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Decision making tools in regional sanitary landfill location selection

Bojana Živković [a,#], Jelisaveta Marjanović [b], Jelena Đokić [a]

[a] University of Pristina in Kosovska Mitrovica, Faculty of Technical Sciences, Serbia
[b] International Business College Mitrovica-IBCM, Kosovska Mitrovica, Serbia

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A B S T R A C T

The paper applies intelligent multicriteria analysis in order to rank the criteria in the process of site selection for the Regional Sanitary Landfill. The analysis was performed for 3 pre-selected sites that were selected based on available area, site access, potential preparation difficulties, groundwater occurrence, biodiversity, and proximity to urban area. These locations were selected as the most suitable for construction, both from the engineering and from the economic and environmental aspect. The analysis is the best example of the application of intelligent multicriteria analysis as a useful tool for environmental management in the decision-making process. The analysis was performed for three proposed locations of the Regional Sanitary Landfill: Kasilo, Kristal, and Savina Stena, in the municipalities of Zvecan and Leposavic. In order to achieve the most objective results, PROMETHEE methods were applied. Using these calculation methods, the following ranking list of locations for the Regional Sanitary Landfill was obtained according to their suitability: Savina Stena, Kasilo, and Kristal. This result can contribute to the decision-making process of determining the development strategy at the local and regional level.

1. Introduction

The adoption of new legislation related to the treatment of municipal waste, with the aim of reducing its generation and disposal and to minimize its harmful impact on the environment, has intensified in the last decade. However, waste disposal at sanitary landfills is still the most common final solution. The purpose of the landfill was to protect the environment and in that respect, it brought certain solutions, but it also opened other, new problems, such as the creation of gas, wastewater, noise, fire, etc. (Zamorano et al., 2005). The leading problems related to the environment and sanitary landfills are leachate, fires, and gas generation. Considering the consequences for the environment, maximum efforts are made and new, modern solutions are found, in order to avoid any negative impact. Stopping the degradation of the environment and improper disposal of municipal waste is supported by laws and regulations on measures that must be followed when building landfills and determining their location. The rules refer to the distance of landfills from settlements, parks, sports fields, rivers, agricultural goods, etc., however, additional efforts are needed to protect the air, land, groundwater and surface water. Complex problems require great effort, work, commitment and introduction of innovations in the planning and design of sanitary landfills.

Waste management is a complex, responsible, and necessary business, encompassing environmental, social, technological, legal, economic, and cultural aspects. Pursuant to the Law on Waste Management, all activities

[#] Corresponding autor: bojanaz1981@gmail.com

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are carried out in a way that provides the lowest risk to endangering the life and health of people and the environment, control and reduction measures:

- Water, air, and soil pollution,
- dangers to flora and fauna,
- dangers of accidents,
- explosions or fires,
- noise levels and unpleasant odors (Official Gazette of the RS, no. 36/2009, 88/2010, 14/2016 and 95/2018).

Even if they are relatively rare, landfill fires are extremely harmful because they emit various pollutants into the air, water, and soil. Landfill fires differ in the place of origin, in the materials that catch fire, the cause of the occurrence, etc., but they are all, without exception, a challenge to bring under control and extinguish (FEMA, 2002).

By penetrating into the interior of the soil or moving through channels and cracks, leachate migrates from the body of the landfill to surface and groundwater and pollutes them. In addition to water, only the soil through which the filtrate passes is contaminated.

Noise from communal landfills can have an extremely negative impact on people, depending on the health profile of the inhabitants of the surrounding settlements. Noise emitters from landfills are transport vehicles, excavators, waste compactors, etc. In the EU, as many as 4% of the population has a permanent hearing problem, due to frequent exposure to noise (Belić et al., 2009). As a product of microbiological decomposition of waste in landfills, intense unpleasant odors are created that significantly affect the quality of life of the local population. The intensity and frequency of unpleasant odors depend on a number of microclimatic factors (Šobot-Pešić et al., 2016).

1.1. Modern methods for selection of suitable location for landfill

In the complex process of waste management, choosing a location for the construction of a municipal landfill is a burning issue. Using the development of science and modern technologies, a multitude of methods for landfill site selection have been developed.

Modern methods, which have enabled us to develop informatics and computing, have an invaluable role in the entire waste management process. Through various software programs that can be used for analysis, calculations, simulations, etc., the speed and accuracy of work has increased. When choosing a site for a sanitary landfill, modern methods such as: GIS, MCDA methods, PROMETHEE, Heuristic approach, logical methods, MCDM obscure methods, etc., have an advantage over earlier methods based on mathematical calculations or manual techniques, such as technique coatings (Mokhtarian et al., 2014).

Geographic information systems, GIS, is a tool that allows you to select the best location and to create maps of exceptional quality (Ajibade et al., 2019). With the improvement of GIS, the possibility of screening, zoning, correlation, data storage, and graphical display of sites was achieved (Shah and Wani, 2014; Dereli and Trecan, 2021). GIS enables data management and combination with other methods (Mohammed et al., 2017). The application of GIS tools, alone or in combination with appropriate methods of analysis, offers solutions to structural problems encountered in the process of finding a suitable site for a landfill (Demesouka et al., 2014). In practice, it is most often combined with MCDA, which results in time saving and cost reduction (Mat et al., 2017; Eghtesadifard et al., 2020). GIS and MCDM methods in combined application define optimal areas, while for precise determination of landfill location subjective weighting method, sum of titles (RS), mutual rank (RR), and order of ranks (ROC) methods are used (Dereli and Tercan, 2021). Looking at the problem as an element or network of decision-making elements enables the analytical network process (ANP), which is basically a generalized AHP (Eghtesadifard et al., 2020). Flexibility in the work of ANP and AHP, enables their application for all sites and declares them as extremely suitable for combination with other methods of analysis in the process of landfill site selection (Afzali et al., 2014). The process of analytical hierarchy (AHP) is a method whose application provides a clear ranking of the final solutions for the landfill location (Mat et al., 2017). In the hierarchy-based AHP method, the Saaty scale is used to evaluate the problem. The Saaty scale is used to classify elements from the same hierarchical level based on importance (Srđević and Srđević, 2004; Lakićević et al., 2017).

SAV (simple additive weighting) is often referred to in the literature as a "scoring method" and is used in the processing of spatial attributes (Mat et al., 2017). The SAV format can be both raster and vector (Mohammed et al., 2017).

The fuzzy AHP method is applied to eliminate inaccuracies, while the integrated fuzzy VIKOR technique highlights priority in the event of conflicting decision-making criteria. The integrated obscure TOPSIS technique contributes to finding the optimal solution for the landfill site, while the integrated obscure ANP method is used to analyze the suitability of the site in an unclear environment. The heuristic approach is a two-phase method, where the first phase selects a significant area for the landfill, while the second specifies the location of the landfill, within the selected area. PROMETHEE is an extremely efficient technique that provides a final and complete ranking of selected locations, from the most to the least desirable (Mat et al., 2017). The Algorithm K method allows clustering, while methods such as MOORA, VASPAS, and KORPAS are used to define locations based on priorities (Eghtesadifard et al., 2020).

For precise standardization of the established criteria, the FUZZI LOGIC method is applied, while the Regulated Weighted Average (OVA) is a newer technique that achieves top results in site planning (Mohammed et al., 2017). VLC (weighted linear combination) is a method used to select the right one from several offered alternatives (Dareli and Tercan, 2021). FUZZI MADM method, unclear AHP method, and Chang's FUZZI AHP method, are often combined, whereby FUZZI MADM in solving problems arising from obscure, subjective and imprecise information, unclear AHP for selection and ranking of obscure programs in simple, while Chang's FUZZI AHP method is necessary in ranking alternatives (Nazari et al., 2012). Apart from the mentioned modern methods, the following are also significantly applied: weighted linear combination (VLC), unclear analytical hierarchical procedure (F-AHP), unclear analytical network process (F-ANP), TODIM, unclear TODIM, gray systems theory, etc. (Rezaeisabzevar et al., 2020).

1.2. Application of modern methods

Choosing a site suitability analysis method is a complex process, depending on many factors. Goulart Coelho et al. (2017) also emphasized the complexity of deciding on the selection of the appropriate multicriteria technique for the selection of the location of the communal landfill, and the analysis of 260 papers dealing with this topic, confirmed that the selection of tools was an extremely sensitive task, but that their application raised the choice of location for the landfill from the bottom to the top of the priority scale.

In Morocco in the Beni Mellal-Khouribga region, using GIS, Boolean logic, and the AHP method, the obtained results show that only 10 % of the land designated as an alternative for the construction of a municipal landfill is highly suitable for this purpose (Barakat et al., 2017). For the Babylon Governorate in Iraq, 10 sites were identified in 5 districts that were responsible for building the landfill, using GIS, AHP, and RSV methods (Chabuk et al., 2019). Ouma et al. (2011) presented the results of GIS analysis, multi-criteria analysis, and overlay analysis, based on which they determined the optimal location for the municipal waste landfill in the city of Eldoret in Kenya. In the southwest of Colombia, a suitable location has been determined for the construction of a communal landfill, using AHP and TOPSIS techniques (Manyoma-Velásquez et al., 2020). Elahi and Samadyar (2014), by a combination of GIS and AHP methods, established suitable sites for a municipal landfill in the city of Tafresh in Iran. The complex analysis resulted in the selection of three appropriate locations and contributed to the city planning process. Nas et al. (2010) using GIS and multicriteria analysis, identified three potential municipal landfill sites for the city of Konya in Turkey.

1.3. Criteria

The basic criteria for determining the location for a sanitary landfill are grouped into three groups:

- social,
- environmentally friendly, and
- techno-operative.

By applying GIS tools in the area where it is necessary to build a sanitary landfill, favorable and unfavorable location areas are singled out, and this is the basic step in the process of determining the most suitable location for the landfill. Elimination criteria in this case are legal regulations and terrain characteristics, such as slope, altitude, soil composition, etc. This way, the number of localities is reduced to a smaller number of potentially suitable ones. Table 1 shows the number of restrictive criteria which is usually from 20 to 40 (Josimović et al., 2011).

Table 1
Restrictive criteria

1.	Hydrogeology	11.	Underground waters
2.	Distance from the boundary zone of the water source	12.	Distance of surface waters
3.	Distance from the settlement	13.	Air temperature
4.	Location acceptability	14.	Precipitation
5.	Landscape characteristics	15.	Geological characteristics
6.	Distance from roads and railways	16.	Relief
7.	Distance from the natural good	17.	Land use
8.	Distance from cultural monuments	18.	Air flow
9.	Existing infrastructure	19.	Water supply
10.	Landscaping	20.	Seismicity

1.4. Examined locations

The regional landfill will serve the municipalities of Leposavic, Mitrovica (north), Zvecan, and Zubin Potok. Municipalities in northern Kosovo have proposed three (3) new landfill sites, for which they have prepared a comparative report. The construction of a new landfill is urgent in the project region in order to protect human life and the environment. Municipalities in the field of research have had the initiative to look for new locations to accommodate the new sanitary landfill. Representatives of the municipalities of Mitrovica, Zvecan, and Leposavic submitted a plan for the implementation of a new landfill in the area, which included an analysis of various elements for potential locations, i.e., land, groundwater, etc. The final result of the fieldwork was a report presenting 3 potential locations, two of which are located in the municipality of Leposavic and one in the municipality of Zvecan:

1. Location Kristal, industrial landfill, Popovacko Polje,
2. Location Kasilo, on the regional road Leposavic - Kursumlija, and
3. Location Savina Stena, on the main road Raska - Mitrovica.

2. Materials and methods

One of the advantages of MCA is its ability to help a researcher overcome doubts and problems in a consistent manner. Complexity of data in MCA is reflected in the large amount of data, different measuring units of some parameters, and different scales used to analyze the problem. These methods do not replace the decision-making process, but can contribute to understanding the deliberated multi-criteria problem (Agarski, 2014; Milentijević at al., 2016). The criteria selection for assessment is an important and very complex step, determining the final results of the MCA.

In order to ascertain the ranking of potential landfill locations PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) is used in this paper. The consideration and description of these method from a mathematical aspect is presented briefly considering that these methods are explained in detail in numerous papers (Milentijević at al., 2016).

The PROMETHEE method is one of the most important in the field of multicriteria analysis. This method finds its application in different industrial sectors (mining, chemistry, ecology, medicine, etc.). It allows complete ranking of the alternatives. The method was developed by Jean-Pierre Brans in two basic versions: PROMETHEE I, a method for partial ranking of the alternatives; and PROMETHEE II, a method for complete or combined ranking of alternatives (Albadvi et al., 2007; Milentijević at al., 2016). The most important advantages of this method are its simplicity and that used parameters have an explanation and meaning (Brans, 1982). This method relies on qualitative and quantitative data for each criterion and alternative. The PROMETHEE method introduces preference function *P*(*a*,*b*) for alternatives, a and b, which are valued by function criterion. Alternative *a* is better than *b* according to criterion f if $f\ (a)\ <\ f\ (b)$ (Albadvi et al., 2007; Milentijević at al., 2016). The value of the preference function is within the interval [0, 1], i.e., higher preference is presented by higher function value and vice versa.

The preference function is defined as:

$$P\ (a,b)\ = \begin{cases} 0, if d \leq 0 \\ 1, if d\ > 0 \end{cases} \tag{1}$$

In this case, the following combinations of the function of preference are possible:

- P(a,b) = 0 no preference, indifference,
- P(a,b) ≅ 0 weak preference, k (a) >k (b),
- P(a,b) ≅ 1 strong preference, k (a) >>k (b),
- P(a,b) = 1 tough preference, k (a) >>> k (b).

After that it can be concluded that there are the following two features of the preference function:

$$\begin{gathered} 0\ \leq\ P(a,b)\ \leq\ 1, \\ P(a,b)\ \neq\ P(b,a) \end{gathered} \tag{2}$$

The basic precondition of the functioning of PROMETHEE is to define the general set of criteria for each individual criterion $k\ (a)$. There are six types of the general criteria. In creation of the specific model for each type of general criterion, the parameters must be determined. In the next section, the presentations of each individual parameter are given. For the shorter text, the sign d is involved, $d\ =\ f\ (a) - f\ (b)$. According to Brans and Mareschal (1984), and Milentijević at al. (2016), there are six types of preference function:

I "Simple" criterion

$$P\ (a,b) = \begin{cases} 0, if d \leq q \\ 1, if d\ > q \end{cases} \tag{3}$$

II Quasi criterion

$$P\ (a,b) =\ \begin{cases} 0, if d \leq 0 \\ 1, if d\ > q \end{cases} \tag{4}$$

III Criteria for linear preference

$$P(a,b) = \begin{cases} 0, if\ d \leq 0 \\ d/_{p}, if\ 0 < d \leq p \\ 1, if\ d > p \end{cases} \tag{5}$$

IV Nivoj criterion-stage criterion

$$P(a,b) = \begin{cases} 0, if\ d \leq 0 \\ 1/_{2}, if\ 0 < d \leq p \\ 1, if\ d > p \end{cases} \tag{6}$$

V Criterion with linear preference and domain of indifference

$$P(a,b) = \begin{cases} 0, if\ d \leq 0 \\ \dfrac{d-p}{p-q}, if\ 0 < d \leq p \\ 1, if\ d > p \end{cases} \tag{7}$$

VI Gauss criterion

$$P(a,b)=\begin{cases} 0, if \ldots d \leq 0 \\ 1-e^{\frac{d^2}{21f^2}}\ if \ldots d > q \end{cases} \quad (8)$$

For the multi-criteria analysis method, PROMETHEE involves preference streams: positive stream and negative stream.

The higher + than the other alternatives, however, means further domination over another alternative in the system of alternatives. As a measure for multi-criteria evaluation, the PROMETHEE II involves absolute flow:

$$\phi_j(a_j) = \phi_j^+(a_j) - \phi_j^-(a_j): j = 1, \ldots, J \quad (9)$$

where J is the number of alternatives (Milentijević at al., 2016).

In the analysis conducted in this paper for the PROMETHEE method, the commercial software Visual PROMETHEE 1.4 Academic Edition (http://www.promethee-gaia.net) was used. The PROMETHEE method does not provide the opportunity to analyze decision making on simpler parts. In cases of a bigger number of criteria, this method makes it harder to come to a conclusion for the analyzed problem (Macharis et al., 2004; Milentijević at al., 2016). For a more complete graphic presentation of the results obtained by the PROMETHEE method, the GAIA plan (Geometrical Analysis for Interactive Assistance) was used from the software Visual PROMETHEE 1.4 Academic Edition. The basic purpose of this application is better visual presentation of the multi-criteria analysis. In the frame of the GAIA plan, some information can be lost after the projection. Based on the main components, the presentation is defined by two vectors, responding to the basic flow of one criterion. Although GAIA includes some percentage of total information, it does not provide strong graphic support (Đokić at al., 2020).

3. Results and Discussion

Municipalities in the field of research had the initiative to look for new locations to house the new sanitary landfill. Representatives of three municipalities, Mitrovica, Zvecan, and Leposavic, formed a commission whose task was to submit a plan for the implementation of a new landfill in the area, to determine the potential location of the new landfill, to analyze various elements for potential locations, i.e. land, groundwater size, etc. The Commission prepared a report in which 3 potential locations were introduced, two of which are located in the municipality of Leposavic and one in the municipality of Zvecan:

1. Location Kristal, industrial landfill - Popovacko Polje,
2. Location - Kasilo - on the regional road Leposavic - Kursumlija, and
3. Location, near the village of Srbovac called Savina Stena - on the main road Raska - Mitrovica.

3.1. Site No1 - Location Kristal

- Land use: The location is not included in any strategic or planning documents for the Leposavic municipality. The estimated volume of the site is: V = 21.218,25 m^3.
- Due to the previous use of the ground striking bays and concrete dam have been created. Ownership: Trepca, public enterprise Srbija Sume and socially owned enterprise Farmers' Cooperative.
- Distance from the inhabited location is 3.35 km.
- Configuration of the site is satisfactory.
- Road access to the site is satisfactory.
- Capacity of the site is not satisfactory.

Figure 1. Location Kristal

3.2. Site No2 - Location Kasilo

- Land use: The location is not included in any strategic or planning documents for the Leposavic municipality.
- The estimated volume of the site is: V = 50.000 m^3 from which 10.500 m^3 for the 1st phase of operation and 30.500 m^3 for the 2nd phase of operation.
- Ownership: Private owners.
- Distance from the inhabited location is 3.15 km.
- Configuration of the site is satisfactory.
- Road access to the site is satisfactory.
- Capacity of the site is satisfactory.

From an existing project documentation the following elements were derived: a) wind orientation is northeast-southwest, the location is not much exposed to wind; due to the hydrology purposes the, regulation of the Kasilo stream will be necessary, as well as detailed analysis of the local springs and their possible contamination by the landfill.

Figure 2. Location Kasilo

3.3. Site No3 - Location Savina Stena

- Land use: The location is not included in any strategic or planning documents for the Zvecan municipality.
- The site is located above the river Ibar.
- The estimated volume of the site is V= 35.000 m³.
- Ownership: Public land.
- Distance from the inhabited location (Srbovac) is 1.5 km.
- Configuration of the site is satisfactory.
- There is no access to the proposed site, therefore new access road should be constructed. The ownership of the land for the access road is private.
- Capacity of the site is satisfactory.

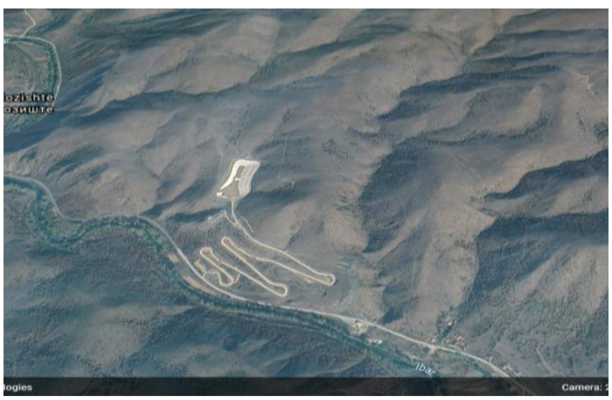


Figure 3. Location Savina Stena

Comparing the influence of certain criteria to the environment was based on relevant data obtained in the field. In Table 2, analyzed criteria, which were used as input data for matrix formatting and quantification for coupled comparison of criteria, are shown. Those data were than included into the calculations by PROMETHEE method, by common steps in calculation process (Milentijević at al., 2016).

Alternatives were evaluated and a quantified matrix of decision making was formed (Table 3) by application of the PROMETHEE method for evaluation of environmental influence of tailing ponds. In this process, certain criteria had a quantitative structure, while others were qualitative. Consequently, certain criteria (C1, C2, C3, C4, C5, C8, and C9) were stated quantitatively, while others were stated qualitatively. The application of qualitative and quantitative scales provided confidence that all criteria were well arranged in the best manner possible (Milentijević at al., 2016).

Table 2
Presentation of criteria of analyzed landfill sites

Criteria	Analyzed Criteria
C1	Proximity of the settlement
C2	Proximity of permanent water flow
C3	Geological environment
C4	Ownership
C5	Volume/ Capacity
C6	Distance from users
C7	Public acceptance
C8	Existence of the flooding water sources
C9	Proximity of the Agricultural area

After quantified matrix of decision making was provided, analyzed alternatives (tailing ponds) were evaluated using Visual PROMETHEE software. This resulted with a rank order of alternatives. Multi-criteria ranking method PROMETHEE introduced qualities of positive, negative, and net flow. The results obtained from positive, negative, and net flow are presented in Table 4 and Table 5 (Milentijević at al., 2016).

Table 4
PROMETHEE positive and negative flows

Alternatives	Ph+	Ph−
Savina Stena	0.4758	0.3808
Kasilo	0.4758	0.4525
Kristal	0.4050	0.5234

Table 5
PROMETHEE NET flow

Alternatives	Net flow Ph
Savina Stena	0.0950
Kasilo	0.0234
Kristal	-0.1184

The ranking was arranged in descending order of net flow value. The best proposal was the one having the highest net flow value, that is, the Savina Stena alternative.

The ranking of the analyzed alternatives is given in Figures 4-6 using the PROMETHEE method.

In Figure 4, the final ranking of analyzed tailing ponds is given. This figure is based on net flow Phi. The upper half of the given scale (colored in green) represents positive Phi value, and the lower half (red) represents negative Phi value. Alternative Savina Stena was at the top of the analyzed alternatives, preceding Kasilo, and

Kristal. Values of the Phi flow for these alternatives are given in Figure 5 (Milentijević at al., 2016).

Figure 5 shows a diamond PROMETHEE solution. This solution shows partial PROMETHEE I and final ranking PROMETHEE II in a two-dimensional model (Đokić at al., 2020).

Table 3
Quantified matrix of decision making (Evaluation matrix)

SCENARIO 1	Proximity of the settlement	Proximity of permanent water flow	Geological environment	Ownership	Volume/ Capacity	Distance from users	Public acceptance	Existence of the flooding water sources	Proximity of the Agricultural area
Unit	m	m	unit	unit	m^3	km	unit	unit	m
Cluster/group		◊	◊	□	□	◊	◊	◊	◊
Preferences									
Min/max	max	max	max	max	max	min	max	min	max
Weight	14.33	9.5	9.5	14.33	9.5	9.5	14.33	9.5	9.5
Preference Fn.	U-shape	usual	usual	usual	usual	usual	level	usual	usual
Tresholds	absolute	absolute	absolute	absolute	absolute	absolute	percentage	absolute	absolute
Q: Indfference	1	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a
P: Preference	n/a	n/a	n/a	n/a	n/a	n/a	2	n/a	n/a
S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics									
Minimum	1500	301	0.2	0.1	21285	13.75	0.1	0	100
Maximum	3350	2758	0.5	1	50000	31.5	1	0.8	1000
Average	2666.67	1519.67	0.33	0.53	33761.67	21.42	0.7	0.3	433.33
Standard Dev.	828.99	1003.16	0.12	0.37	12020.83	7.45	0.42	0.36	402.77
Evaluations									
Kristal	3350	301	0.5	average	bad	19	1	0.5	200
Savina Stena	1500	1500	0.2	very good	good	13.75	1	0.1	1000
Kasilo	3150	2758	0.3	good	very good	31.5	0.3	0	100

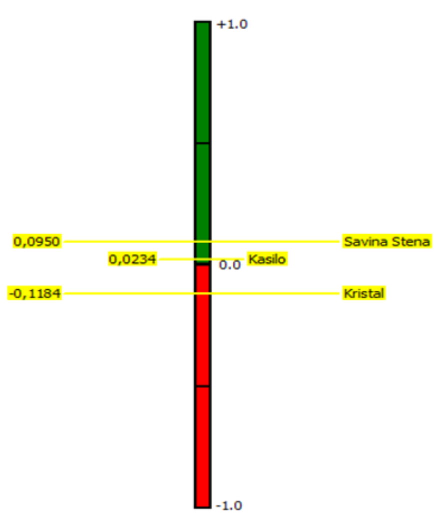


Figure 4. Final ranking

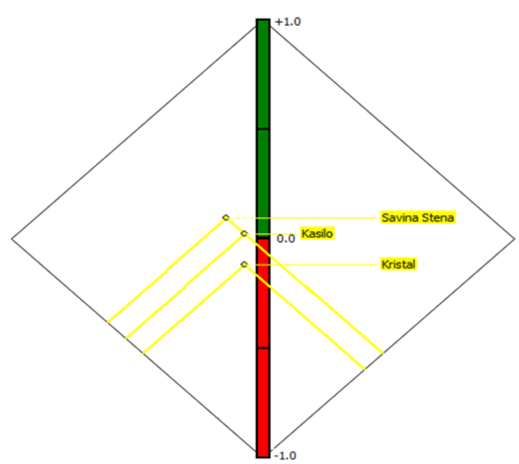


Figure 5. PROMETHEE diamond solutions

The PROMETHEE diamond solution was presented with the dot on (Phi+, Phi−) flat. The flat was at an angle of 45° so that the vertical dimension (red-green axis) corresponded to Phi net flow. A cone was drawn for every alternative (Milentijević at al., 2016). The highest priority alternative was Savina Stena, and the lowest was alternative Kristal.

In Figure 6, the GAIA plan is shown (Geometrical Analysis for Interactive Assistance), which is a descriptive addition to the PROMETHEE ranking. Every alternative was presented with a dot found on the GAIA plan. The position of these alternatives was connected with the marks of a set of criteria. Each criterion was presented with the axis from the center of the GAIA plan. The orientation of these axes showed how these criteria were interrelated. The determination axis (red axis) suggested the alternative tailing Kristal had the least favorable impact on the surrounding ecosystem (Milentijević at al., 2016).

The performance profiles shown in Figure 7 show a special view of the strengths and weaknesses of the alternatives based on the inserted criteria values. Action profiles are a graphical representation of the net flow results for the criteria. For each alternative, upward is interpreted as a positive result, while downward bands are interpreted negatively. For example, for the Savina Stena alternative, only the criteria Proximity of the settlement and Geological environment had negative results.

The results of the comparison are affected by the weights assigned to the criteria, so it is important to know how the ranking changes when the weights change. A special feature of the software called walking weights allows the sensitivity analysis of the final results, when the weights change. The Walking Weights feature allows you to increase the weight of a certain criterion while reducing the weight of other criteria proportionally. Variations were observed, but there were no changes in the order of alternatives. When the criteria gained equal weight, the sensitivity analysis showed that the ranking of alternatives was quite stable, i.e. that there was no change in the final ranking (Figure 8). Savina Stena's alternative was still the best choice. It is clear from this analysis that the weights of the criteria do not affect the final ranking.

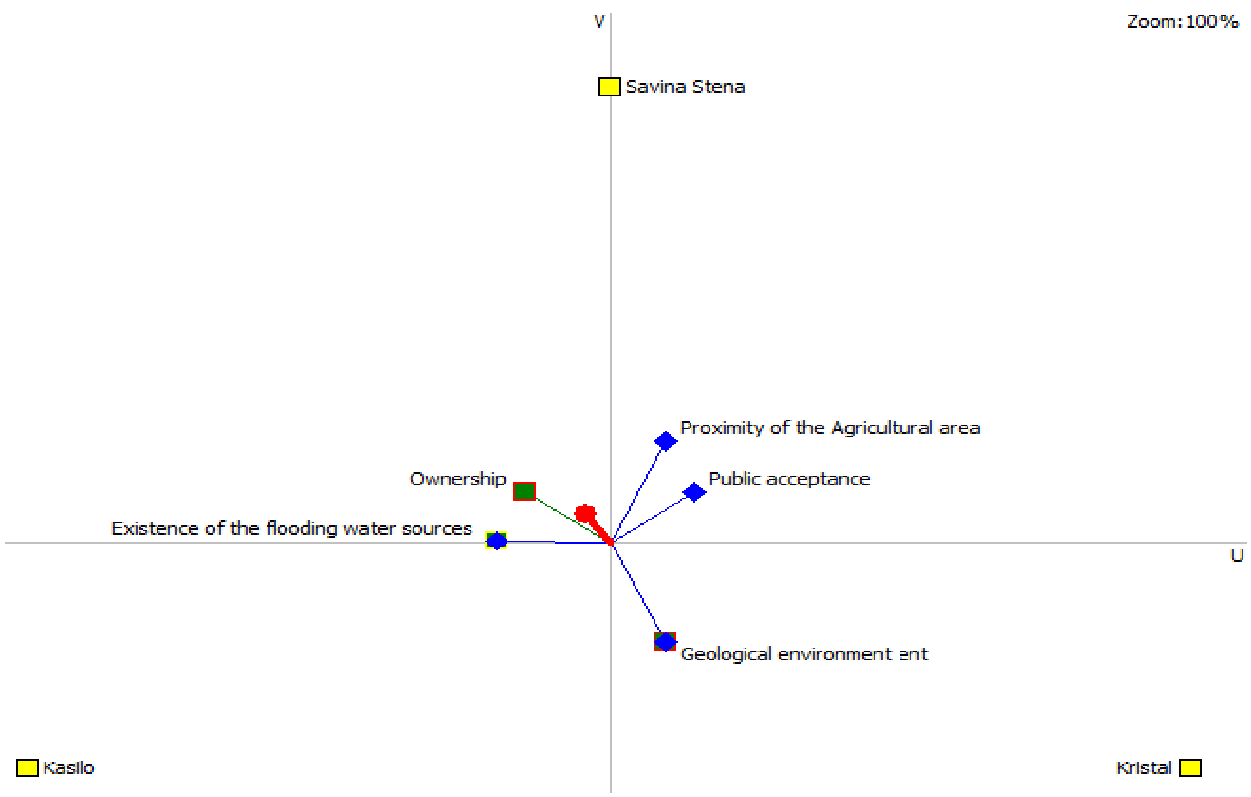


Figure 6. GAIA plan for landfill location

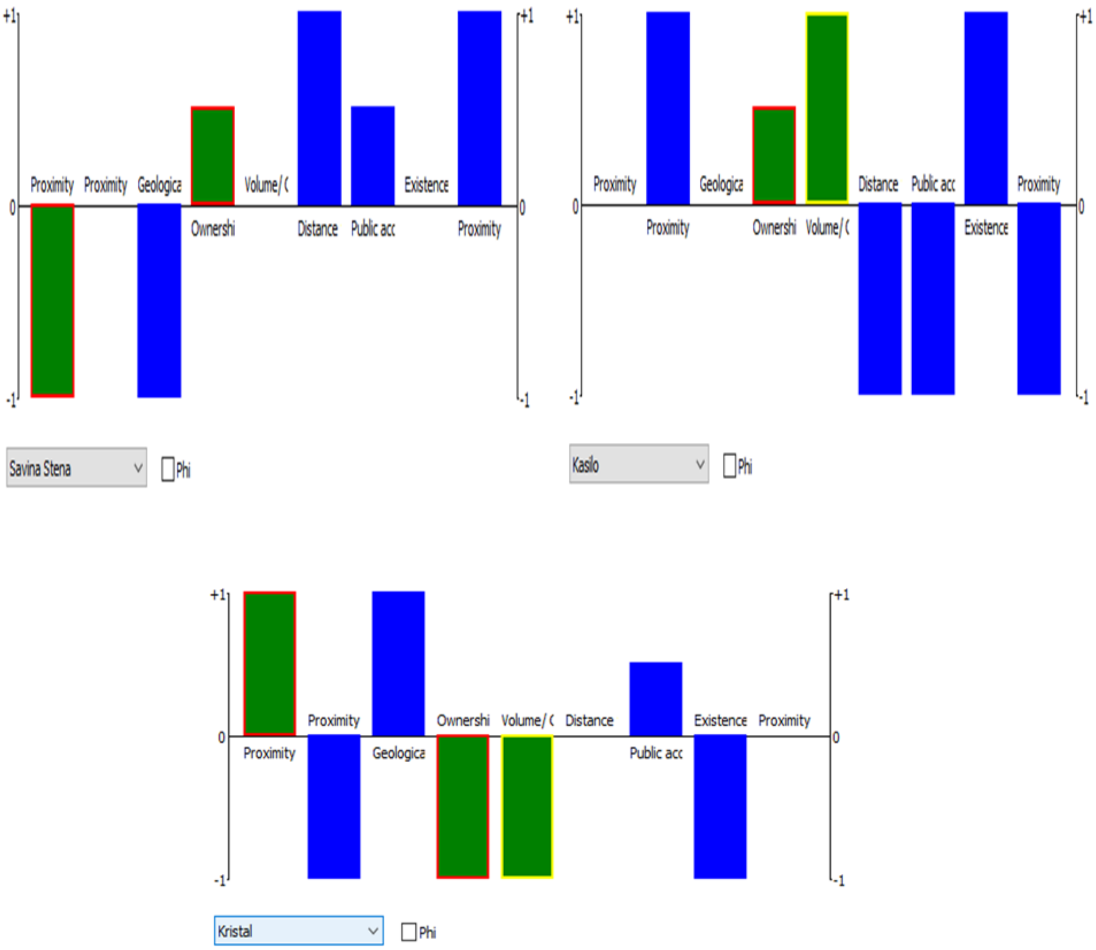
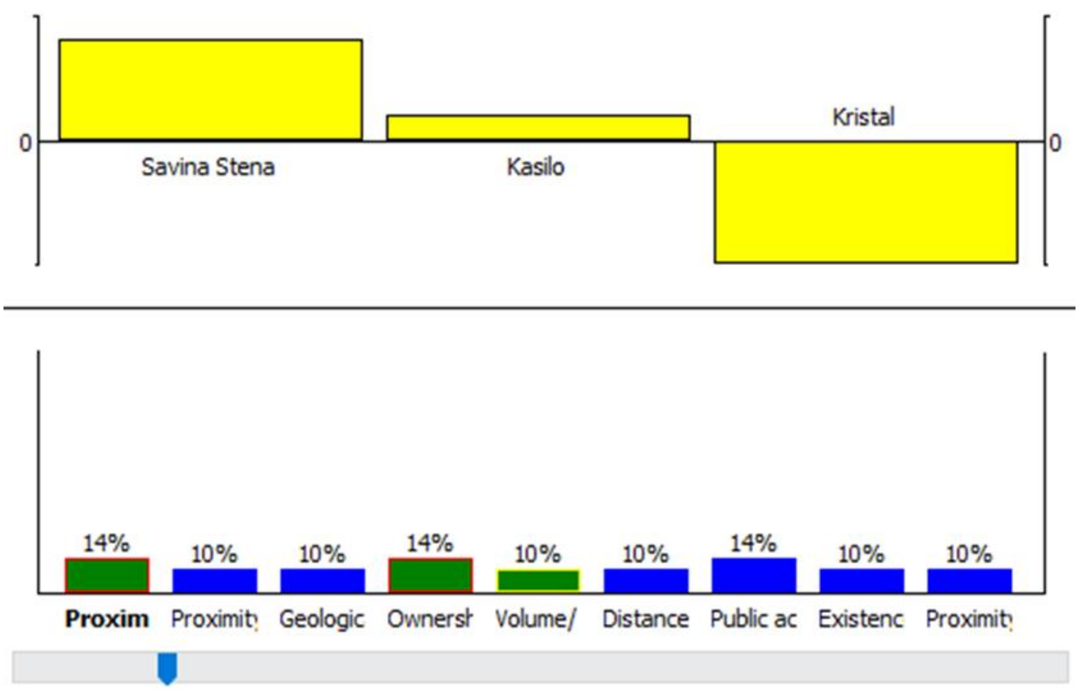


Figure 7. Action profile



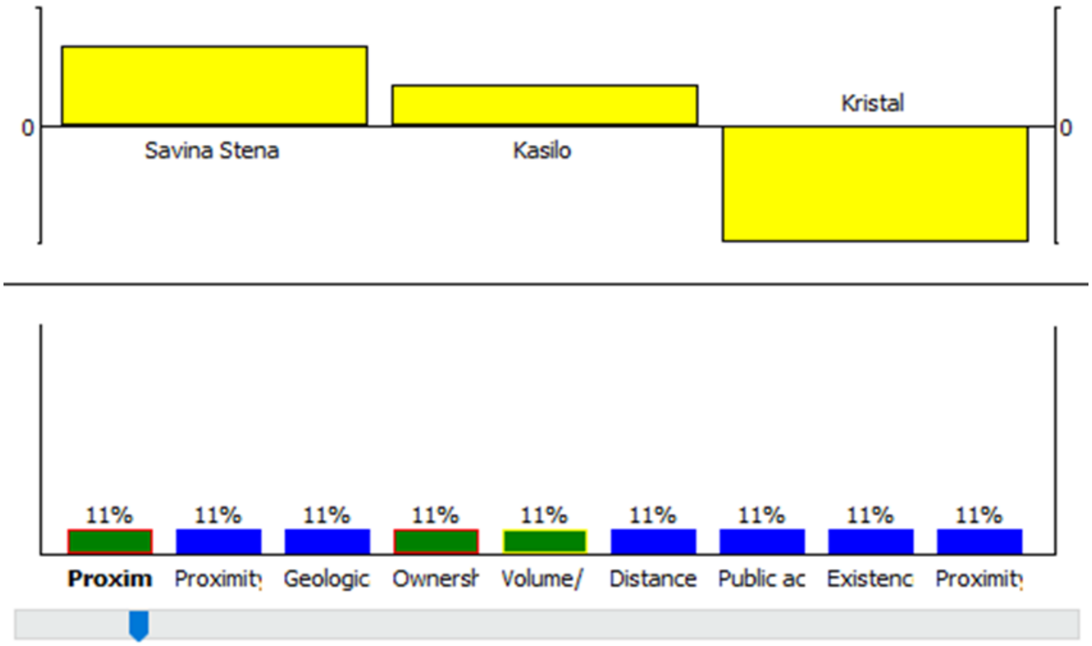


Figure 8. Walking Weights

This paper analyzes and ranks sites for the construction of a sanitary landfill based on the criteria of sustainable development. The result obtained by multi-criteria analysis of ranking the possibility of successful construction between the three proposed construction sites, based on nine selected criteria, using the PROMETHEE method showed a certain reality, which was consistent with the situation on the ground. Different preference functions were used depending on the criteria. The obtained results of NET flow, PROMETHEE diamond solutions, GAIA landfill site plan, Action profile for all alternatives, and sensitivity analysis of Walking Weights are presented. Based on the conducted analysis, the most adequate location for the construction of the sanitary landfill was Savina Stena, followed by Kasilo and Kristal. The application of the obtained results can be used in the decision-making process for spatial planning and development plans, as well as for solid waste management plans.

The application of the method for multi-criteria analysis of waste management plans should be an integral part of the overall management system to the highest level, because the implementation of environmental protection is an interactive process. In the case of a sanitary landfill, the capacity of the method for multicriteria analysis is demonstrated in the area of analysis and ranking of the landfill's impact on the surrounding ecosystem, economic benefits and society as a whole.

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Alati za donošenje odluka u izbor lokacije regionalne sanitarne deponije

Bojana Živković [a,#], Jelisaveta Marjanović [b], Jelena Đokić [a]

[a] Univerzitet u Prištini, Fakultet tehničkih nauka, Kosovska Mitrovica, Srbija
[b] Međunarodni Poslovni Koledž Mitrovica-IBCM, Kosovska Mitrovica, Srbija

INFORMACIJE O RADU

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Ključne reči:
Višekriterijumska analiza
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Regionalna sanitarna deponija
Životna sredina

I Z V O D

U radu je primenjena inteligentna višekriterijumska analiza u cilju rangiranja kriterijuma u procesu izbora lokacije za Regionalnu sanitarnu deponiju. Analiza je obavljena za 3 unapred odabrane lokacije koje su odabrane na osnovu raspoložive površine, pristupa lokaciji, potencijalnih poteškoća u pripremi, pojave podzemnih voda, biodiverziteta i blizine urbanog područja. Ove lokacije su odabrane kao najpogodnije za izgradnju, kako sa inženjerskog tako i sa ekonomskog i ekološkog aspekta. Analiza je najbolji primer primene inteligentne višekriterijumske analize kao korisnog alata za upravljanje životnom sredinom u procesu donošenja odluka. Analiza je izvršena za tri predložene lokacije Regionalne sanitarne deponije: Kasilo, Kristal i Savina Stena, u opštinama Zvečan i Leposavić. Da bi se postigli što objektivniji rezultati, primenjene su PROMETHEE metode. Ovim metodama proračuna dobijena je sledeća rang lista lokacija za Regionalnu sanitarnu deponiju prema njihovoj podobnosti: Savina Stena, Kasilo i Kristal. Ovaj rezultat može doprineti procesu donošenja odluka o utvrđivanju strategije razvoja na lokalnom i regionalnom nivou.