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Managing renewable energy resources choosing the sustainable development projects in Eastern Serbia – MCDM methods

Introduction

Great potential in the modern world for the development of both the economy and the protection of natural values lies in using up renewable energy resources [Magdalinovic, 2007]. Undoubtedly, a decision-maker has the hardest task. The analysis of the way people make decisions or the way people ought to make decisions is perhaps as old as the recorded history of mankind [Traintaphyllou, 2000]. Although good decisions are mainly the result of good decision-making processes, Henig and Buchanan [Henig and Buchanan, 1996] and Buchanan et al. [Buchanan et al. 1998] agree that the subjective and objective parts of the decision-making process should be separated. The purpose of Multi-Criteria Decision Making (MCDM) is to support decision-makers facing and solving problems. This paper presents the possibility of finding adequate solutions in deciding between several projects for development strategies, applying MCDM methods, the ELECTRE method, but also using the AHP method as an ancillary method to determine the weights of criteria. The concept of the paper was made as follows: the first part is the introduction, while the second part explains Multiple-Criteria Decision Making. Section three presents the theory of the ELECTRE method, and section four explains the application of the selected method used for ranking projects in Gamzigrad. The discussion section examines the effectiveness of the ELECTRE method, and also provides an overview of the final results. Finally, the conclusion, gives recommendations for the final selection of projects.

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Multi-Criteria Decision Making

Multi-Criteria Decision Making (MCDM) is one of the most well-known branches of decision making. According to many authors, such as Zimmerman, MCDM is divided into Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM) [Zimmerman, 1996]. MODM studies problems in which the decision space is continuous. A typical example is mathematical programming problems with multi-objective functions, also known as the „vector-maximum" problems [Kuhn, Tucker, 1951]. On the other hand, MADM concentrates on problems with discrete decision spaces [Zimmerman, 1996]. It can be said, that the complexity of making decision requires a multi-criteria model, as the basis for the initial condition in the selection of appropriate solutions [Radojicic, Zizovic, 1998]. The concept of MCDM refers to situations when there are a number of conflicting criteria [Cupic et al. 2001]. The decision-making process is made up of the components of objectively defined projects and the components of subjectively defined criteria. The decision-maker's preferences are subjective, and examining criteria on the basis of attributes is definitely a subjective process [Vanderpooten, 1990]. However, it is generally accepted that analysing a decision-making problem should improve the process itself and enhance the quality of the decision-made issue [Schwenk and Thomas, 1983]. The selection of MCDM methods largely depends on the characteristics of the decision and its significance, but also it depends on time [Vincke, 1992].

ELECTRE method

The ELECTRE method (ELimination Et Choix Traduisant la REalité) was created by Bernard Roy in 1971, as an answer to the lack of existing methods for decision-making, as well as a part of the philosophy „Multi Criteria Decision Making – MCDM" [Roy, 1968]. The basic version originated in the period from 1993 to 1996 [Roy, 1993]. The basic version has continued to evolve with ELECTRE II, ELECTRE III, ELECTRE IV, ELECTRE IS and ELECTRE TRI (electre tree) [Figueira, Greco, Ehrgott, 2005]. Relevant principles of mentioned versions are common to all methods [Hokkanen and Salminen, 1997]. Talking about some individual methods, ELECTRE I is used to determine the partial order of alternatives [Rogers and Bruen, 1998]. At the very beginning of a process, it is necessary to define the initial decision matrix and the general form of this is shown in Table 1. Beyond that, it should be quantified matrix via the linear scale. The linear scale usually has values ranging from ^{0} to ^{10} for estimating the importance of criteria, meaning that ^{0} represents the lowest level, while ^{10} is the value for the highest possible level that can be realised. In this paper, the following grades of criteria are used: ^{1} – very low, ^{3} – low, ^{5} – average, ^{7} – high and ^{9} – very high.

Table 1. General form of the initial matrix

Criteria	C1	C2	...	Cn
Alternative				
A1	X11	X12	...	X1n
A2	X21	X22	...	X2n
A3	X31	X32	...	X3n
...	...	...	...	...
An	Xn1	Xn2	...	Xmn

Source: Metode Odlučivanja, Nikolic, 2009.

The first step involves calculating normalized decision matrix via adequate formulas (1, 2) by which normalized elements are calculated. The formula 3 is applied to the attribute of type max, while the formula 4 is applied to the attribute of type min. Each element of vector columns from the normalized decision matrix is divided by its norm [Nikolic, 2009].

(1) $$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}$$

(2) $$n_{ij} = 1 - \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}$$

The general form of the normalized decision matrix is shown in Table 2.

Table 2. General form of normalized decision matrix

n_{11}	n_{12}	...	n_{1n}
n_{21}	n_{22}	...	n_{2n}
...	...	...	...
n_{m1}	n_{m2}	...	n_{mn}

Source: Teorija Odlučivanja, Mitevska, 2005.

The second step involves calculated weighted normalized matrix, where the decision-maker actively participates in the procedure of solving the problem by determining the preference that is the weight of user's criterion (formula 3) [Mitevska, 2005]. The general form of weighted normalized matrix is shown in Table 3.

(3) $$TN = T \bullet N$$

Table 3. General form of weighted normalized matrix – TN

$t_1\ n_{11}$	$t_1 n_{12}$	...	$t_1 n_{1n}$
$t_1\ n_{21}$	$t_1 n_{22}$	...	$t_1\ n_{2n}$
...	...	...	...
$t_1\ n_{m1}$	$t\ n_{m2}$	...	$t_1 n_{mn}$

Source: Teorija Odlučivanja, Mitevska, 2005.

In this paper, in is the section where the Analytical Hierarchical Process (AHP) method is applied, by comparing in pairs, on the basis of opinion of three experts, it is possible to get more a exact determination of criteria weights. The AHP method was developed at the start of the 1970s, by Thomas Saaty [Saaty, 1980]. It is a useful tool in decision-making analysis to solve problems involving a large number of decision-makers, in which there are a large number of criteria, and it that can be applied in many time periods [Cupic et al. 2001]. The AHP method can be applied in MCDM. The third step of the ELECTRE method, determines groups of agreements and disagreements by comparing pairs of actions where, by forming a group of agreements, desirable and less desirable actions are separated (less desirable actions form the group of disagreements). This step compares all pairs of the analysed actions on the basis of the value of elements from the weighted normalized matrix [Mitevska, 2005]. There, we compare the pairs of actions and. Firstly, it is determined the group of agreements for the actions and (actions mark the alternatives), made up of all criteria, for which the action, or alternative is more desirable than the alternative, or action, that is shown in formula 4 [Mitevska, 2005].

(4) $$S_{pr} = \left\{ j \middle|\ xpj \geq xrj \right\}$$

Then, it forms the complementary group of disagreements –, by using the formula 5 [Mitevska, 2005]:

(5) $$NS_{pr} = J - S_{pr} = \left\{ j \middle|\ xpj < xrj \right\}$$

In the fourth step, the matrix of agreement is defined on the basis of the group of agreements. The elements of the matrix of consent are the indices of agreement, and they are calculated as a sum of the weights of criteria belonging to certain groups of agreements. Based on the group of agreements, it is determined the matrix of agreement S. For calculating the values of the matrix, formula 6 is used [Mitevska, 2005].

(6) $$S_{pr} = \sum_{j \in Spr} t_j$$

The fifth step refers to determining the disagreement matrix on the basis of the group of disagreements. The elements of the matrix are the indices of disagreement, determined by formula 7 [Mitevska, 2005]. The element of weight normalized matrix in the formula is marked as *tn*.

(7) $$ns_{pr} = \frac{\max_{j \in NSpr} \left[tn_{pj} - tn_{rj} \right]}{\max_{j \in J} \left[tn_{pj} - tn_{rj} \right]}$$

In the sixth step,the matrix of agreement domination is determined, and on the basis of the value of so-called threshold of agreement index (the average index of consent) – which can be also defined as average index of agreement – **PIS** (formula 8) [Nikolic, 2009].

(8) $$PIS = \sum_{p=1}^{m} \sum_{r=1}^{m} \frac{s_{pr}}{m(m-1)} \quad where \;\; p \neq r$$

The matrix of agreement domination – MSD is calculated on the basis of the following criteria:

(9) $$msd_{pr} = 1 \;\; for \;\; s_{pr} \geq PIS$$

(10) $$msd_{pr} = 0 \;\; for \;\; s_{pr} < PIS$$

Determining the matrix of disagreement domination is the basis of the seventh step. It is calculated on the basis of the average index of disagreement, as it is analogous to the matrix of agreement domination [Cupic, Tummala, 1997]. First, the average index of disagreement is calculated – PINS (formula 11) [Nikolic, 2009].

(11) $$PINS = \sum_{p=1}^{m} \sum_{r=1}^{m} \frac{ns_{pr}}{m(m-1)} \quad where \;\; p \neq r$$

The matrix of disagreement domination is formed on the basis of the following criteria:

(12) $$mnsd_{pr} = 1 \;\; for \;\; s_{pr} \leq PINS$$

(13) $$mnsd_{pr} = 0 \;\; for \;\; s_{pr} > PINS$$

The eighth step determines the matrix of aggregate domination. The elements of this matrix are equal to the product of the elements on definite position in matrices of agreement and disagreement domination (Formula 14) [Mitevska, 2005].

(14) $$mad_{pr} = msd_{pr} \bullet mnsd_{pr}$$

Finally, in the ninth step, less desirable actions are eliminated, while one or more alternatives is/are sorted out as most desirable. The matrix of aggregate domination gives partial preferred order of actions [Adamovic et al. 2008].

Ranking projects of Gamzigrad Spa by applying the ELECTRE method

Gamzigrad Spa is a little village with a geo-thermal well, in Eastern Serbia. Taking into consideration how much the existing facilities are used, we should point out that the business operations of Gamzigrad Spa are based on relatively modest capacities of one hotel „Kastrum" and a rehabilitation institution called the Institute for Specialized Rehabilitation „Gamzigrad". So far, the state has invested relatively small funds in Gamzigrad. This paper emphasises the choice of the best alternatives for making adequate decisions about the development of the geo-thermal well as a renewable energy resource. Regarding the geographic position of Gamzigrad Spa and its tourism potential, proposed projects were considered in order to find the ones which would best contribute to sustainable development and relate to future development strategy. To determine good possibilities for the future development of Gamzigrad, a group of experts, including financial consultants, accountants and potential investors, drew up a list of projects that could be acceptable relating to financial and other criteria. The following five development projects have been defined and accepted: health tourism, sport tourism, recreation tourism, rural tourism, conference tourism. Each project, or the alternative for future development strategy, was defined by its attributes, that is, appropriate criteria. After talks with the management team, the following five criteria (with some attributes shown in brackets) were defined for evaluation of the projects:

1. FI (financial investments) (investment in Euros – 200,000).
2. EN (the environment) – (the influence on resources and approach to resources) – maximum care for the environment.
3. SD (solution delivery) – relating to subsequent appropriate solutions if initial ones are not adequate (proof of technology, uncertainness, if benefits are measurable)- expressed in Euros – 250,000.

4. SC (strategic contribution) (the contribution to the business plan for Gamzigradska Spa and its surroundings) – it was estimated that maximum is necessary.
5. RM (risk management) (the risk that a new investment will be a failure) – it is necessary to lessen the risk to its minimum.

Table 4 shows the values of the five projects and the five criteria that were used to select the optimum development project for Gamzigrad.

Table 4. Values of criteria and project

Criteria	FI	SD	SC	RM	EN
Project	min	min	max	min	max
Health (P_1)	200,000	250,000	high	average	v. high
Sport (P_2)	70,000	90,000	v. high	average	high
Recreation (P_3)	60,000	70,000	v. high	low	v. high
Rural (P_4)	120,000	140,000	high	low	high
Conference (P_5)	40,000	60,000	high	low	v. high

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

Financial criterion (FI), as well as the criterion „second solution choice" (SD – solution delivery), is measured by calculating the *Net Present Value* (*NPV)*. The results of the remaining three criteria were obtained by arbitrary ranking on the adequate scale. The evaluation of the project attributes is carried out as objectively as possible, together with experts familiar with the details of the project. Table 1 was used to create the initial decision matrix, shown in Table 5.

Table 5. Initial decision matrix

Criteria	FI	SD	SC	RM	EN
Project	min	min	max	min	max
P_1	200,000	250,000	7	5	9
P_2	70,000	90,000	9	5	7
P_3	60,000	70,000	9	3	9
P_4	120,000	140,000	7	3	7
P_5	40,000	60,000	7	3	9

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

Applying formulas 3 and 4 [Mitevska, 2005] using the data from the Table 5, the normalized decision matrix was obtained, shown in Table 6.

Table 6. Normalized decision matrix

	FI	SD	SC	RM	EN
P_1	0.790	0.800	0.398	0.570	0.487
P_2	0.275	0.286	0.511	0.570	0.380
P_3	0.236	0.222	0.511	0.341	0.487
P_4	0.472	0.445	0.398	0.341	0.380
P_5	0.157	0.190	0.398	0.341	0.487

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

By applying formula 3, the weighted normalized matrix – TN – is calculated. Here, the decision-maker determines the criteria weights. In the case of Gamzigrad, three experts (ecologist, sociologist, and economist) were consulted to calculate the criteria weights. Using the AHP method [see Saaty, 1980], based on the experts' comparisons of the criteria in pairs, the criteria weights were calculated. This needs reworded – suggest 'The final criteria values were calculated using the arithmetic mean and each expert's results are shown in Tables 7, 8 and 9.

Table 7. Weights of criteria – Expert 1

	FI	EN	RM	SC	SD	Cr	Wt
FI	1	1/7	1/3	1	1	FI	0.072
EN	7	1	5	7	7	EN	0.580
RM	3	0.200	1	3	3	RM	0.188
SC	1	0.143	0.333	1	0.333	SC	0.061
SD	1	0.143	0.333	3	1	SD	0.099

Consistency Ratio (CR) = 7.39%
Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

Table 8. Weights of criteria – Expert 2

	FI	EN	RM	SC	SD	Cr	Wt
FI	1	1/7	1	5	1	FI	0.136
EN	7	1	3	7	7	EN	0.539
RM	1	0.333	1	5	3	RM	0.190
SC	0.200	0.143	0.200	1	0.333	SC	0.042
SD	1	0.143	0.333	3	1	SD	0.093

Consistency Ratio (CR) = 9.30%
Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

Table 9. Weights of criteria – Expert 3

	FI	EN	RM	SC	SD	Cr	Wt
FI	1	1/7	1/3	3	1	FI	0.091
EN	7	1	5	7	7	EN	0.569
RM	3	0.200	1	5	3	RM	0.204
SC	0.333	0.143	0.200	1	0.333	SC	0.045
SD	1	0.143	0.333	3	1	SD	0.091

Consistency Ratio (CR) = 9.50%
Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

The final values of criteria weights, obtained by calculating the arithmetic mean for each criterion, are shown in Table 10.

Table 10. Arithmetic mean – weights of criteria

Criteria	Weight
FI	0.100
SD	0.094
SC	0.049
RM	0.194
EN	0.563
Σ	1

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

The weighted normalized matrix – TN, is shown in Table 11.

Table 11. Weighted normalized matrix – TN

	FI	**SD**	**SC**	**RM**	**EN**
P_1	0.078	0.074	0.020	0.110	0.274
P_2	0.028	0.026	0.025	0.110	0.213
P_3	0.024	0.021	0.025	0.066	0.274
P_4	0.047	0.042	0.020	0.066	0.213
P_5	0.016	0.018	0.020	0.066	0.274
W_{Cr}	0.100	0.094	0.049	0.194	0.563

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

Formulas 6 and 7 determine the groups of agreements **– S –** and disagreements **– NS** (Table 12).

Table 12. Groups of agreements (S) and disagreements (NS)

Groups of agreements S	Groups of disagreements NS
S_{12} = 1,2,4,5	NS_{12} = 3
S_{13} = 1,2,4,5	NS_{13} = 3
S_{14} = 1,2,3,4,5	NS_{14} = –
S_{15} = 1,2,3	NS_{15} = 4, 5
S_{21} = 3,4	NS_{21} = 1,2,5
S_{23} = 1,2,3,4	NS_{23} = 5
S_{24} = 3,4,5	NS_{24} = 1,2
S_{25} = 1,2,3,4	NS_{25} = 5
S_{31} = 3,5	NS_{31} = 1,2,4
S_{32} = 3,5	NS_{32} = 1,2,4
S_{34} = 3,4,5	NS_{34} = 1,2
S_{35} = 1,2,3,4,5	NS_{35} = –
S_{41} = 3	NS_{41} = 1,2,4,5
S_{42} = 1,2,5	NS_{42} = 3,4
S_{43} = 1,2,4	NS_{43} = 3,5
S_{45} = 1,2,3,4	NS_{45} = 5
S_{51} = 3,5	NS_{51} = 1,2,4
S_{52} = 5	NS_{52} = 1,2,3,4
S_{53} = 4,5	NS_{53} = 1,2,3
S_{54} = 3,4,5	NS_{54} = 1,2

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigrada.

The matrix of agreement – MS, for definite values of the index is calculated by applying formula 6 and is shown in Table 13.

Table 13. Matrix of agreement – MS

0	0.757	0.563	0.612	0.612
0.437	0	0.049	0.806	0.049
1	1	0	1	0.806
0.437	0.757	0.194	0	0.243
1	0.951	0.951	1	0

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

The matrix of disagreement – MNS, is calculated by applying formula 7 (Table 14).

Table 14. Matrix of disagreement – MNS

0	0.840	1	0.725	1
1	0	1	1	1
0	0	0	0	1
1	0.045	1	0	1
0	0.092	0.708	0	0

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

Matrix of agreed domination – MSD is shown in Table 15 (applying formula 9 and 10).

Table 15. Matrix of agreed domination – MSD

0	1	0	0	0
0	0	0	1	0
1	1	0	1	1
0	1	0	0	0
1	1	1	1	0

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

The matrix of disagreed domination – MNSD, is shown in Table 16 (formulas 12 and 13).

Table 16. Matrix of disagreed domination – MNSD

0	0	0	0	0
0	0	0	0	0
1	1	0	1	0
0	1	0	0	0
1	1	0	1	0

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

The next step is determining the aggregate domination matrix – MAD (matrix of aggregate domination). This is shown in Table 17 (calculated by applying formula 14).

Table 17. Matrix of aggregate domination – MAD

P_1	0	0	0	0
0	P_2	0	0	0
1	1	P_3	1	0
0	1	0	P_4	0
1	1	0	1	P_5

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

The last step, step nine, of the ELECTRE method, by eliminating less desirable actions, projects, („→" = „dominates"), led us to the following recommended projects (Table 18).

Table 18. Final rank of projects

$P_3 \rightarrow P_1, P_2, P_4$	Dominates P_1, P_2, P_4
$P_5 \rightarrow P_1, P_2, P_4$	Dominates P_1, P_2, P_4
P_2	Does not dominate
$P_4 \rightarrow P_2$	Dominates P_2
P_1	Does not dominate

Source: Strategijski pravci regionalnog ekonomskog i ekološkog razvoja turističkog potencijala Gamzigradske Banje, Doctoral thesis.

Discussion

The process of evaluation of the suggested projects ran its own course. To the employees in the sector for the development of Gamzigrad, who could submit smaller projects for consideration, an online form was available for collecting relevant data. Ten small value projects were submitted; the data for each was represented in an adequate way (with definite values and necessary investments). Business analysts and the group of accountants examined the data for each project, so that co-existence, or impartiality, could be provided. The matrix of performance was formed in this way. At the same time, a presentation of the projects was prepared for sponsors and investors who took into consideration the basic concepts of the ELECTRE method and gave answers to questions asked. The aim of this approach was to lessen the costs and shorten the time. A group of experts created a short survey of each project to prove their safety and accuracy. The revised list was approved and submitted from which the five most financially favourable projects were chosen. In order to weight each selected project, the criteria were precisely defined, and the AHP

method was applied, which compared and ranked three expert opinions. Applying the ELECTRE method to the five selected projects, showed that two projects dominated the other three.

As mentioned in the basic version of ELECTRE method, it is often not possible to establish a state of domination, in other words it is possible that more than one project dominates the others. Here, although project P4 dominates P2, it is itself dominated by P3 and P5). The two dominant projects are the recreation tourism and the conference tourism projects. In the paper „Determination of Gamzigrad spa development strategies using TOPSIS and ELECTRE", by applying two methods of MCDM: TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and ELECTRE, the results obtained are not completely identical [Ilic et al. 2013]. TOPSIS shows conference tourism as the most appropriate choice. Recreation tourism was in second place, sports tourism in the third, and lastly rural tourism and health tourism. It can be concluded that solution given by the TOPSIS is more accurate and elegant because it ranks all the options precisely [Ilic et al. 2013]. So, it can be concluded that the ranking of development projects requires the application of two or more methods of MCDM, helping the decision-maker to choose the optimal solution.

Conclusion

It can be said that the application of the ELECTRE method, as a pilot method for ranking smaller projects for development of Gamzigrad Spa, was relatively successful. The whole process could be called a kind of „test of common sense". It means that the decision-makers accepted both the process of ranking and the issue. The approach of the ELECTRE method, described in this paper, besides the ranking projects, also separates objective components from subjective ones. The performances – influences of each project on five criteria – are objective and should be separated from the preferences of the decision-makers. This is in accordance with the noted supposition of the decision analysis.

Summary

The paper presents the ranking of projects for Gamzigrad Spa in Eastern Serbia, applying two methods of MCDM; ELECTRE I and AHP. Using these methods, it has been calculated that the projects of health and sport tourism do not dominate, while the project of rural tourism dominates the project of sport tourism. However, the projects of recreation and conference tourism dominate the other projects which means that these are the most appropriate ones. A further question can be asked: between the two projects that

the ELECTRE method has determined as acceptable, which one is better? If we take into account the financial criterion, then the development strategy of Gamzigrad Spa in eastern Serbia should be based on conference tourism, because the investment needed for this project is lower than the investment required for recreation tourism. Therefore, the project of conference tourism is economically better than the others. In the experts' opinions and on its rank in the selected methods, beside requiring the least investment, the conference tourism project requires the shortest time for implementation. So, it can be said that the conference tourism is the best option for development that meets the needs of the people and nature in the region of Eastern Serbia.

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Zarządzanie odnawialnymi źródłami energii i wybieranie projektów zrównoważonego rozwoju we wschodniej Serbii – metody MCDM

Streszczenie

Współczesny świat staje przed potrzebą globalnej, wspólnej odpowiedzialności za rozwój zgodnie z potrzebami ludzi i środowiska. Korzystanie ze źródeł energii odnawialnej stwarza duży potencjał rozwoju w zakresie ekonomii oraz ochrony wartości naturalnych. Serbia jest krajem bogatym w odnawialne zasoby naturalne, które nie są wykorzystywane w wystarczający sposób. Praca ta skupia się na uszeregowaniu projektów zrównoważonego rozwoju we wschodniej Serbii, mieście Zajecar, resorcie spa Gamzigrad i jego studni termalno-mineralnych. Projekty rozwoju są uszeregowane poprzez zastosowanie metody ELECTRE oraz metody AHP, jako metody wspomagającej w celu określenia wagi kryteriów. Obie te metody stosowane są w obszarze podejmowania decyzji na podstawie wielu kryteriów (ang. Multiple-Criteria Decision Making). Metoda ELECTRE I jest często stosowana do określania częściowego uszeregowania alternatyw. Ten sposób szeregowania projektów przyczynia się do zrównoważonego rozwoju i zrównoważonego zarządzania zasobami naturalnymi w Serbii. Zrównoważone zarządzanie zasobami naturalnymi przyczynia się do podnoszenia jakości życia mieszkańców Serbii oraz wschodniego regionu kraju.

Słowa kluczowe: ranking projektów, podejmowanie decyzji na podstawie wielu kryteriów (ang. *Multiple-Criteria Decision Making*), energia geotermalna, źródła odnawialne

Managing renewable energy resources choosing the sustainable development projects in Eastern Serbia – MCDM methods

Abstract

The modern world is faced with the need of global, common responsibility for development in accordance with the needs of people and nature. Great potential for development of both economic and protection of natural values lies in using up renewable energy resources. Serbia is the country rich in renewable natural resources, which are not used enough. The focus of this paper is the ranking of sustainable development projects in Eastern Serbia, the city of Zajecar, the resort of Gamzigrad spa and its thermo-mineral wells. Development projects are ranked by application of the ELECTRE method and by application of the AHP method, as an ancillary method to determine the weights of criteria. Both of the methods are in the field of Multiple-Criteria Decision Making. The ELECTRE method I is often used for determining partial orders of alternatives. This way of ranking projects is contributing to sustainable development and sustainable management of natural resources in Serbia. Sustainable management of natural resources contributes to raising the quality of life of the citizens of Serbia, and in the Eastern region of the country.

Key words: project ranking, Multiple-Criteria Decision Making, geothermal energy, renewable resource

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