Determination the advantage of solution in Eastern Serbia using the FTOPSIS method and comparison with the TOPSIS method

Sandra Milutinović, Milena Kostović, Ivana Jovanović, Miomir Mikić, Daniel Kržanović

DETERMINATION THE ADVANTAGE OF SOLUTION IN EASTERN SERBIA USING THE FTOPSIS METHOD AND COMPARISON WITH THE TOPSIS METHOD

Sandra Milutinović[1], Milena Kostović[2], Ivana Jovanović[1], Miomir Mikić[1], Daniel Kržanović[1]

[1]Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia, sandra.milutinovic@irmbor.co.rs
[2]Faculty of Mining and Geology, University of Belgrade, Đušina 7, 11120 Beograd, Serbia

Abstract

Using the Fuzzy TOPSIS method, the ore deposit selection methodology was determined. The selection of the best deposit is presented, as well as a comparative analysis of the output values of this method and the classical TOPSIS method.
***Keywords**: FTOPSIS, TOPSIS, MCDM*

1 INTRODUCTION

The choice of the optimal, best deposit is a strategic problem, due to a large number of alternatives and criteria that should be considered in a decision making. The decision that will be made will significantly impact business in terms of achieving the technical, environmental, and economic goals. Accordingly, the main goal of this work is to present the choice of the best deposit and a comparative analysis of the output values of the applied methods. The methods to be used are the TOPSIS and FTOPSIS.

2 APPLICATION OF THE FTOPSIS METHOD IN THE SELECTION OF ORE DEPOSITS IN EASTERN SERBIA

Phase logic ("fuzzy" - vague, indefinite) is not the same as the classical Aristotelian logic and therefore represents a view of the world that is different from the ingrained and based on the classical logic, i.e. the predicate calculus, and ZF (Zermelo-Frankel) set theory. [1]

Table 1 *Basic data*

Deposit/ Criterion	Copper content in ore (%)	Silver content in the ore (g/t)	Gold content in the ore (g/t)	Tested quantities of minerals in the ore deposit	Location	Mining and geological parameters
Čukaru Peki – Upper Zone	2.71	3.16	1.7	Very high	High	High
Veliki Krivelj	0,322	0,79	0,7	High	Average	High
South Mining District	0,316	1,365	0,178	High	Average	High
North Mining District	0,298	1,730	0,238	High	Average	High
Cerovo	0,340	1,8	0,11	High	Low	Very low

The analyzed area of Eastern Serbia has several deposits where the base metal that can be found is copper, followed by a certain amount of silver and gold. If the right ore deposit, which has the best characteristics, is chosen for exploitation, the contribution will be of a great importance, especially for an economic growth in Eastern Serbia. The comparison was made for five deposits, as follows: A_1 – Čukaru Peki – Upper Zone; A_2 – Veliki Krivelj; A_3 – Majdanpek – South Mining District; A_4 – Majdanpek – North Mining District; A_5 – Cerovo.

The basic criteria for the selection of an ore deposit are: k1 - Copper content in ore (%); k2 - Silver content in the ore (g/t); k3 - Gold content in the ore (g/t); k4 - Tested quantities of minerals in the ore deposit; k5 - Location; k6 - Mining and geological parameters. The basic data required for the preparation of this work are given in Table 1.

3 APPLICATION OF THE FUZZY TOPSIS METHOD

The basic criteria for analysis, i.e. the selection of appropriate linguistic variables for the evaluation of attributes are shown in Table 2.

Table 2 *Defining THE basic parameters for analysis and values of fuzzy numbers*

	K1	K2	K3	K4	K5	K6	Term	Fuzzy number
A1	Very high	Very high	High	Very high	High	High	Very low	1,1,3
A2	Low	Very low	Average	High	Average	High	Low	1,3,5
A3	Low	Low	Low	High	Average	High	Average	3,5,7
A4	Very low	Average	Low	High	Average	High	High	5,7,9
A5	Low	Average	Very low	High	Low	Very low	Very High	7,9,9

In the next step (Table 3) the values of fuzzy numbers for each alternative, based on Table 2, are introduced in the next step, the normalized matrix is calculated. In order to do that, it is necessary to define the BENEFIT criteria (Table 3). If there are costs, then these are the COST criteria, which in this case do not exist since all the criteria are taken as the most favorable.

Table 3 *Introducing the value of fuzzy numbers and criteria*

	K1	K2	K3	K4	K5	K6
A1	7,9,9	7,9,9	5,7,9	7,9,9	5,7,9	5,7,9
A2	1,3,5	1,1,3	3,5,7	5,7,9	3,5,7	5,7,9
A3	1,3,5	1,3,5	1,3,5	5,7,9	3,5,7	5,7,9
A4	1,1,3	3,5,7	1,3,5	5,7,9	3,5,7	5,7,9
A5	1,3,5	3,5,7	1,1,3	5,7,9	1,3,5	1,1,3
Criterions	*BENEFIT*	*BENEFIT*	*BENEFIT*	*BENEFIT*	*BENEFIT*	*BENEFIT*

In this scientific work, a linear normalization of type 1 will be used. When applying this type of normalization, the following relations are formed to maximize [2]: $r_{ij} = (\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+})$, wherein $c_j^+ = 7{,}9{,}9$ max value of the fuzzy number, where the results are shown in Table 4.

Table 4 *Calculated matrix values*

	K1	K2	K3	K4	K5	K6
A1	1;1;1	1;1;1	0.71;0.77;1	1;1;1	0.71;0.77;1	0.71;0.77;1
A2	0.14;0.33;0.55	0.14;0.11;0.33	0.42;0.55;0.77	0.71;0.77;1	0.42;0.55;0.77	0.71;0.77;1
A3	0.14;0.33;0.55	0.14;0.33;0.55	0.14;0.33;0.55	0.71;0.77;1	0.42;0.55;0.77	0.71;0.77;1
A4	0.14;0.11;0.33	0.42;0.55;0.77	0.14;0.33;0.55	0.71;0.77;1	0.42;0.55;0.77	0.71;0.77;1
A5	0.14;0.33;0.55	0.42;0.55;0.77	0.14;0.11;0.33	0.71;0.77;1	0.14;0.33;0.55	0.14;0.11;0.33

In the next step, the normalized fuzzy matrix is expanded, based on the defined initial values of the fuzzy numbers for each of the alternatives according to the defined criteria (Table 5).

Based on the given Table 5, the FPIS was determined in Tables 6 and 7, the distance from the FPIS ideal solution,obtained by the formula [2]:

$$d(\tilde{a},\tilde{b}) = \sqrt{\frac{1}{3}[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]} \quad (1)$$

By the same procedure, the deviation from the fuzzy negative (FNIS) ideal solution will be shown (Tables 8 and 9).

In the next step, the sum is calculated D_i^+ i D_i^- (Table 10.)

Table 5 *Extension of the normalized fuzzy matrix*

Fuzzy number	7,9,9	5,7,9	5,7,9	3,5,7	3,5,7	3,5,7
	K1	K2	K3	K4	K5	K6
A1	7;9;9	5;7;9	3.55;5.39;9	3;5;7	2.13;3.85;7	2.13;3.85;7
A2	0.98;2.97;4.95	0.7;0.77;2.97	2.1;3.85;6.93	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A3	0.98;2.97;4.95	0.7;2.31;4.95	0.7;2.31;4.95	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A4	0.98;0.99;2.97	2.1;3.85;6.93	0.7;2.31;4.95	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A5	0.98;2.97;4.95	2.1;3.85;6.93	0.7;0.77;2.97	2.13;3.85;7	0.42;1.65;3.85	0.42;0.55;2.31

Table 6 *FPIS*

	K1	K2	K3	K4	K5	K6
A1	7;9;9	5;7;9	3.55;5.39;9	3;5;7	2.13;3.85;7	2.13;3.85;7
A2	0.98;2.97;4.95	0.7;0.77;2.97	2.1;3.85;6.93	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A3	0.98;2.97;4.95	0.7;2.31;4.95	0.7;2.31;4.95	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A4	0.98;0.99;2.97	2.1;3.85;6.93	0.7;2.31;4.95	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A5	0.98;2.97;4.95	2.1;3.85;6.93	0.7;0.77;2.97	2.13;3.85;7	0.42;1.65;3.85	0.42;0.55;2.31
A*	**7;9;9**	**5;7;9**	**3.55;5.39;9**	**3;5;7**	**2.13;3.85;7**	**2.13;3.85;7**

Table 7 *Distance from the FPIS ideal solution*

	K1	K2	K3	K4	K5	K6
A1	0	0	0	0	0	0
A2	5.44	5.59	2.96	1.44	1.23	0
A3	5.44	4.35	3.37	1.44	1.23	0
A4	6.75	2.74	3.37	1.44	1.23	0
A5	5.44	2.74	4.68	1.44	2.43	3.4

Table 8 *FNIS*

	K1	K2	K3	K4	K5	K6
A1	7;9;9	5;7;9	3.55;5.39;9	3;5;7	2.13;3.85;7	2.13;3.85;7
A2	0.98;2.97;4.95	0.7;0.77;2.97	2.1;3.85;6.93	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A3	0.98;2.97;4.95	0.7;2.31;4.95	0.7;2.31;4.95	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A4	0.98;0.99;2.97	2.1;3.85;6.93	0.7;2.31;4.95	2.13;3.85;7	1.26;2.75;5.39	2.13;3.85;7
A5	0.98;2.97;4.95	2.1;3.85;6.93	0.7;0.77;2.97	2.13;3.85;7	0.42;1.65;3.85	0.42;0.55;2.31
A^-	**0.98;0.99;2.97**	**0.7;0.77;2.97**	**0.7;077;2.97**	**2.13;3.85;7**	**0.42;1.65;3.85**	**0.42;0.55;2.31**

Table 9 *Distance from the FNIS ideal solution*

	K1	K2	K3	K4	K5	K6
A1	6.75	5.59	4.68	0.83	2.42	3.45
A2	1.61	0	2.51	0	1.2	3.45
A3	1.61	1.45	1.45	0	1.2	3.45
A4	0	3	1.45	0	1.2	3.45
A5	1.61	3	0	0	0	0

Table 10 D_i^+**and** D_i^-

	K1	K2	K3	K4	K5	K6	D_i^+	K1	K2	K3	K4	K5	K6	D_i^-
A1	0	0	0	0	0	0	**0**	6.75	5.59	4.68	0.83	2.42	3.45	**23.75**
A2	5.44	5.59	2.96	1.44	1.23	0	**16.66**	1.61	0	2.51	0	1.2	3.45	**8.77**
A3	5.44	4.35	3.37	1.44	1.23	0	**15.83**	1.61	1.45	1.45	0	1.2	3.45	**9.16**
A4	6.75	2.74	3.37	1.44	1.23	0	**15.53**	0	3	1.45	0	1.2	3.45	**9.1**
A5	5.44	2.74	4.68	1.44	2.43	3.4	**20.13**	1.61	3	0	0	0	0	**4.61**

The coefficient of similarity with the ideal solution is calculated using the following formula: $CC_i = \frac{D_j^-}{D_j^+ + D_j^-}, i = 1,2, \dots, m$ and in the end the ranking is done (Table 11).

Table 11 *Coefficient of similarity with ideal solution and ranking*

	D_i^*	D_i^-	CC_i	RANG
A1	0	23.75	1	**1**
A2	16.66	8.77	0.3448682658	**4**
A3	15.83	9.16	0.3665466186	**3**
A4	15.53	9.1	0.3694681283	**2**
A5	20.13	4.61	0.1863379143	**5**

In this work, a comparative analysis was done for the selection of ore deposits in Eastern Serbia using the classical TOPSIS [3] and Fuzzy TOPSIS method (Figure 1).

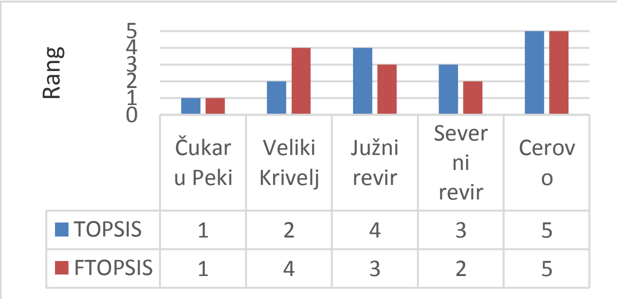

Figure 1 *Comparative analysis*

4 CONCLUSION

Based on the obtained results from the calculation of these two methods, it was concluded that the ore deposit Čukaru Peki - the Upper Zone is the best choice in the existing conditions, for both methods, and that Cerovo is the most unfavorable deposit. For the other three deposits, the FTOPSIS and TOPSIS methods do not agree, so in the classic TOPSIS method, the second-ranked deposit is Veliki Krivelj, the third North Mining District - Majdanpek, then the South Mining District, and in the FTOPSIS method the second-ranked deposit is the North Mining District, then the South Mining District and Veliki Krivelj. Since the North and South Mining District and Veliki Krivelj have similar content of useful components, it could be assumed that such results could be obtained. The choice of ore deposits can be based on other criteria, not only those given in this work, so that different results can be obtained.

ACKNOWLEDGEMENTS

This work was financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Contract No. 451-03-68/2022-14/200052.

REFERENCES

[1] L.A. Zadeh, Fuzzy Sets, 1965.
[2] K.P. Anagnostopoulos, M. Gratziou, A.P. Vavatsikos, Using the FUZZY ANALYTIC HIERARCHY PROCESS for Selecting Wastewater Facilities at Prefecture Level, European Water, 19(20) (2007) 15-24.
[3] S. Milutinović, M. Mikić, M. Stojanović, The Use of Multicriteria Decision-Making Methods in Determining the Optimal Solution in the Form of Selection the Priority in Exploitation the Ore Deposit in Eastern Serbia, Mining and Metallurgy Engineering Bor, 1-2 (2021) 63-74.