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# BALKAN MINING CONGRESS

# BOOK OF ABSTRACTS

18th-21st September 2013

**Ohrid, Republic of Macedonia**


V. BALKANMINE
OHRID 2013

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# MINING METHOD SELECTION FOR DEEPER PARTS OF "SVINJA REKA" ORE DEPOSIT - "SASA" MINE

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**Abstract:** The paper presents a scientific approach in mining method selection for deeper parts of "Svinja Reka" ore deposit. Rational mining method selection include in depth analysis of the all important montan-geologycal parameters of ore deposit, as much as technical and economical indicators. As a decision support tool for optimal method selection, a multi-criteria evaluation techniques are used.

***Key words:*** *mining method, rational choice, multi-criteria decision*

## 1. INTRODUCTION

Mining method selection for underground mine presents essential problem, especially considering that mining method should to provide safe and healthy working conditions. Also, should constantly bearing in mind the fact that the excavation costs occupy the largest part of the total mine operating costs, and therefore the adequate mining method selection is essential for positive financial effects of mine working.

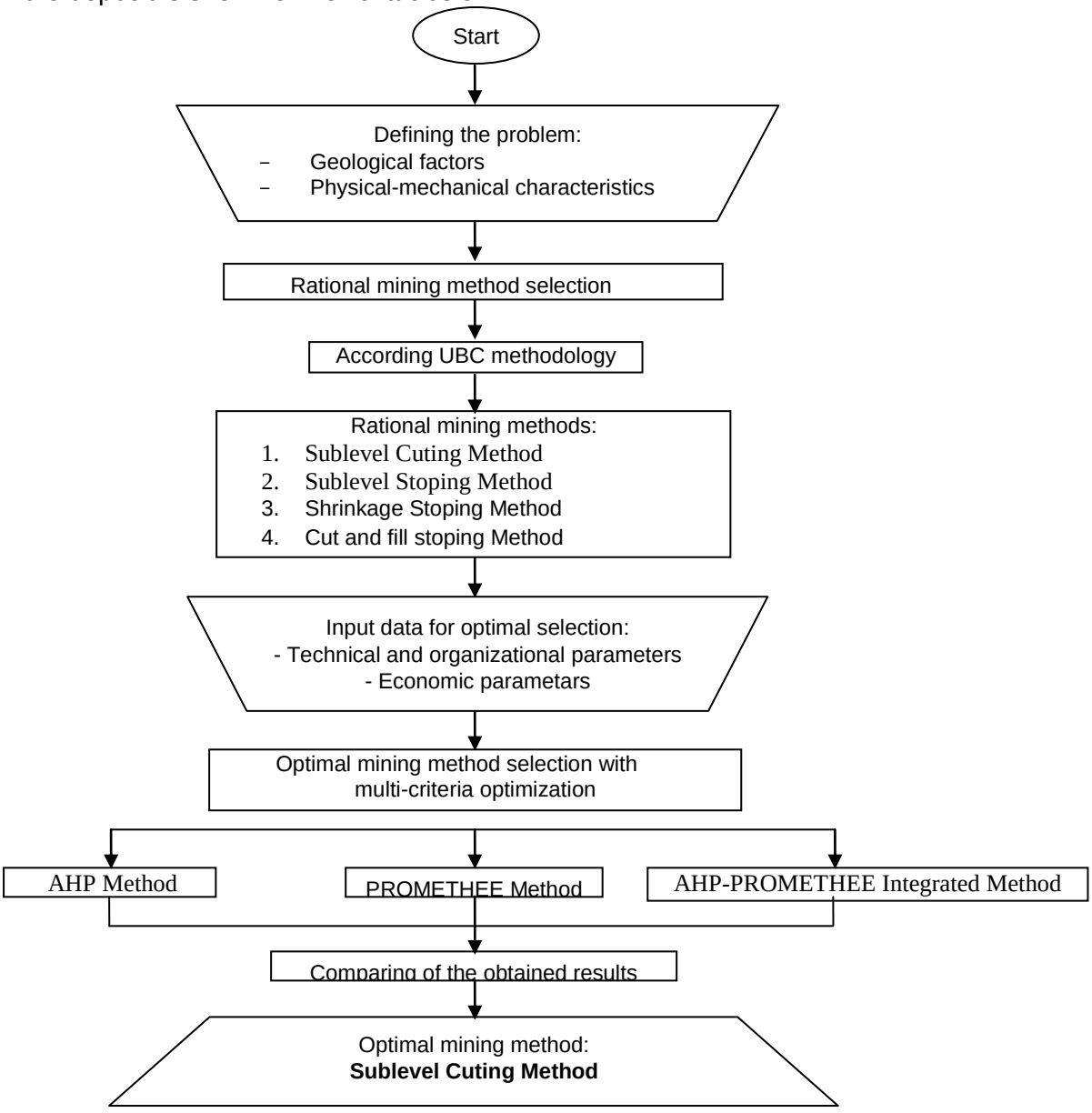
The purpose of this paper is contribute to establishing the methodology for preliminary method selection for deeper parts of "Svinja Reka" ore deposit in the underground metalic mine "Sasa" in M. Kamenica, including depth analysis of more mining-geological, technical and economic factors.

## 2. MINING METHOD SELECTION FOR DEEPER PARTS OF "SVINJA REKA" ORE DEPOSIT

The procedure for mining method selection can be divided into two parts:

- Rational mining method selection
- Optimal mining method selection.

Basic concept of the proposed methodology for optimal mining method selection of "Svinja Reka" ore deposit is shown on flowchart below:




## 2.1. Rational mining method selection

First we perform rational choice or mining methods selection according to geological factors that influence on the mining method selection. This includes: the geometry and the prevalence of ore bodies (shape of mineral bodies, the power of mineral bodies, the overlap angle of ore bodies, overlap depth of ore bodies, the prevalence of ore bodies) and physical-mechanical characteristics of the ore and adjacent rocks (strength of the rock mass, the distance between the cracks, the number of cracks / m ', RQD and RMR index, the strength of the shear cracks).

There are several procedures for mining methods selection by geological factors. The most important are:

- Boshkov`s and Wright`s procedure (1973);
- Morrison`s procedure (1976);
- Nicholas`s procedure (1981);
- Laubscher`s procedure (1981 и 1990);
- Hartman`s procedure (1987);
- UBC procedure (1995).

For rational mining method selection commonly used UBC procedure. This procedure is a modified version of the Nicholas`s approach and was proposed by the University of British Columbia - Canada. Mining methods selection by UBC procedure (Miller - Tait L., Pakalnis R. and Poulin R., 1995 g.) presents a numerically ranking for mining method selection or group of mining methods, which are suitable for excavation of given ore deposit.

Based on the mentioned input parameters for the ore body mining methods selection by UBC procedure was performed. After the calculation according to this methodology following sequence of mining methods was obtained:

**Table 1.** Ranking mining methods by UBC

| **MINING METHOD** |
|---|
| Sublevel Caving Mining Method |
| Sublevel Stoping Mining Method |
| Shrinkage Stoping Mining Method |
| Cut and fill stoping Mining Method |
| Room and Pillar Mining Method |
| Block Caving Mining Method |
| Top slicing mining Method |
| Square Set Stoping Mining Method |

For further mining methods selection the first four methods will be used.

### 2.2. Optimal method selection using a multi-criteria evaluation techniques

After rational mining methods selection and separation the most acceptable mining methods according to geological factors (top four highest ranked mining methods), follows optimal choice, ie selecting the separated mining methods according to technical-economic and organizational factors that influence when choosing mining method. This includes: the value of excavated ore, occupational safety and health conditions, the cost of one ton ore, utilizing of the excavated ore, coefficient of depletion of ore substance, coefficient of preparation works, effect of excavation, degradation of terrain and other environmental impacts.

For optimal mining methods selection by technical-economic and organizational factors are used multi-criteria optimization methods. In this paper PROMETHEE, AHP and AHP-PROMETHEE integrated methodology are developed. Three multi-criteria optimization methods to compare outcomes were used and so will choose the optimal mining method.

Multi-criteria model consists of four alternatives, including (Table 2):

**Table 2.**

| **No.** | **Alternative** | **Mark** |
|---|---|---|
| 1 | Sublevel Caving Method | $A_1$ |
| 2 | Sublevel Stoping Method | $A_2$ |

| | | |
|---|---|---|
| 3 | Shrinkage Stoping Method | $A_3$ |
| 4 | Cut and fill stoping Method | $A_4$ |

After identifying the problem, and its detailed analysis, were selected and identified eight criteria that have the greatest impact on solving the model given in Table 3.

**Table 3.**

| No | Criteria | Mark |
|---|---|---|
| 1 | Value of excavated ore | $K_1$ |
| 2 | Occupational safety and health conditions | $K_2$ |
| 3 | Coefficient of preparation works | $K_3$ |
| 4 | Utilizing of the excavated ore | $K_4$ |
| 5 | Coefficient of depletion of ore substance | $K_5$ |
| 6 | Cost of one ton ore (1 t) | $K_6$ |
| 7 | Effect of excavation | $K_7$ |
| 8 | Degradation of terrain and other environmental impacts | $K_8$ |

Each of these criteria has impact on alternative solutions. To define the impact of criteria function to the alternative solutions :

- analysis of technical and economic parameters and other technical information;
- consultations and surveys of experts in the field of underground mining;
- Calculation of average values on the impacts obtained from the above procedures were made.

Based on the theory and equations of PROMETHEE method as well as on our assessment, were selected certain types of generalized criteria.

After analysis for evaluation of individual criteria for each alternative solution, this multi-criteria model was obtained (table 4):

**Table 4.** Input model

| **Alternatives** | | **Criteria** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **$K_1$** | **$K_2$** | **$K_3$** | **$K_4$** | **$K_5$** | **$K_6$** | **$K_7$** | **$K_8$** |
| **Aim** | | **max.** | **max.** | **min.** | **max.** | **min.** | **min.** | **max.** | **min.** |
| **$A_1$** | | 94,3 | 9 | 2,56 | 75 | 22 | 3 | 30 | 9 |
| **$A_2$** | | 81,6 | 5 | 23,9 | 80 | 18 | 7 | 22 | 5 |
| **$A_3$** | | 88,2 | 7 | 17,55 | 85 | 12 | 7 | 10 | 3 |
| **$A_4$** | | 93,3 | 7 | 8,65 | 94 | 6 | 9 | 15 | 3 |
| Criteria features | **Impacts** | 0,19 | 0,12 | 0,115 | 0,14 | 0,09 | 0,185 | 0,0975 | 0,0625 |
| | **Type** | III | IV | III | II | IV | IV | III | IV |
| | **m** | - | 2 | - | 5 | 4 | 2 | - | 2 |
| | **n** | 4,3 | 4 | 6,09 | - | 6 | 4 | 5 | 6 |

Table 5 compares the results obtained with multi-criteria optimization ie, results obtained by applying the PROMETHEE II, AHP and AHP-PROMETHEE integrated methodology.

**Table 5.** Different multi-criteria ranking methods

| Alternatives | PROMETHEE II | AHP | AHP- PROMETHEE |
|---|---|---|---|
| **$A_1$** | **1** | **1** | **1** |
| **$A_2$** | **4** | **4** | **4** |
| **$A_3$** | **3** | **3** | **3** |
| **$A_4$** | **2** | **2** | **2** |

The results from the PROMETHEE II, AHP and AHP-PROMETHEE integrated method application suggest that the solution is uniquely and identical.

So, the final ranking of alternatives is: $A_1 \rightarrow A_4 \rightarrow A_3 \rightarrow A_2$. From the above table can be concluded that the most acceptable alternative is $A^* = A_1$, because it has the highest value

according three methods. Hence it follows that the most acceptable alternative mining method is Sublevel Caving Method.

## 3. CONCLUSION

Mining method selection presents the biggest problem for each designer during design a new underground mine or developing an existing one. When making the decision about which mining method will apply should take into account many factors that influence on the mining method selection. Selected mining method will be more suited to specific mining and geological conditions if a number of relevant factors are included.

Very important indicators for exploitation of a ore deposit depends of the selected mining method, such as: working effect, costs of mining, losses and depletion of ore and finally financial effects which are exercised thereby.

Providing safety working conditions, utilization of ore deposit and depletion of ore can also be among the influential factors on the mining method selection, which also have a significant impact on the financial effects that are achieved with the use of mining method to a given ore deposit.

Numerous studies and researches indicate that the underground mining method selection depends of a number of relevant factors, that can be grouped into three basic groups: geological factors, technical and economic factors and organizational factors.

The problem of underground mining method selection, because of its importance was studied by many authors. As a common stage of the proceedings which the individual authors was proposed, in order to select the underground mining method can be distinguished two stages: a rational mining method selection and optimal mining method selection.

First a rational mining method selection was performed with selection a group of methods suitable for the application, and then optimal mining method selection was performed based on the technical-economic and organizational factors, in addition multi-criteria optimization can be used.

In the begining a rational mining method selection was performed with separation a group of methods suitable for the application, and then optimal mining method selection was performed based on the technical-economic and organizational factors, in addition multi-criteria optimization can be used.

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