



**MINING AND METALLURGY INSTITUTE BOR**

**and**



**TEHNICAL FACULTY BOR, UNIVERSITY OF BELGRADE**

**IOOC 2018**  
**International October**  
**Conference**

**50<sup>th</sup> International October Conference  
on Mining and Metallurgy**

**PROCEEDINGS**

**Editors:**

**Ana Kostov  
Milenko Ljubojev**

**30<sup>th</sup> September – 3<sup>rd</sup> October 2018**

**Hotel “Jezero” Bor Lake, Serbia**

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## THE MCDM APPROACH IN A CRITERIA PRIORITIZATION IMPORTANT FOR THE COPPER ORE MINING METHOD SELECTION

Gabrijela Popović<sup>1</sup>, Bojan Djordjević<sup>1</sup>, Dragan Milanović<sup>2</sup>

<sup>1</sup>Faculty of Management in Zaječar, Megatrend University Belgrade, Park šuma Kraljevica bb,  
19000 Zaječar, Serbia, E-mail: gabrijela.popovic@fmz.edu.rs

<sup>2</sup>Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia

### Abstract

Identification of the list of criteria on which the mining method selection should be based and measuring their influence on the final decision is a very complex task for a decision-maker. Although this problem is usually considered by the experienced professionals, introduction of the appropriate mathematical models could help in the priority determination of considered criteria. In this paper, the Pivot Pairwise Relative Criteria Importance Assessment – PIPRECIA is used for a criteria prioritization important for the copper ore mining method selection in a combination with a group decision making.

**Keywords:** MCDM, PIPRECIA method, criteria prioritization, mining, copper

### 1 INTRODUCTION

The first step in the mining method selection is certainly defining the list of the most significant criteria. The Multiple-Criteria Decision-Making - MCDM methods could be a useful instrument for determination the importance of considered list of criteria and its prioritization. The MCDM represents the fastest-growing area of the operational research and becomes very popular lately. There are many different methods proposed for resolving a different kind of business problems [1,2]. There are examples of utilization the MCDM methods for selection the optimal mining method [3,4].

In this paper, the PIPRECIA method is used for defining the priority of criteria on which the selection of mining method for the copper ore exploitation should be based. The three decision-makers (DM) are involved in the decision-making process that are the experts in the considered area. The rest of the paper is organized as follows: in the second part the PIPRECIA method is explained; the third part consists of a numerical example; and in the end, the conclusions are given.

### 2 PIPRECIA METHOD

The PIPRECIA method is proposed by Stanujkic et al. [5] and represents an extension of the Step-wise Weight Assessment Ratio Analysis - SWARA [6,7]. It is very suitable for the application in the cases when the greater number of the DMs is involved in the decision-making process. The numerical procedure of the proposed method contains the following steps:

**Step 1.** Selection of the criteria involved in the evaluation process. As it was said previously, the preceding sorting of considered criteria is not necessary.



**Step 2.** Determination of the relative importance  $s_j$ , starting from the second criterion, as follows:

$$s_j = \begin{cases} >1 & \text{when } C_j \succ C_{j-1} \\ 1 & \text{when } C_j = C_{j-1} \\ <1 & \text{when } C_j \prec C_{j-1} \end{cases} \quad (1)$$

**Step 3.** Determination of the coefficient  $k_j$  as follows:

$$k_j = \begin{cases} 1 & j=1 \\ 2-s_j & j>1 \end{cases} \quad (2)$$

**Step 4.** Determination of the recalculated weight  $q_j$  as follows:

$$q_j = \begin{cases} 1 & j=1 \\ \frac{q_{j-1}}{k_j} & j>1 \end{cases} \quad (3)$$

**Step 5.** Determination of the relative criteria weights in the following way:

$$w_j = \frac{q_j}{\sum_{k=1}^n q_k} \quad (4)$$

where  $w_j$  denotes the relative importance of the criteria  $j$ .

### 3 NUMERICAL EXAMPLE

The list of criteria, on which the mining method selection for the copper ore exploitation should be based, is formulated according to the following papers [7-9], and is presented in Table 1. As it can be seen, the three groups of criteria are defined and they are: technical parameters, production parameters and economic parameters. Every of the mentioned criteria is further elaborated in the greater number of sub-criteria.

As it was said previously, in this case, three *DMs* are included in the decision-making process. Firstly, the significance of the main criteria is defined using the equations (1)-(4), and then the same is done for the considered sub-criteria. In that way the local significance of the criteria and sub-criteria are determined. The overall importance of the considered criteria and sub-criteria is determined using the following equations:

$$GM_j = \left( \prod_{k=1}^K w_j^k \right)^{1/K} \quad (5)$$

$$w_j = GM_j / \sum_{l=1}^n GM_l \quad (6)$$

where  $GM_j$  represents the geometric mean of importance obtained from the *DMs* involved in the evaluation of the factor  $j$ ,  $w_j$  denotes the importance of the factor  $j$ , and  $K$  is the number of the *DMs*.



The global significance is calculated by multiplying the local significance of the criteria and sub-criteria. Due to the paper limitation, Table 1 presents the final results obtained from the DMs.

**Table 1** Local and global significance of criteria for the mining method selection for the copper ore exploitation

Criteria	Criteria significance	Sub-criteria	Local significance of sub-criteria	Global significance of sub-criteria
C <sub>1</sub> Technical parameters	0.350	C <sub>11</sub> Ore body thickness	0.110	0.038
		C <sub>12</sub> Ore body shape	0.095	0.033
		C <sub>13</sub> Ore body depth	0.092	0.032
		C <sub>14</sub> Ore body dip	0.092	0.032
		C <sub>15</sub> Ore body size	0.075	0.026
		C <sub>16</sub> Footwall RMR	0.073	0.025
		C <sub>17</sub> Hanging wall RMR	0.084	0.030
		C <sub>18</sub> Ore body RMR	0.079	0.028
		C <sub>19</sub> Footwall RSS	0.079	0.028
		C <sub>110</sub> Hanging wall RSS	0.100	0.035
		C <sub>111</sub> Ore body RSS	0.120	0.042
C <sub>2</sub> Production parameters	0.339	C <sub>21</sub> Safety	0.084	0.029
		C <sub>22</sub> Health	0.084	0.029
		C <sub>23</sub> Environmental impacts	0.077	0.027
		C <sub>24</sub> Subsidence	0.093	0.032
		C <sub>25</sub> Dilution	0.088	0.031
		C <sub>26</sub> Flexibility	0.078	0.027
		C <sub>27</sub> Production rate	0.086	0.030
		C <sub>28</sub> Technology	0.094	0.033
		C <sub>29</sub> Expert labor	0.081	0.028
		C <sub>210</sub> Ventilation	0.114	0.040
		C <sub>211</sub> Underground water	0.122	0.043
C <sub>3</sub> Economic parameters	0.311	C <sub>31</sub> Operating cost	0.165	0.051
		C <sub>32</sub> Capital cost	0.177	0.055
		C <sub>33</sub> Reclamation costs	0.172	0.053
		C <sub>34</sub> Mineral value	0.167	0.052
		C <sub>35</sub> Mineable ore tons	0.162	0.050
		C <sub>36</sub> Ore body grades	0.157	0.049

The sub-criterion with a bigger significance has the greater priority than the one with the worse results.

The relative significance of the criteria shows that the technical parameters (0.350) are the most important criteria group, while the economic parameters are placed in the last place (0.311). But, as Table 1 shows, the difference among importance of the criteria groups is not significant leading to the conclusion that all of them have an important influence on the final decision that is nearly equal.

The sub-criteria C<sub>111</sub> - Ore body RSS that belongs to the criteria group connected to the technical parameters, has the biggest significance among the sub-criteria from the mentioned group. When the production parameters are in question, the most significant is the sub-criteria C<sub>211</sub> - Underground water, and the sub-criteria C<sub>32</sub> - Capital cost is in the first place among the economic parameters. In general, as the most important group of criteria, the economic parameters singled out.



#### 4 CONCLUSION

The selection of the mining method is very important because the future operating, as well as financial results, depend on it. Defining the list of criteria, on which the decision process should be based, is a very sensitive issue that requires a full attention. Although the DMs involved in this process have the formal education and experience, the introduction of the MCDM methods and group decision-making would be very helpful and will contribute to the reliability of decisions that are made.

The PIPRECIA method is a newly proposed method whose possibilities are not fully tested, yet. It was very useful in the criteria prioritization on which the mining method for the copper ore exploitation should be based, because it is very simple, easy to use and convenient for the group decision-making. The gained results are reliable and adequate.

The main deficiency of this paper reflects neglecting of the uncertainty and vagueness because the crisp numbers were used. By introduction the fuzzy, intuitionistic fuzzy and grey numbers, this shortage would be overcome and the proposed model would be further improved.

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#### REFERENCES

- [1] K. Govindan, S. Rajendran, J. Sarkis, P. Murugesan, Multi-Criteria Decision Making Approaches for Green Supplier Evaluation and Selection: A Literature Review, *J. Clean. Prod.*, 98 (2015) 66-83.
- [2] A. Mardani, A. Jusoh, K. MD Nor, Z. Khalifah, N. Zakwan, A. Valipour, Multiple Criteria Decision-Making Techniques and their Applications – A Review of the Literature from 2000 to 2014, *Ekon. Istraž.*, 28 (1) (2015) 516-571.
- [3] D. Bogdanović, D. Nikolić, I. Ilić, Mining Method Selection by Integrated AHP and PROMETHEE Method, *An. Acad. Bras. Ciênc.*, 84 (1) (2012) 219-233.
- [4] S. Alpay, M. Yavuz, Underground Mining Method Selection by Decision-Making Tools, *Tunn. Undergr. Sp. Tech.*, 24 (2) (2009) 173-184.
- [5] D. Stanujkić, E. K. Zavadskas, D. Karabašević, F. Smarandache, F., Z. Turskis, The Use of the Pivot Pairwise Relative Criteria Importance Assessment Method for Determining the Weights of Criteria, *Rom. J. Econ. Forecast.*, 4 (2017) 116-133.
- [6] V. Keršulienė, E. K. Zavadskas, Z. Turskis, Selection of Rational Dispute Resolution Method by Applying New Step-Wise Weight Assessment Ratio Analysis (SWARA), *J. Bus. Econ. Manag.* 11 (2) (2010) 243-258.
- [7] A. Yazdani-Chamzini, S. H. Yakchali, E. K. Zavadskas, Using an Integrated MCDM Model for Mining Method Selection in Presence of Uncertainty, *Ekon. Istraž.* 25 (4) (2012) 869-904.
- [8] M. Bitarafan, Mining Method Selection by Multiple Criteria Decision-Making Tools, *J. South. Afr. Inst. Min. Metall.*, 104 (9) (2004) 493-498.
- [9] M. Ataei, M. Jamshidi, F. Sereshki, S. M. E. Jalali, Mining Method Selection by AHP Approach, *J. South. Afr. Inst. Min. Metall.*, 108 (12) (2008) 741-749.