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Suitable Underground Mining Method Selection Using EEM and PROMETHEE: A Case Study of a Glauberite Mine

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***Abstract*: Underground Mining Method Selection (UMMS) is the first stage and the most important problem in mining design. Selecting the suitable mining method among many alternatives is a multi-criteria decision-making problem. To apply decision making theory for Mining Method Selection (MMS) problem, researchers have faced two difficulties in recent years: (i) calculation of relative weight for each attributes, (ii) uncertainty in judgment for decision makers. The aim of this paper is to demonstrate the implementation of an integrated approach that employs expert evaluation method (EEM) and preference ranking organization method for enrichment evaluation (PROMETHEE) together for selecting the most suitable mining method in the Glauberite Mine. Mining method selection depends on some parameters, such as geological and geotechnical properties, economic parameters and geographical factors. This problem includes seven possible mining methods and eleven attributes to evaluate them. These attributes include shape of deposit, slope of orebody, thickness of orebody, depth below the surface, grade distribution, hanging wall RMR, orebody RMR, recovery, dilution, mining cost and annual productivity. Firstly, we calculated the weights of these attributes using the expert evaluation method (EEM). A simple case study has also been presented to illustrate the competence of this method. Here, we compared the seven mining methods for a Glauberite mine and selected the optimal mining method using PROMETHEE method. Finally, the Block stoping method was selected as the most suitable method to this mine. The results have shown that the proposed integrated method can be successfully used in solving mining engineering problems.**

***Keywords*: Coal mining, Underground mining method selection, expert evaluation method (EEM), preference ranking organization method for enrichment evaluation (PROMETHEE), Hierarchical structure, multi-criteria decision making technique (MCDMT).**

1. Introduction

Underground Mining Method Selection (UMMS) problem is one of the most critical and vital steps in designing an ore extraction system. Underground mining depends on many physical, mechanical, economical and technical parameters. These parameters may be qualitative and quantitative. Hence, underground mining method selection falls under multi-attribute decision making work. Many multi-attribute decision making techniques are available such as weighted product method (WPM), expert evaluation method (EEM), analytical hierarchy process (AHP), technique for order of preference by similarity to ideal solution (TOPSIS), preference ranking organization method for enrichment evaluation (PROMETHEE), graph theory and matrix approach (GTMA), Grey and TODIM (an acronym in Portuguese, i.e. Tomada de Decisão Interativa Multicritério) decision-nmaking method, hesitant fuzzy group decision-making (HFGDM) etc.

In the proposed work, EEM and PROMETHEE are selected for the most suitable underground mining method selection for a Glauberite Mine. The proposed techniques are very accurate in the evaluation process and give the optimum results.

The decision-making techniques were used by many researchers in different fields of engineering, technology, and science. In 1981 Nicholas has presented the first quantitative technique for underground mining method selection. Most of the researchers use the Nicholas techniques as a base for research works. The research works on underground mining method selection using multi-attribute decision-making techniques are as follows: Azadeh et al. [1] used fuzzy AHP for mining method selection by modifying Nicholas technique for Choghart iron mine.

It becomes the responsibility of the geologists and engineers to work together to ensure that all attributes are considered in the mining method selection process. One of the common techniques to select the optimal mining method is Analytical Hierarchy Process (AHP). AHP is a widely used multiple criteria decision-making tool and firstly proposed by Saaty [2]. The traditional AHP method is problematic in that it uses an exact value to express the decision maker's opinion in a comparison of alternatives. Especially, AHP method is often criticized due to its use of unbalanced scale of judgments and its inability to adequately handle the inherent uncertainty and imprecision in the pair-wise comparison process [3]. Ataei et al. [4] used the analytic hierarchy process to choose the best mining method. Jamshidi et al. [5] applied the analytic hierarchy process to choose the optimal underground mining method in the Jajarm bauxite mine. Bitarafan and Ataei [6] selected an appropriate mining method in anomaly No. 3 of the Gol-Gohar iron mine using fuzzy multiple attribute decision

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making method. Naghedehi et al. [7] suggested fuzzy AHP (FAHP) method for selection of suitable mining method for Bauxite ore deposit in Iran.

Gelvez and Aldana [8] applied the AHP and the VIKOR methods to select optimum mining method in the coal mine in Colombia. Karimnia and Bagloo [9] used AHP to choose the better mining method at a salt mine in Iran. Lv and Zhang [10] predicted a suitable mining method for thin coal seam by using artificial neural networks. Chen and Tu [11] applied AHP and PROMATEHEE methods for selecting the most suitable technique for mechanized mining in a thin coal mine in china

Dehghani et al. [12] chose the most optimal mining method in the Gol-e-gohar mine using the Grey and TODIM (an acronym in Portuguese, i.e. Tomada de Decisão Interativa Multicritério) decision-making techniques. Namin et al. [13] proposed a new model to select the mining method based on the fuzzy TOPSIS. Namin et al. [14] investigated the application of several decision-making techniques such as AHP, TOPSIS, and PROMETHEE to select an appropriate mining method in Iran. Also, Bogdanovic et al. [15] applied the PROMETHEE and analytic hierarchy process methods to determine an appropriate mining method in the Coka Marin mine in Serbia. Ataei et al. [16] applied the Monte Carlo analytic hierarchy process method to select the best mining method in the Jajarm bauxite mine. Yavuz [17] used the AHP method to choose a suitable underground mining method for a lignite mine located in Istanbul. Chen et al. [18] compared the results of the TOPSIS method with those for the AHP-VICOR method in the mining method selection problems. The results of this work showed that the proposed model could predict a mining method with more precision.

Ataei et al. [19] also used TOPSIS to do the same for the Jajarm mine in Iran. Nourali, et al [20] used a Hierarchical Preference Voting System (HPVS) for MMS problem that uses a Data Envelopment Analysis (DEA) model to produce weights associated with each ranking place.

Some studies have been devoted to address this issue and developed some completely unknown weight generation processes within the hesitant fuzzy environment. Hu et al. [21] constructed the entropy weight model to determine the attributes weights based on the proposed entropy measures. Liu et al. [22] took advantage of the linear programming technique for multidimensional analysis of preference (LINMAP) to determine the attribute weights objectively in the hesitant fuzzy multiple attribute decision making. Xu and Zhang [23] established an optimization model based on the maximizing deviation method to determine the optimal relative weights of attributes under hesitant fuzzy environment.

In this paper, an EEM-PROMETHEE integrated approach for the selection of the suitable mining method will be introduced, and the implementation process will be explained with a real-world example. We shall use the EEM method to determine the weights of the attributes. After that, we shall use the PROMETHEE method for final ranking of the alternatives.

This paper is divided into six sections. In Section 2 the EEM method to determine weights of multiple attributes and PROMETHEE method are briefly described. In Section 3 we investigated a case study of a Glauberite Mine and made the model of mining method. In Section 4 we selected the suitable mining method selection using EEM and PROMETHEE.

2. Methodology

A. Expert Evaluation Method to Determine Weights of Multiple Attributes

In this section, we propose the expert evaluation method to determine the weights of multiple attributes.

In real practical situations, the decision makers' evaluation for each attribute may differ with one another because the decision makers have different experiences and specialties. Therefore, to determine more reasonable weights for set of the whole attributes, it should be considered the decision makers' hesitant evaluation for each attribute.

Let $X=\{x_1, x_2, \ldots, x_m\}$ be the set of attributes to determine the weights of attributes, $W=\{w_1, w_2, \ldots, w_m\}$ the set of weights of attributes, $Z=\{z_1, z_2, \ldots, z_n\}$ the set of experts to determine the weights of attributes, and $Q=\{q_1, q_2,\ldots,q_n\}$ the fuzzy information set.

The expert evaluation method to determine the weights of attributes is as follows.

(i) Each expert who participated in the evaluation reveals a fuzzy information value p_j (j=1, 2, …, m) for each attribute x_j (j=1, 2, …, m) with respect to his opinion.

For the most important attribute, we give the fuzzy information value m, and for the most neglected attribute, the fuzzy information value 1.

Table 1
The fuzzy score to determine the weights of attributes

Experts	Attributes					
	x_1	x_2	…	x_j	…	x_m
z_1	$q_{1\text{-}1}$	$q_{1\text{-}2}$	…	$q_{1\text{-}j}$	…	$q_{1\text{-}m}$
z_2	$q_{2\text{-}1}$	$q_{2\text{-}2}$	…	$q_{2\text{-}j}$	…	$q_{2\text{-}m}$
…	…	…	…	…	…	…
z_k	$q_{k\text{-}1}$	$q_{k\text{-}2}$	…	$q_{k\text{-}j}$	…	$q_{k\text{-}m}$
…	…	…	…	…	…	…
z_n	$q_{n\text{-}1}$	$q_{n\text{-}2}$	…	$q_{n\text{-}j}$	…	$q_{n\text{-}m}$

$$Q=\begin{Bmatrix} q_{11} & q_{12} & \cdots & q_{1j} & \cdots & q_{1m} \\ q_{21} & q_{2-2} & \cdots & q_{2j} & \cdots & q_{2m} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ q_{k1} & q_{k2} & \cdots & q_{kj} & \cdots & q_{km} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ q_{n1} & q_{n2} & \cdots & q_{nj} & \cdots & q_{nm} \end{Bmatrix} \tag{1}$$

Where q_{kj} is kth expert's fuzzy score for jth attribute and n is the number of experts.

(ii) Write a priority score matrix.

$$A_{ij}=\sum_{k=1}^{p} A_{ki\,j}\left(i \neq j\right) \tag{2}$$

$$A_{kij} = \begin{cases} 1, & \dfrac{q_{kj}}{q_{ki}} \geq 1 \\ 0, & \dfrac{q_{kj}}{q_{ki}} < 1 \end{cases} \tag{3}$$

(iii) Calculate a_j, $a_{\max}$, $a_{\min}$ in the priority score matrix.

$$a_j = \sum_{i=1}^{m} A_{ij}, \ \left(j = \overline{1,\ m}\right) \tag{4}$$

$$a_{\max} = \max\{a_1, a_2, \cdots, a_m\} \tag{5}$$

$$a_{\min} = \min\{a_1, a_2, \cdots, a_m\} \tag{6}$$

(iv) Calculate the difference of grade (d).

Assume $A_{\max}$=1 and $A_{\min}$=0.1, calculate the difference of grade (d) follows.

$$d = \frac{a_{\max} - a_{\min}}{A_{\max} - A_{\min}} \tag{7}$$

(v) Calculate the weighte of the attributes as follows.

$$a'_j = \frac{a_j - a_{\min}}{d} + A_{\min} \tag{8}$$

or

$$a'_j = A_{\max} - \frac{a_{\max} - a_j}{d} \tag{9}$$

The weight is given by following expression:

$$w_j = \frac{a'_j}{\sum_{j=1}^{m} a'_j} \tag{10}$$

B. Promethee Method

Preference ranking organization method for enrichment evaluations (PROMETHEE) was developed by Brans et al. [24] and is an outranking method for a finite set of alternatives. In this paper, improved PROMETHEE proposed by Rao [25], [26] is used.

The procedure of improved PROMETHEE as follows:

Step-1: Construction of an evaluation matrix: Identify the attributes and alternatives for the decision-making problem. A quantitative or qualitative value to be assigned to each selected attribute. The identified alternatives will be evaluated using the proposed technique. The values of the selected attributes for selected alternatives are based on the available data or may be the estimations made by the decision maker.

The basic data must be prepared in the evaluation matrix in which the performance of each alternative with respect to each criterion is provided.

Step-2: Weights of the selected attributes are decided by EEM.

Step-3: Preparation of dominance matrices for the attributes used in the problem-solving.

Dominance matrix is prepared in between the alternatives with respect to each attribute based on step-1 data. Preparation of dominance matrix follows the below procedure.

- Assume m attributes and n alternatives, such that there will be m dominance matrices of the size n×n.
- Identify the beneficiary and non-beneficiary attributes.
- The comparison between the same alternatives can be represented as blank. Hence, the diagonal elements in the dominance matrix would be blank.
- For each attribute prepare the dominance matrix as follows.

(1) If the attribute is the beneficiary, the comparing alternative has greater value than compared alternative, then represents element value with 1 otherwise 0.

$$P_{ij-k} = \begin{cases} 1 & \left(\dfrac{g_i}{g_j} > 1\right) \\ 0 & \left(\dfrac{g_i}{g_j} < 1\right) \end{cases} \tag{11}$$

$i = \overline{1, n},\ j = \overline{1, n},\ k = \overline{1, m}, i \neq j$

(2) If the attribute is non-beneficiary, the comparing alternative has lesser value than compared alternative, then represents element value with 1 otherwise 0.

$$P_{ij-k} = \begin{cases} 1 & \left(\dfrac{g_i}{g_j} < 1\right) \\ 0 & \left(\dfrac{g_i}{g_j} > 1\right) \end{cases} \tag{12}$$

Step-4: Multiply the corresponding elements of the dominance matrices with their respective attribute weights. Sum up the corresponding multiplied elements and write in the final matrix as specified in the Eq. (2). Π is the strength of preference of the decision maker for alternative 'a_1' over 'a_2'. w_k is the weight of the attribute. P_{ij-k} indicates the values in the dominance matrix.

$$\Pi = \sum_{k=1}^{m} w_k P_{ij-k} \tag{13}$$

Step-5: Calculation of outranking flows for each alternative $a \in A$: In the final matrix sum up the corresponding row elements and sum up the corresponding column elements as specified in the Eqs. (14) and (15) respectively, where $\Phi^+(a)$ represents row sum and$\Phi^-(a)$ represents column sum.

Positive preference flow (outranking):

$$\Phi^+(a) = \frac{1}{m-1} \sum_{j=1}^{n} \Pi_{ij} \tag{14}$$

Negative preference flow (being outranked):

$$\Phi^-(a) = \frac{1}{m-1} \sum_{i=1}^{n} \Pi_{ij} \tag{15}$$

Table 2
Some information about glauberite mine

Orebody	Type of deposit	Layer lattice
	slope of deposit	55~70°
	thickness of orebody	65~120m
	depth below the surface	320~340m
	mineable reserve	135,700,000t
	production rate	500,000t
Geomechanical data	Hanging wall Rock Mass Rating (RMR)	35
	Footwall RMR	40
	Orebody RMR	55
Hydrogeology	Hydrogeology conditions	Dry

Step 6 Prepare a net dominance matrix by subtracting column sum from row sum as specified in the Eq. (16).

$$\Phi(a) = \Phi^+(a) - \Phi^-(a) \tag{16}$$

Step-7: Rank the results based on the net dominance matrix.

3. Model of Mining Method Selection in Glauberite Mine Using EEM and PROMETHEE

A. Description of the Studied Site

In this study, to select a suitable mining method in Glauberite Mine, the EEM and PROMETHEE techniques are used.

Physical parameters such as deposit geometry (type of deposit, slope of deposit, thickness of orebody and depth below the surface) and rock mechanics characteristics have been shown in Table 2.

B. Model of mining method selection

For selecting the most economical and appropriate mining method using EEM-PROMETHEE method, in first stage all alternatives and decision attributes are determined.

Characteristics that have a major impact on the mining method selection include:

- Physical and mechanical characteristics of the glauberite deposit such as ground conditions of the deposit zone, shape of deposit, thickness and dip of orebody, plunge, depth below the surface, hangingwall, and footwall, grade distribution, quality of resource, etc. The basic components that define the ground conditions are: shear strength of rock material, natural fractures and discontinuities, orientation, length, spacing and location of major geologic structures, in situ stress, hydrologic conditions, etc.
- Economic attributes such as: capital cost, mining cost, mineable ore tons, grades and mineral value.
- Technical attributes such as: mine recovery, dilution, flexibility of methods, machinery and mining rate.
- Productivity attributes such as annual productivity, equipment efficiency and environmental considerations.

In this regard, in order to form the initial decision-making matrix, the parameters shape of deposit(X_1), slope of orebody(X_2), thickness of orebody(X_3), depth below the surface(X_4), grade distribution(X_5), hanging wall RMR(X_6), orebody RMR(X_7), recovery(X_8), dilution(X_9), mining cost(X_{10}) and annual productivity(X_{11}) were selected as the effective attributes involved in choosing the mining method.

Likewise, based on physical, mechanical, economical and technical parameters, the mining methods including Sublevel stoping(A_1), Block stoping(A_2), Sublevel caving(A_3), Block caving(A_4), Cut and fill(A_5), Shrinkage stoping(A_6) and Room and pillar(A_7) were selected as the alternatives.

The hierarchical structure of the problem is shown in Fig. 1.

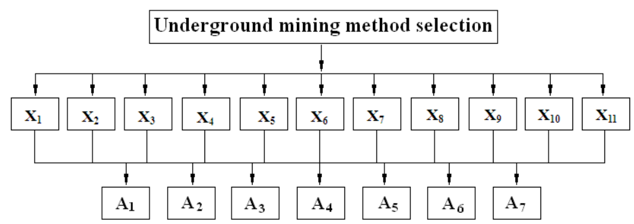

Fig. 1. Hierarchical structure of decision problem

4. Underground Mining Method Selection Using EEM-Promethee Method

A. Determination of the Weight of Attributes Using EEM

Using EEM, the weights of 11-attributes are determined by 5-steps in Sec. 2.1.

Step-1: For the most important attribute of 11 attributes in Fig. 1, we give the fuzzy information value 11, and for the most neglected attribute, the fuzzy information value 1.

The fuzzy information value of the attributes determined by these seven experts are listed in Table 3.

Table 3
The fuzzy score to determine the weights of attributes

Experts	Attributes										
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
Z_1	1	7	6	2	3	5	4	11	8	10	9
Z_2	3	5	4	1	2	7	6	9	8	11	10
Z_3	2	6	5	1	4	3	7	11	8	10	9
Z_4	3	4	5	1	6	7	2	9	8	10	11
Z_5	1	6	7	2	3	5	4	10	9	11	8
Z_6	3	11	10	1	5	4	2	9	7	6	8
Z_7	3	11	10	1	2	7	6	9	8	4	5

$$Q = \begin{Bmatrix} 1 & 7 & 6 & 2 & 3 & 5 & 4 & 11 & 8 & 10 & 9 \\ 3 & 5 & 4 & 1 & 2 & 7 & 6 & 9 & 8 & 11 & 10 \\ 2 & 6 & 5 & 1 & 4 & 3 & 7 & 11 & 8 & 10 & 9 \\ 3 & 4 & 5 & 1 & 6 & 7 & 2 & 9 & 8 & 10 & 11 \\ 1 & 6 & 7 & 2 & 3 & 5 & 4 & 10 & 9 & 11 & 8 \\ 3 & 11 & 10 & 1 & 5 & 4 & 2 & 9 & 7 & 6 & 8 \\ 3 & 11 & 10 & 1 & 2 & 7 & 6 & 9 & 8 & 4 & 5 \end{Bmatrix} \tag{17}$$

Step-2: Write a priority score matrix using Eq. (2), (3), (16).

$$A_{ij}=\begin{Bmatrix}0&7&7&2&5&7&5&7&7&7&7\\0&0&2&0&1&2&2&5&5&5&5\\0&5&0&0&1&2&2&5&5&5&5\\5&7&7&0&7&7&7&7&7&7&7\\2&6&6&0&0&5&5&7&7&7&7\\0&5&5&0&2&0&1&7&7&6&6\\0&5&5&0&2&6&0&7&7&6&6\\0&2&2&0&0&0&0&0&0&3&2\\0&2&2&0&0&0&0&7&0&5&5\\0&2&2&0&0&1&1&4&2&0&3\\0&2&2&0&0&1&1&5&2&4&0\end{Bmatrix} \tag{18}$$

Step-3: Calculate a_j, $a_{\max}$, $a_{\min}$ using Eq. (4), (5), (6), (18).

$$\begin{cases}a_j=\{9\quad 43\quad 40\quad 2\quad 18\quad 31\quad 24\quad 61\quad 49\quad 55\quad 53\}\\a_{\max}=61\\a_{\min=2}\end{cases} \tag{19}$$

Step-4: Calculate the difference of grade (d) using Eq. (7), (19). d=65.56

Step-5: Calculate the weight of the attributes using Eq. (8) or (9), (10).

$$w_j=(0.031, 0.109, 0.102, 0.015, 0.052, 0.082, 0.066, 0.151, 0.123, 0.137, 0.132) \tag{20}$$

B. Selection of the Suitable Underground Mining Method Using Promethee Method

The suitable underground mining method is selected by PROMETHEE methods of 4-steps in section 2.2.

Step-1: Making of the evaluation matrix.

The evaluation matrix is made by the importance linguistic values of the 7-alternatives (underground mining methods) for each attributes.

The decision-makers use the linguistic variables to evaluate the importance of attributes and the ratings of alternatives with respect to various attributes. In this work, to select the suitable underground mining method for the studied mine, in order to illustrate the idea of EEM- PROMETHEE, we deliberately transform the existing precise values to seven-levels, fuzzy linguistic variables (Table 4).

Table 4
Fuzzy linguistic variables

Linguistic variables	Numerical values
Very high (VH)	0.9~1
High (H)	0.7~0.9
Middle high (MH)	0.6~0.7
Middle (M)	0.4~0.6
Middle low (ML)	0.3~0.4
Low (L)	0.1~0.3
Very low (VL)	0~0.1

The importance linguistic values of the 7-alternatives for the 11-attributes are listed in Table 5.

Using table 4, 5, the evaluation matrix as follow.

$$G=\begin{Bmatrix}0.95&0.95&0.95&0.5&0.8&0.65&0.5&0.65&0.5&0.8&0.8\\0.95&0.95&0.95&0.5&0.65&0.65&0.5&0.5&0.35&0.95&0.95\\0.8&0.95&0.5&0.2&0.5&0.2&0.2&0.8&0.2&0.5&0.5\\0.8&0.95&0.8&0.2&0.35&0.2&0.2&0.8&0.2&0.5&0.65\\0.35&0.95&0.35&0.35&0.95&0.8&0.5&0.95&0.95&0.5&0.35\\0.5&0.95&0.2&0.5&0.8&0.8&0.8&0.8&0.8&0.8&0.3\\0.8&0.2&0.5&0.5&0.8&0.8&0.8&0.35&0.65&0.8&0.8\end{Bmatrix} \tag{21}$$

Step-2: Making of the dominance matrix using Eq. (11), (12), (21).

The dominance matrix for shape (k=1)

$$p_{ij-1}=\begin{Bmatrix}&0&1&1&1&1&1\\0&&1&1&1&1&1\\0&0&&0&1&1&0\\0&0&0&&1&1&0\\0&0&0&0&&0&0\\0&0&0&0&1&&0\\0&0&0&0&1&1&\end{Bmatrix}$$

From Eq. (13), (20), (21)

$$\Pi=\begin{Bmatrix}&0.326&0.74&0.74&0.417&0.265&0.393\\0.269&&0.74&0.74&0.417&0.402&0.662\\0.151&0.151&&0.052&0.265&0.265&0.26\\0.151&0.151&0.234&&0.265&0.265&0.362\\0.408&0.408&0.489&0.489&&0.56&0.435\\0.422&0.473&0.475&0.475&0.249&&0.383\\0.271&0.323&0.607&0.607&0.483&0.265&\end{Bmatrix} \tag{22}$$

Step-3: Calculation of outranking flows for each alternative

Table 5
The importance linguistic values of 7-alternatives for the 11-attributes

Alternatives	Attributes										
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}
A_1	VH	VH	VH	M	H	MH	M	MH	M	H	H
A_2	VH	VH	VH	M	MH	MH	M	M	ML	VH	VH
A_3	H	VH	M	L	M	L	L	H	L	M	M
A_4	H	VH	H	L	ML	L	L	H	L	M	MH
A_5	ML	VH	ML	ML	VH	H	M	VH	VH	M	ML
A_6	M	VH	L	M	H	H	H	H	H	H	L
A_7	H	L	M	M	H	H	H	ML	MH	H	H

($a \in A$) using Eq. (14), (15).

Positive preference flow (outranking):

$$\Phi^{+}(a) = (0.262 \quad 0.294 \quad 0.104 \quad 0.130 \quad 0.254 \quad 0.225 \quad 0.232) \tag{23}$$

Negative preference flow (being outranked):

$$\Phi^{-}(a) = (0.152 \quad 0.167 \quad 0.299 \quad 0.282 \quad 0.191 \quad 0.184 \quad 0.227) \tag{24}$$

Step-4: Prepare a net dominance matrix using Eq. (16), (23), (24) and rank the results based on the net dominance matrix.

$$\Phi(a) = (0.11 \quad 0.127 \quad -0.195 \quad -0.152 \quad 0.063 \quad 0.041 \quad 0.006) \tag{25}$$

According to the net dominance matrix(Eq. 25), the highest rank is held by the alternative A_2.

The order of these alternatives is $A_2 > A_1 > A_5 > A_6 > A_7 > A_4 > A_3$.

Block stoping method is selected as suitable mining method in Glauberite mine.

5. Conclusion

UMMS is one of the most important and the most essential of decisions of an underground mining project that have a significant influence on the all of the mine decision making problems.

In this paper, the suitable mining method for glauberite mine has been selected using EEM-PROMETHEE based on the estimation of the experts considering 11-criteria and 7-alternatives. After calculating the priority of the alternatives, the feasible mining methods for this mine have been ranked. The results showed that the block stoping method with the priority of 0.125 is the suitable for the studied mine.

The results indicated that by application of EEM-PROMETHEE for UMMS problem, some difficulties related to the previous methods could be reduced. Moreover, proposed approach could be applied simply in calculating weight of attributes. Hence, it is expected that this method will be applied to various problems of multi-criteria decision making.

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