	SL	1.8%	12	0.14	0.14	0.17	0.33	0.33	0.33	0.33	0.33	0.50	0.33	0.50	1
Number of comparisons = 66				Principal eigen value = 13.383											
Consistency Ratio CR = 8.2%				Eigenvector solution: 7 iterations, delta = 2.2E-9											

RANK	SITE 0	SITE 1	SITE 2	SITE 3	SITE 4
UR	0	5	6	8	10

IN	0	1	1	1	1
ST	0	1	1	1	1
WP	0	2	5	5	5
SW	0	4	5	5	5
LU	3	4	5	5	5
AE	5	5	6	8	8
ST	2	5	5	5	5
PL	2	5	5	5	5
RO	2	5	8	8	10
LG	2	4	4	5	5
SL	5	2	2	3	4
VALUE	1.75	3.58	4.42	4.92	5.33

5. Conclusion

The most suitable landfill sites are sites 3, 4. They have suitable geological properties to use as landfill sites for urban waste management. They are in safe distances from urban areas, industrial zones, pipelines, streams, roads, etc. Both sites are suitable to fulfil Berat County needs for landfilling, they are of large areas, they are not far away from main and secondary roads.

Anyway, the county needs a much better local policy of waste management and a much more modern approach from central and local government to deal the urban problems, starting by increasing the recycling percentage, because it is not acceptable to have such a low recycling percentage of less than 10%. Albania ranks among last european countries in the percentage of recycling.

For the purpose of evaluation and selection of the most suitable landfill sites for urban waste, Mcda and AHP have been proved to be very useful tools to do the job. They are methods of evaluating different alternatives under the conditions to respect all the necessary constraints and criteria for the selection of the best solution.

Further study and evaluation are needed for distant urban centres in order to avoid the not necessary cost of transportation. Other solutions may be small landfill sites to cover local needs.

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