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Site Selection For Sanitary Landfill in Kuksi Region in Albania, Using Multi-criteria Analysis Evaluation

Oltion Marko[1], Neritan Shkodrani[2], Meivis Struga[1],
[1] Department of Environmental Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana
[2]Department of Civil Engineering, Faculty of Civil Engineering, Polytechnic University of Tirana

Abstract
Landfill is a common solution for the final disposal of municipal solid waste (MSW) in Albania. Landfill siting is an extremely difficult task to accomplish because the site selection process depends on different factors and regulations. To ensure that an appropriate site is chosen, a systematic process should be developed and followed.
Unsuccessful landfill siting is typically the result of strong public opposition. In this study, 11 candidate sites for an appropriate landfill area in Kukës Region are determined by using the integration multi-criteria evaluation (MCE).
From the application of the exclusion criteria provided in the study methodology, it was able to find the best three alternatives.
The statistical processing for the determination of the best place was accomplished through Multi-criteria Analysis and Environmental Management. The application of this method has led to the identification of the most suitable site for the construction of sanitary landfill in the Kukës Region.

Key words: *Landfill siting, Multi-criteria evaluation, Solid waste, Site selection*

1. Introduction

This study, through a methodology that uses multifactorial evaluation of a set of alternatives and based in the Albanian and EU legislation on urban solid waste landfills, makes the classification of three best sites for the construction of a regional landfill in Kukesi Region.
The methodology for the evaluation of the best option passed through two phases, applying two different groups of criteria:

1. **Exclusions criteria**- for the reduction of a list of 10 proposals to three preferred alternatives. After applying the exclusion criteria, the following three sites were the most appropriate for the construction of the sanitary landfill in Kukesi Region:

- Alternative 2 - Pobreg, Hardhici Stream, Kukës
- Alternative 3 - Gjegjan, Kukës
- Alternative 4 – Bicaj, Kukës

2. **Development criteria** – for the selection of the best option among the three favorite alternatives. After the application of the development criteria, the ranking of three above sites resulted as follows:

- Alternative 2 - Pobreg, Hardhici Stream, Kukës
- Alternative 4 – Bicaj, Kukës
- Alternative 3 - Gjegjan, Kukës

The objective of this paper is to present the assessment of the most optimal location for sanitary landfill construction in the Kukesi Region based on the data collected for three potential alternatives through the methodology of multi-criteria analysis.

Materials and Method

2.1 Landfill siting, Multi-criteria evaluation, Solid waste, Site selection

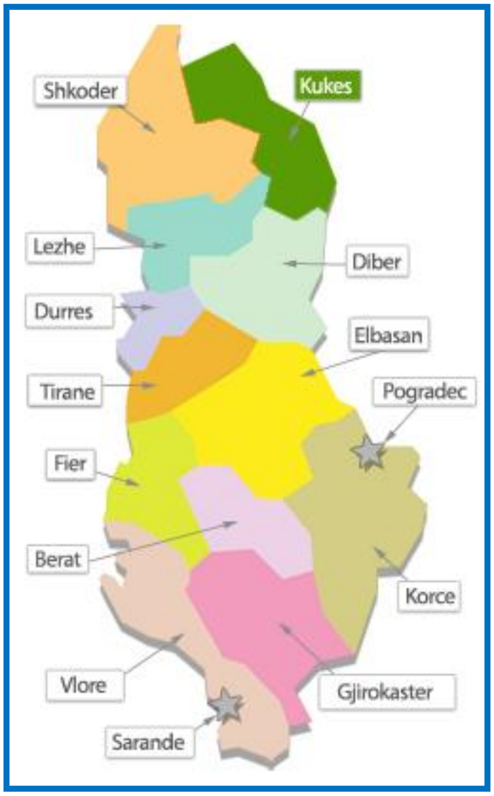


Figure 1: Regions in Albania

Kukës Region is located in the north part of Albania and lies between longitudes 42° 5′ 0″ N and between latitudes 20° 25′ 0″ E and area coverage of about 2,374 km^2. The population of the region has been estimated to be about 84,035 people as of 2016 INSTAT data [1]. The rate of population growth in Kukës Region shows instability and in the last 5 years according to INSTAT this rate has been -2% per year [1].
Most recently the increase in population as well as the economic growth in the study area has transformed and urbanized the area and led to the change in land use and a substantial increase in

municipal solid waste generated.
Solid waste management system in the town is not effective as wastes are seen dumped on all manner of places including roads, near sensitive areas, and on private properties. It is therefore of importance that solid waste collected are properly disposed at designated sites in the city in order to avoid environmental degradation. In locating proper sites (Landfills), consideration is giving to environmental factors mainly to avoid environmental risk. Again landfill site should be located far from residential areas and settlement.

2.2.1Multi criteria Analysis

Based on the procedures as set out in the Albanian legislation [2] [8], the European Union, in consultation with relevance to contemporary literature, and based on the current conditions that are provided from study areas (urban waste generation rate, total amount and infrastructure), for defining a suitable waste facility site for a sanitary landfill [3], the following additional criteria are developed:

- Exclusion criteria;
- Development Criteria.

2.2.2Analysis of criteria

2.2.2.1Exclusion criteria

An area which will host SWM facilities must meet a large number of parameters in order to satisfy the purpose, as developed previously. If a position does not meet a minimum degree of certain basic criteria, e.g. safety, land use compatibility or healthy, you cannot proceed with further investigation for sitting SWM projects.
So it is possible, in some region SWM facilities to be sited only with exclusion criteria, criteria which exclude certain positions from the sitting of such projects and in particular sanitary landfill which as mentioned above are the most stringent criteria.

Exclusion criteria proposed in accordance with different organizations and legislations are as follows:

- Regional and urban spatial planning requirements.
- Distance from supply systems of drinking water <50-200m (second and third zone of sanitary protection) [4].
- Distance from natural elements (water leakage, water springs, protected natural resources, natural monuments >200m (buffer zones) [5].
- Distance from anthropogenic spatial elements (infrastructure, settlements, protected cultural and archaeological objects).
- Extreme morphology of terrain.
- High level of groundwater, even and seasonal.
- Carstic or active seismic zone.
- Areas which containing mining works..
- Within 3 km of an airport runway in the direction of landing and elevating the aircraft.
- Waste transportation distances (tons / km)

2.2.2.2 Development Criteria

Finding the best way to address a management problem is a very complex process, because of the

need to evaluate different options / scenarios, which, in many cases, are apparently equivalent. In order to achieve an evaluation of all the different suggested solutions, and as in our case it is necessary to compare different critical parameters and criteria. These criteria are common to all suggested scenarios and their importance for solving the problem is characterized by a weighting factor. The weighing for the criteria are combined using a cumulative function, which involves the rating of each criterion weighted but with the help of weighing. Furthermore, for reasons of better understanding of the marking process and without reliability compromise, the criteria are subdivided into four categories or groups of criteria which have fixed gravity coefficients. The emphasis coefficients that express the relevant importance of one criteria group compared to all others are determined according to international specifications as well as the local conditions.
The factors with their specific weight that are considered for Multi-criteria Analysis and Environmental Management are given in the table below [6].

Table No.1: Factors with specific weight

A. GEOLOGICAL CRITERIA	**GRAVITY COEFFICIENT (%)**
A1. Permeability of the underground layer liable of the Sanitary Landfill Site	20
A2. Tectonic structure as a factor of permeability	18
A3. Position of water intake works – Large aquatic works	10
A4. Usage of underground water	10
A5. Ground Erosion – Stability of the slope	5
A6. Active tectonics	5
A7. Protection of surface water	7
A8. Protection of underground water	10
A9. Geomorphology of the area	10
A10. Covering demands	5
TOTAL	**100**
B. ENVIRONMENTAL CRITERIA	**GRAVITY COEFFICIENT (%)**
B1. Green areas, ecological characteristics, landscape	20
B2. Optical isolation	15
B3. Annoyances by smells	10
B4. Annoyances by biogas	10
B5. Annoyances during access	10
B6. Residences within 1000 meters	10
B7. Public opinion	10
B8. Number of private owners of site	15
TOTAL	**100**
C. PLANNING CRITERIA	**GRAVITY COEFFICIENT (%)**
C1. Distance from settlements	30
C2. Agricultural activities	10
C3. Cattle breeding activities	4

C4. Industrial and mining activities	6
C5. Proximity to incompatible uses	15
C6. Tendency to residential/ tourist development	20
C7. Ownership status	15
TOTAL	**100**
D. OPERATING CRITERIA	**GRAVITY COEFFICIENT (%)**
D1. Climatic conditions	10
D2. Capacity	60
D3. Adequacy of coating layer	30
TOTAL	**100**
E. CRITERIA ECONOMIC COST	**GRAVITY COEFFICIENT (%)**
E1. Size/magnitude of infrastructure works	35
E2. Value of the earth	20
E3. Availability networks of common utility	15
E4. Cost of transportation	30
TOTAL	**100**

Each sub-criterion is evaluated with points in the villas varies from 1 to 5. Value 1 belongs to the minimum valuation, while value 5 belongs to the maximum (table below).

Table No. 2:

No	Assessments	1	2	3	4	5
1.	Greats of assessment	Very low	Low	Moderate	High	Very high

To determine the sensitivity of the results on the importance of criteria can be formulated evaluating different scenarios, with different sub-groups of gravity benchmarks. This study proposed and used in the following scenarios:

Table No. 3. Alternative scenarios evaluation of candidate positions of IWMF

MAIN CRITERIA	Scenario A	Scenario B	Scenario C
A. Geological - Hydrogeological suitability	20%	25%	25%
B. Environmental and Social suitability	20%	30%	25%
C. Land-planning suitability	20%	15%	30%
D. Functional fitness	20%	15%	10%
E. Economic parameter	20%	15%	10%
TOTAL	**100%**	**100%**	**100%**

So, if we call these groups of the criteria A, B, C, D and E and by using the above weights the cumulative function is the following:

S= 0,20A + 0,20B + 0,20C + 0,20D + 0,20E (A' Scenario)

S = 0,30A + 0,25B + 0,15C + 0,15D + 0,15E (B' Scenario)

S = 0,25A + 0,25B + 0,30C + 0,10D + 0,10E (C' Scenario)

The selection of appropriate criteria is particularly important for the export of the optimal conclusions. The kind of criteria depends:

A. Directly from the type of problem to be solved and its particular characteristics; and,
B. Indirectly as the problem is affected or affects the attitude of various stakeholder groups.

The simultaneous analysis of the characteristics of various alternative scenarios through the evaluation and rating of all the different criteria, for the extraction of the optimal solution, is the Multi – Criteria Analysis.

2.2.3 Multi-criteria Analysis and Environmental Management

The decisions taking process regarding the management of environmental problems, is a very complicated and difficult process. The various environmental problems are related (affecting or affected) directly or indirectly with a large number of factors, the severity of which is a key factor in choosing the best solution for every problem.

The use of a single criterion (e.g. the applied technology performance or operational costs) for the comparison evaluation between scenarios may not lead to a result which ensures optimal solution of the problem as well as the taking of appropriate decisions / actions.

Therefore, the need to implement a data multi-criteria evaluation system, which are connected with an environmental management problem is conspicuous.

The methodology followed for the implementation of the Multi – Criteria Analysis (MCA) includes:

- determination of the problem and selection of possible alternative scenarios
- selecting the appropriate model
- selection and classification of criteria
- mathematical description of the criteria
- assessing the weighting of each criterion in relation to the problem to be solved
- an evaluation matrix fixing various restrictive parameters depending on the subject of the assessed problem.

The selected methodology for the Multi-Critical Analysis of selection of area for landfill construction in Kukes Region is **Visual PROMETHEE-GAIA .**

The **PROMETHEE-GAIA** is a method for multi-criteria analysis developed by J. P. Brans [7]. Methods of the PROMETHEE type are based on a paired comparison of the variants, progressively in the sense of all the criteria.

3. Results

Based on the study methodology, field visits, consultation with previous studies in the selected area and co-ordination of work with the staffs of the Local Government Units, the expert group selected 11 potential sites for the construction of sanitary landfill in the Kukes Region. These areas are shown in the following table and figure.

Table no 4. Potential site for landfill in Kukës Region

No	Alternatives	Alternative Areas	Coordinates	
1	Alternative 1	Gjegjan highway, Kukës	42° 5'21.27"N	20°28'7.42"E
2	Alternative 2	Pobreg, Hardhici stream, Kukës	42° 5'28.39"N	20°27'46.21"E
3	Alternative 3	Landfill_Gjegjan, Kukës	42° 5'46.58"N	20°28'0.06"E
4	Alternative 4	Bicaj	41°59'37.48"N	20°23'53.36"E
5	Alternative 5	Koj, Tropoje	42°21'18.34"N	20° 5'7.18"E
6	Alternative 6	Actual Landfill Kukës	42° 4'13.53"N	20°24'4.00"E
7	Alternative 7	Actual Landfill Fierzë	42°21'35.78"N	20° 5'21.53"E
8	Alternative 8	Landfill Has	42°11'33.95"N	20°23'11.53"E
9	Alternative 9	Myç Mamez	42.081025°	20.386542°
10	Alternative 10	Resnik, Bardhoc	42.122903°	20.506421°
11	Alternative 11	Fajze (Has)	42.151092°	20.368820°

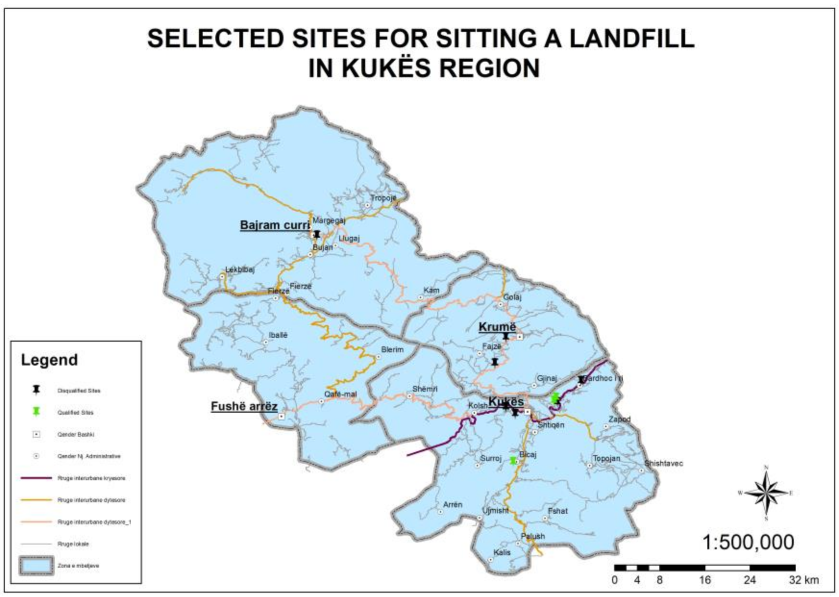


Figure 2: Selected Sites for Sitting a Landfill in Kukes Region

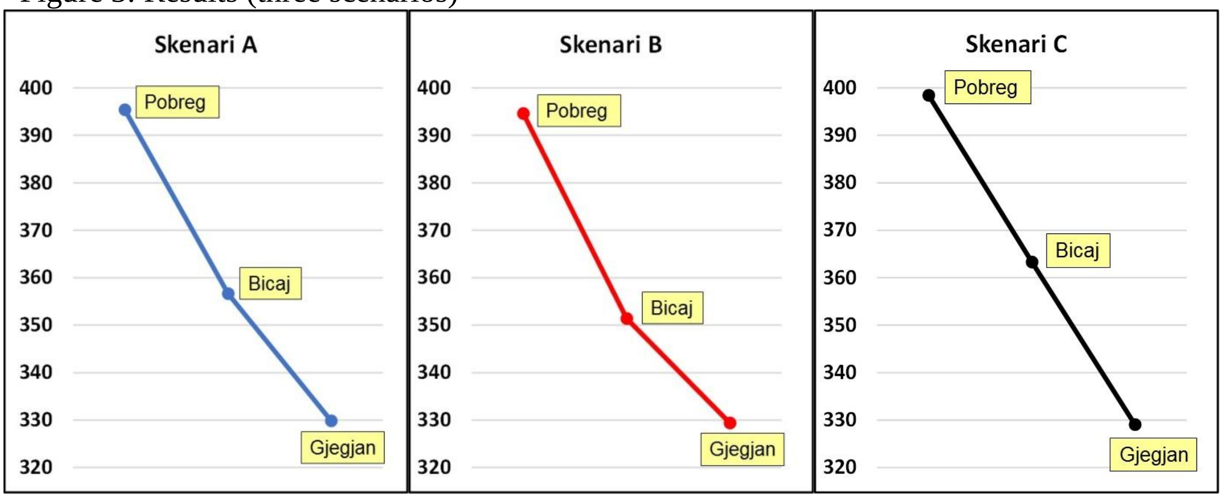
From the application of the exclusion criteria set out in the study methodology, we came to the selection of the three best areas which are given in the table below:

Table no 5. The selected alternatives

No	Alternatives	The best alternative areas	Coordinates	
1	Alternative 2	Pobreg, Hardhici Stream, Kukës	42° 5'28.39"N	20°27'46.21"E
2	Alternative 3	Landfill_Gjegjan, Kukës	42° 5'46.58"N	20°28'0.06"E
3	Alternative 4	Bicaj, Kukës	42.122903°	20.506421°

The multi-criteria analysis that was used to select the best area is Visual Promethee-Gaia, which leads us to the following results.

Figure 3: Results (three scenarios)



From the above schematic representation of the comparative evaluation results, of alternative scenarios, is calculated by applying the method of multi-criteria analysis using the Promethee - Gaia model, resulting following conclusions:

- In all evaluation scenarios in the first position of preference seems to rank the 3rd alternative which is the area located in Pobreg.
- As a second option seems to rank the 4th alternative which is the area located in Gjegjan administrative unit.
- As a third option seems to rank the 11th alternative which in the area located in Bardhoc administrative unit.

In particular the assessment scenario A, where all sets of criteria have the same weight, the ranking is as follows:

- 1st: Pobreg (alternative 2)
- 2nd: Bicaj (alternative 4)
- 3rd: Gjegjan (alternative 3)

In the assessment scenario B, where prevailing environmental criteria, the ranking is as follows:

- 1st: Pobreg (alternative 2)
- 2nd: Bicaj (alternative 4)
- 3rd: Gjegjan (alternative 3)

In the assessment scenario C, where the prevailing technological and economic criteria, the ranking is same as in scenario B as follows:

- 1st: Pobreg (alternative 2)
- 2nd: Bicaj (alternative 4)
- 3rd: Gjegjan (alternative 3)

The final evaluation of the scenarios, as shown by the model, is similar for all calibrations and in this table compare the best and the worst scenarios. In this case the best scenario for the emplacement of landfill in Kukës Region is Pobreg (figure 2).

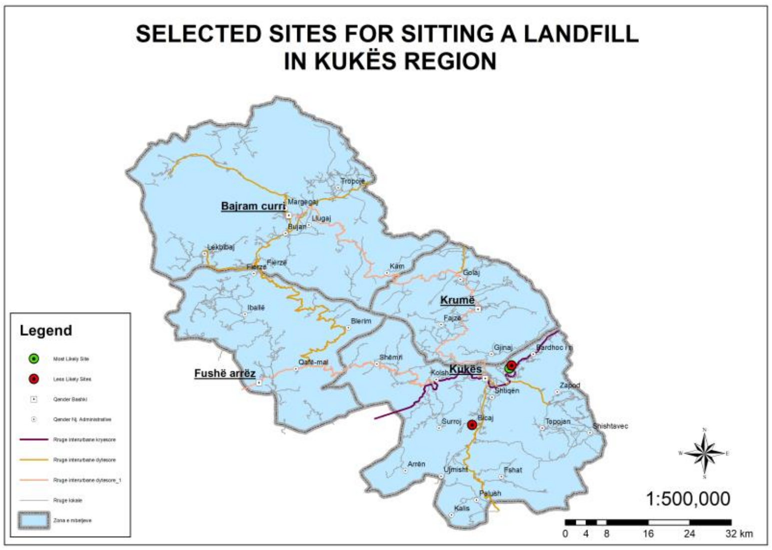


Figure 4: Selected Sites for Sitting a Landfill in Kukes Region

4. Conclusions

This paper presents an vanguard method for the selection of the optimal site for a Sanitary Landfill in Kukës Region based. In the past landfill selection problems were solved by applying various unstructured tradeoff approaches which compare only a few criteria simultaneously. Also, a decision maker's subjective preference is usually not reflected in the decision-making process. The Multi-criteria Analysis approach addresses these shortcomings and renders the selection process more systematic and accountable, while allowing the decision maker to include their preferences in the decision-making process. Three scenarios were selected and examined. The results obtained by the presented evaluation for the selection of the sanitary landfill site in Kukës Region, showed that, according to the selected indicators, the best alternative for the emplacement of the landfill is Pobreg (alternative 2).

Given the lack of official methodologies in our country, for defining the selection criteria for sites for construction of sanitary landfills we propose that this methodology should be taken into consideration and for other case studies.

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