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Comparative Analysis of AHP and TOPSIS Multi-Criteria Decision-Making Methods for Mining Method Selection

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ABSTRACT

In the realm of mineral resource extraction, the adoption of decision-making methodologies for the selection of appropriate mining techniques has garnered considerable attention in recent decades. This study aims to provide a comparative assessment of the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) as multi-criteria decision-making methods in the context of mining method selection. Case in point, the Gol Gohar Iron Mine No. 3, situated in Kerman province, was chosen for this investigation. In light of numerical scoring procedures, three primary extraction methods — Open Pit, Cut & Fill, and Sublevel Caving — were selected for initial consideration. Subsequently, these primary options were evaluated using decision-making models, taking into account management indicators. The goal was to determine the ranking and efficacy of these models in the selection of the extraction method. Our findings suggest that the AHP method, premised on paired comparisons, exhibits superior efficacy in mining method selection compared to the TOPSIS method. Furthermore, due to the interaction between indicators, the AHP method is recommended as the more suitable model relative to the TOPSIS method. Upon implementation of the model, the Open Pit mining method emerged as the most optimal extraction method for the anomaly No. 3 of Gol Gohar Iron Mine.

1. INTRODUCTION

The selection of an appropriate mining method constitutes a fundamental cornerstone in mining operations. This process, referred to as Mining Method Selection (MMS), involves the determination of an optimal method for mineral extraction [1-4]. Once a method has been chosen for a particular deposit, it is generally not feasible to switch to an alternative due to the substantial costs associated with the transition, which could render the entire project economically unviable [1, 5]. Over the past few decades, decision-making models have been increasingly utilized in the process of selecting among alternative extraction methods. Concurrent with the development of these models, a wealth of research articles has been published, expanding the knowledge base in this field [3, 6, 7]. The models employed in the majority of these studies are typically confined to multi-criteria decision-making methods [8-10].

A segment of researchers in the field of mineral studies [5, 7, 11, 12] have proposed qualitative models for the selection of the most suitable extraction method. Concurrently, another group of mineral scientists [11, 13, 14] have leveraged strategic approaches to this selection process.

The present research aims to evaluate the effectiveness of these decision-making models, with a focus on management decision-making indicators, in the context of the Gol Gohar Iron Mine No. 3. As the subject of this study, the open pit mine of the No. 3 Gol Gohar mine in Kerman province was selected. In order to identify the most suitable options for this site, the Nicholas and UBC numerical scoring methods were employed.

Subsequently, multi-criteria decision-making methods, particularly the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), were utilized to determine the most advantageous approach among the identified options in terms of management indicators.

Table 1. Classification of selection method selection criteria

Target	Indicator	Scale		
Select the extraction method	**Occupational factors**	**Technical**	Score selective extraction methods of the first stage	a_1
		Operational	The production rate of each method and the ability to increase production	a_2
			The flexibility of any extraction method in changing the extraction method	a_3
		Time	Life of mine	a_4
			Minimum access time to mineral	a_5
		Economic	Capital cost	a_6
			Operational cost	a_7
			The proceeds from the method and the net present value	a_8
			The minimum return on investment and the internal return rate of each method	a_9
		Environment	The impact of each method on the environment	a_{10}
	Outside factors	**Economic**	The potential loss of capital in any way	a_{11}
			Losses in case of project failure and change of set strategy	a_{12}
		Managerial	Optimal use of financial equipment and manpower	a_{13}
			The desire to invest in any method	a_{14}
			Absorbing or not absorbing the workforce and the conditions of skilled supply	a_{15}
		Executive and operational	Associate with any machinery in the company	a_{16}
			The technological, experimental and practical capabilities of the company in every way	a_{17}
			Manpower related to each method in the company	a_{18}

2. METHODOLOGY

In this section, input data and a brief description of the method are introduced. The effective indexes in the selection of extraction methods are generally divided into two categories of internal indicators (related to the conditions of the depository, such as geometric and geomechanical indices) and external factors of the mine (executive and management indicators). These indicators are subdivided into criteria and sub-criteria, as presented in Table 1. These criteria are determined according to the views of well-qualified and experienced experts in the field of mining. Primary options will be determined according to the geometric and geomechanically parameters of the area and the use of Nicholas and UBC scoring methods.

Geometric indices are classified in terms of thickness, slope, shape and grade distribution, and geomechanical indices are classified in terms of RSS ratio (the ratio of uniaxial compressive strength to the pressure of cover rocks), distance of joints, shear strength of joints, RMR (rock mechanics classification) and primary mining options have been selected using Nicholas and UBC scoring methods.

2.1 Multi-criteria decision making method – AHP

The AHP hierarchy process was developed by Thomas Sathy in 1980. In this way, complex problems are decomposed and analyzed in a hierarchy. This method is based on the paired comparison. The AHP evaluation process consists of six steps: hierarchical structure, AHP decision matrix, paired comparisons, incompatibility rate calculation, non-scaling of the paired comparison matrix, and the calculation of special values [15-18].

2.1.1 Hierarchical construction

In the first step, the creation of a hierarchy of problem is where the purpose of the problem lies at the highest level and in the next step, the criteria and below are the criteria and finally, the decision options. There is no limit to the number of levels in a hierarchy. The following criteria for each criterion may be quantitative or qualitative [17-19].

2.1.2 Calculate the weight of the elements in AHP

Table 2. Classification for a paired comparison of criteria [16-18]

Relative Comparison of Indicators (Oral Judgment)	Credit Score
Absolute Importance	9
Very strong importance	7
Strong importance	5
Poor importance	3
The same importance	1
Preferences between the above intervals	2,4,6,8

To calculate weight in a hierarchical analysis, if the importance of a criterion (*i*) is equal to the other criterion (*j*) equal to W_{ij}, In this case, the importance of criterion (*j*) relative to criterion (i) is $\frac{1}{W_{ij}}$. Also, the importance of each criterion in relation to the same criterion in the decision matrix is equal to one. To weigh the criteria, a n×n matrix is first formed, making up the decision criteria for the rows and columns of this matrix. The main diameter of this matrix is equal to one, and a pairwise comparison of the criteria is done according to Table 2. The pair comparison matrix is then used to determine the relative weight of the elements [17, 18].

The most important method for calculating relative weights based on the paired comparison matrix that is more accurate is the special vector method. In this method W_i is determined by relation 1 [17, 18]:

$$A.W = \lambda.W \tag{1}$$

where, λ represents the special value and W denotes the special vector of the pair comparison matrix A. To calculate λ, the determinant value of the matrix A-$\lambda.I$ is zero. Also, put the largest value λ in Eq. (2) to calculate W_i values [17, 18].

$$A - \lambda_{max}.I = 0 \tag{2}$$

For anomalies No. 3 of Gol Gohar Iron Mine, according to the judgments of the experts and the elite of the matrix, the pair of matrices were made according to Table 2. In the next step, weighing of each criterion was done using MATLAB software and special vector method.

2.1.3 Calculating the final weight

The final weight of each option in the hierarchical process is equal to the sum of the product of the weight of each criterion in the option rating. Which is given in Appendix III. [17, 18]:

$$A_{AHPscore} = \sum_{j=1}^{n} b_{ij}.W_{ij} \qquad i = 1,2,\dots,m \tag{3}$$

$$\sum_{i=1}^{m} b_{ij} = 1 \quad \text{j=1,2,…,n} \tag{4}$$

$$\sum_{j=1}^{n} W_j = 1 \tag{5}$$

where, b_{ij} represents the relative importance of the i-th option for the index a_j and W_j indicating the importance of the index a_j. Also, the values of the options and the weight of the indicators should be normalized [17, 18].

2.1.4 Calculating the inconsistency rate

In the AHP method, the calculation of the incompatibility rate is very important and one of the main advantages of this method. In a hierarchical analysis method, this rate should be less than 0.1 [17, 18]. With respect to the following relationships, the inconsistency index, the random inconsistency index and the hierarchical incompatibility rate are obtained.

$$I.I. = \frac{\lambda_{max} - n}{n-1} \tag{6}$$

$$R.I.I = 1.98\frac{n-2}{n} \tag{7}$$

$$I.R. = \frac{I.I.}{R.I.I} \tag{8}$$

where, *I.I.* refers to an inconsistency index, *R.I.I* represents an inconsistency index, *I.R.* indicates the inconsistency rate, λ_{max} denotes the largest special value of the matrix and n is the size of the matrix.

2.2 Multi-criteria decision making method– TOPSIS

In multi-criteria decision-making issues, we need to analyze some options. Each issue also has several indicators that are analyzed and analyzed in relation to each of the options, and should carefully identify these indicators in the issues [6, 19]. Among the multi-criteria decision-making methods, the TOPSIS method, which was presented in 1981, was pointed out. This model is one of the best multi-criteria decision making models [9, 20]. In this method, the decision matrix m×n, which has m option and n is the criterion and the measurement, is evaluated. In this model, for mathematical calculations, all quantities assigned to the criteria must be quantitative and, if qualitatively attributed to the criteria, they should be converted into small quantities. In the TOPSIS method, you must have the option of choosing the ideal positive solution with the least distance and with the ideal negative solution is the greatest distance [15, 21, 22]. The TOPSIS technique has six steps to solve the decision problem. Which is described below [5, 23, 24]:

1. Without scaling the decision matrix according to the 9th relationship

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} {r_{ij}}^2}} \tag{9}$$

2. Creating a weightless matrix as the input of the algorithm, assuming the vector W derived from expert opinions

$$\text{Weightless matrix} = N_D.W_{n*n} \tag{10}$$

So that N_D represents a matrix whose scores of indices are scalar and comparable, and W_{n*n} denotes a diagonal matrix whose nonzero elements are only non-zero.

3. Determine the positive ideal solution and the negative ideal solution

A^+ denotes the positive ideal option and A^- denotes the negative ideal option.

$$v^+ = \{(max v_{ij} | j \in J'), (min v_{ij} | j \in J') | i = 1,2,\dots,n\} = \{v_1^+, v_2^+, \dots, v_j^+, \dots, v_n^+\} \tag{11}$$

$$v^- = \{(min v_{ij} | j \in J'), (max v_{ij} | j \in J') | i = 1,2,\dots,m\} = \{v_1^-, v_2^-, \dots, v_j^-, \dots, v_n^-\} \tag{12}$$

4. Determine the separation distance or size

$$d_{i+} = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2\right\}^{0.5} ؛ i = 1,2,\dots,m \tag{13}$$

$$d_{i-} = \left\{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2\right\}^{0.5} ؛ i = 1,2,\dots,m \tag{14}$$

5. Determine the relative v_i proximity to the ideal solution

$$Cl_{i+} = \frac{d_{i-}}{(d_{i+} + d_{i-})} ; 0 \leq Cl_{i+} \leq 1; i = 1,2,\dots\dots,m \tag{15}$$

6. Ratings options (Descending order Cl_{i+})

In the TOPSIS method, it is possible to make a decision if there are positive and negative criteria (even together in the same issue) and a significant number of criteria can be examined to determine the best option. This method is simple and fast, and it responds well to a large number of criteria. In the TOPSIS method, it is easy to quantify qualitative criteria, and decision-making is possible despite qualitative and quantitative criteria. In this method, the output of the system is quantitative and in addition to determining the best option, the ranking of other options is expressed numerically. The TOPSIS method has appropriate mathematical foundations and deals with distances. Another advantage of this method is the involvement of the weight of all options and criteria in decision-making, and no weight is ignored in this method.

3. CASE STUDY: ANOMALY NO. 3 GOL GOHAR IRON ORE MINES

Gol Gohar Iron ore, one of the main reserves of Iranian iron ore, is located 60 kilometers southwest of Sirjan in Kerman province. The third anomaly is located two kilometers west of the mine, which is being extracted. The geographic length of the mass is 55˚17" and the latitude of the mass is 29˚6". Gol Gohar Mineral Area is located on the northeastern edge of the Sanandaj-Sirjan Zone. After determining the characteristics of the deposit and the geometric and geotechnical criteria presented in Table 3. Using UBC and Nicholas numerical scoring methods, three methods for the extraction, Open Pit, Cut & Fill and Sublevel Caving were selected as the initial options for exploitation of the mine. The results of selecting the extraction method using numerical scoring methods are presented in Table 4. In numerical scoring models, only geometric and rock mechanic indices are considered, for this reason, the resulting responses, such as extraction, Cut & Fill and/or Sublevel Caving high-cost, are a reality for a mine such as the No. 3 Gol Gohar mine.

Table 3. Characteristics of anomalous No. 3 Gol Gohar Iron ore mines [20, 21]

	Indicator	Description
Ore	Shape of the ore	Layer
	Thickness	An average of 40 meters
	Slope	20 degrees
	Cutie distribution	Gradual
	Depth	95 to 600 meters
	RQD	75%
	RSS	8.9
	RMR	Good (60-80)
	Save amount	643 million tons
	Jugging status	Filled (low resistance)
Hangwall	RQD	38%
	RSS	6
	RMR	Good (60-80)
	Jugging status	Clean with a smooth surface
Footwall	RQD	15%
	RSS	6.5
	RMR	Good (60-80)
	Jugging status	Clean with a toothed surface

The above result indicates the importance of side and managerial indicators in selecting the mining method and inappropriate numerical scoring models. Therefore, in order to select the extraction method in mines, it is suggested that numerical scoring models be used only to determine the initial options and the final choice should be made from the initial options using decision models and taking into account other indicators. The weight of the indexes, weighted weights, is obtained by comparing the pair according to Table 5. AHP pattern inputs are paired matrix matrices, which are presented in Tables 6-23. The input of the TOPSIS method is the weight of the indicators and the matrix. Also, in Figure 1, the importance of different parameters in the selection of the extraction method is shown.

According to Table 5, a pairwise comparison between the parameters has been made, which compares the effect of each parameter with respect to the other parameter, and finally, according to the effect of each parameter on the other parameter, a weight is given to that parameter, which is effective in choosing the appropriate extraction method. and the total weight of the parameters should be equal to 1. For example, a_1, which is related to the technical criterion, its influence weight is equal to 0.0714, and a_2, which is related to the production rate of each method, its influence weight is equal to 0.0706, and a_3, which is related to the flexibility of each extraction method in changing the extraction method, the weight of its effect in choosing the extraction method is less than the previous two components and is equal to 0.0499. Among the available parameters, the weight of parameter $\boldsymbol{a_{18}}$, which is related to the income from the method and the current net worth, has the most impact, and the weight of parameter a_{13}, which is related to the optimal use of financial and human resources and equipment, has the least impact.

Table 4. Results of scoring patterns in iron mine No. 3 Gol Gohar

Extraction Methods	UBC Pattern Scores	Rank in UBC Pattern	Nicholas Pattern Scores	Rank in Nicholas Pattern
Open Pit	32	1	38	2
Cut & Fill	30	2	39	1
Sublevel Caving	27	3	31	3

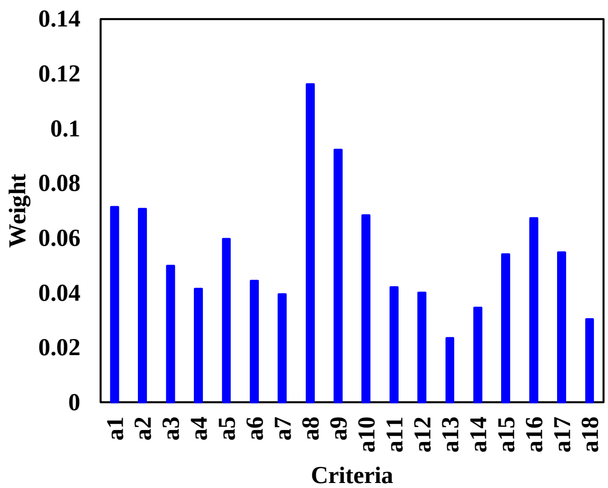

Figure 1. The importance of different parameters in selecting the extraction method

For the options in the anomaly No. 3 of Gol Gohar Iron Mine, the final weight of each option is calculated and is shown in Table 24. The values of λ_{max}, the inconsistency index, the random inconsistency index and the matrix inconsistency rate are shown in Table 25. Given that the incompatibility rate for all matrices is less than 0.1, Therefore, the judgment given regarding the paired comparison of parameters and options is logical. The matrix of the normalized decision to select the mining method No. 3 Gol Gohar as an input to the TOPSIS approach is presented in Table 26. The results of the AHP decision-making model for selecting the mining method of Gol Gohar No. 3 are shown in Figures 2-20. In the AHP model, Open Pit extraction method with the highest score and subsequently extraction, Cut & Fill and Sublevel Caving methods are suggested. Also, in the TOPSIS decision-making model shown in Figure 21, the Open Pit method is the first priority followed by the method of extracting, Cut & Fill and Sublevel Caving.

Table 5. Comparison of pairs between parameters

	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}	a_{11}	a_{12}	a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}	**Weight**
a_1	**1**	1	1	4	3	4	3	1/3	1/3	1	1/3	1/3	3	1	3	1	1	3	0.0714
a_2	1	**1**	1	1	1	3	3	1	1	1	1	1	3	3	2	1	3	3	0.0706
a_3	1	1	**1**	½	1/3	1/3	1/3	1/5	1/5	1	1	1	3	3	3	1	1	3	0.0499
a_4	¼	1	2	**1**	1	1	1	1/3	1/3	½	½	½	1	3	1	1	2	3	0.0414
a_5	1/3	1	3	1	**1**	1/3	1	1/5	1/3	1	½	½	3	3	3	1	3	3	0.0597
a_6	¼	1/3	3	1	3	**1**	1	1/3	½	½	1	1	1	2	1	½	1	1	0.0444
a_7	1/3	1/3	3	1	1	1	**1**	1/3	1/3	½	1	1	1	2	1	½	1	1	0.0395
a_8	3	1	5	3	5	3	3	**1**	2	1	3	3	4	3	3	2	3	3	0.1162
a_9	3	1	5	3	3	2	3	½	**1**	1	2	2	3	2	3	1	2	3	0.0923
a_{10}	1	1	1	2	1	2	2	1	1	**1**	3	3	1	1	2	2	2	3	0.0683
a_{11}	3	1	1	2	2	1	1	1/3	½	1/3	**1**	1	1	1	½	1/3	1/3	1	0.0420
a_{12}	3	1	1	2	2	1	1	1/3	½	1/3	1	**1**	1	1	½	¼	¼	½	0.0400
a_{13}	1/3	1/3	1/3	1	1/3	1	1	¼	1/3	1	1	1	**1**	½	¼	¼	¼	1/3	0.0235
a_{14}	1	1/3	1/3	1/3	1/3	½	½	1/3	½	1	1	1	3	**1**	1	½	½	2	0.0345
a_{15}	1/3	½	1/3	1	1/3	1	1	1/3	1/3	½	2	3	4	1	**1**	2	2	3	0.0540
a_{16}	1	1	1	1	1	2	2	½	1	½	3	4	4	2	½	**1**	1	3	0.0672
a_{17}	1	1/3	1	½	1/3	1	1	1/3	½	½	3	4	4	2	½	1	**1**	2	0.0547
a_{18}	1/3	1/3	1/3	1/3	1/3	1	1	1/3	1/3	1/3	1	2	3	½	¼	1/3	½	**1**	0.0303

4. RESULTS AND DISCUSSIONS

In the previous section, a model was proposed for the selection of the mining method and was implemented at the Gol Gohar iron mine. To reduce the long calculation in the proposed model for selecting the method of extraction of reserves, in the first step, based on the inherent criteria of the deposit, and with the help of numerical scoring models, possible extraction methods (or methods with the highest rates) are obtained. At this stage, for the storage of Iron No. 3 Gol Gohar, the method of Open Pit, Cut & Fill and Sublevel Caving is suggested. At this stage, the method of extracting Cut & Fill the first rank, and the method of Open Pit and Sublevel Caving were in the next ranks. Feasibility studies and operations indicate that Open Pit extraction method is the most economical and economical way to exploit this storage. However, no numerical scoring algorithms have been obtained. The above result suggests that numerical scalar models do not have enough efficiency in choosing the method of extraction of reserves. In the second stage, by applying the economic, managerial and environmental criteria (as well as the technical criteria that are obtained in the first stage), the initial options are ranked by the AHP and TOPSIS decision-making patterns. One of the features of the proposed model is the decision-making process in selecting the mining method with local and native conditions. The decision-making process will reduce the volume and error rates in the calculations. The final result can be used as a benchmark for comparing the efficiency of decision patterns especially in selecting the mining method of Gol Gohar No. 3 and TOPSIS model are based on decision matrices and distances from ideal and anti-ideal responses. Also, due to the difference in the method of Open Pit extraction in AHP compared to the TOPSIS model, and that the iron mine No. 3 Gol Gohar is exploited by the open method economically and successfully. Indeed, some of the evaluation criteria in decision-making problems are not independent of each other, especially in the issue of selection of extraction methods, and they are interactive.

In the AHP decision model, which is based on pairwise comparisons, in each parameter, the impact of the extraction options obtained in the first stage of scoring methods is calculated and weight is given to each extraction method. which shows the influence of each parameter in each of the extraction methods obtained in the first stage. For example, in parameter a_1, which is related to the technical criteria, the weight of the open pit extraction method is 0.32, the weight of the Cut & Fill method is 0.57, and the weight of sublevel caving method is 0.11. In Table 24, the weight of each extraction method in the desired parameters is calculated and in Figure 2, the appropriate extraction method using the AHP pattern is shown. In the TOPSIS model, which is based on the decision matrix and intervals of ideal and anti-ideal responses. The weight of the extraction methods of the first stage has been calculated in each parameter. For example, for parameter a_1, which is related to the technical criterion, the weight of the open pit mining method and the Cut & Fill method is the same and equal to 0.425, and the weight of sublevel caving is equal to 0.15. In Table 26, the decision matrix normalized by TOPSIS method, which has the weight of each extraction method in the desired parameters, is given, and in Figure 3, the appropriate extraction method using the TOPSIS pattern is shown.

Table 6. Comparison of paired a_1

	Open Pit	**Cut & Fill**	**Sublevel Caving**	**Weight**
Open Pit	1.00	4.00	6.00	0.69
Cut & Fill	0.25	1.00	2.00	0.20
Sublevel Caving	0.17	0.50	1.00	0.11

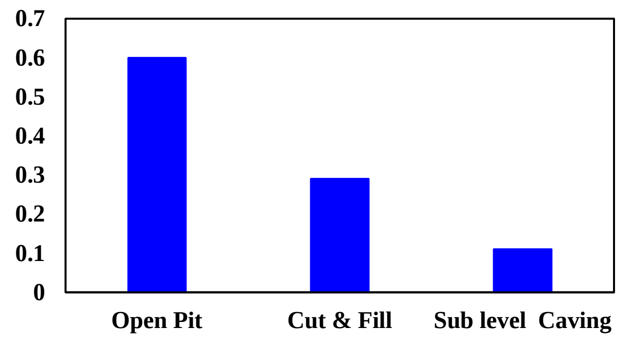

Figure 2. Rated first stage of selective mining methods

Table 7. Comparison of paired a_2

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	0.50	3.00	0.32
Cut & Fill	2.00	1.00	5.00	0.57
Sublevel Caving	0.33	0.20	1.00	0.11

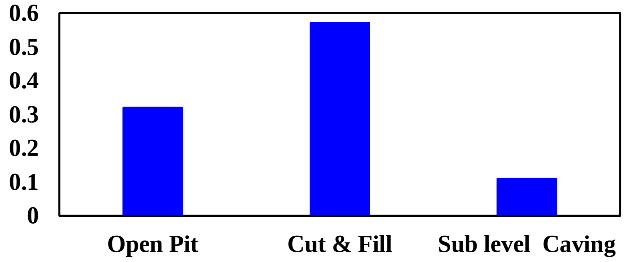

Figure 3. The rate of production of each method and

Table 8. Comparison of paired a_3

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	5.00	7.00	0.70
Cut & Fill	0.20	1.00	3.00	0.22
Sublevel Caving	0.14	0.33	1.00	0.08

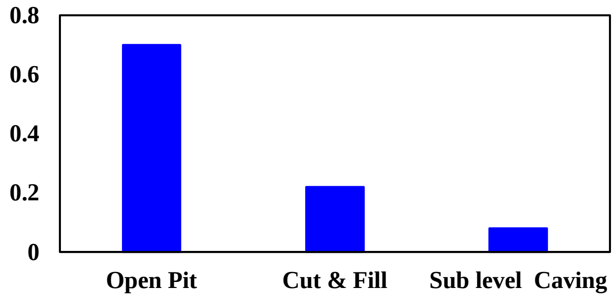

Figure 4. Flexibility in changing the extraction method

Table 9. Comparison of paired a_4

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	3.00	5.00	0.60
Cut & Fill	0.33	1.00	3.00	0.29
Sublevel Caving	0.20	0.33	1.00	0.11

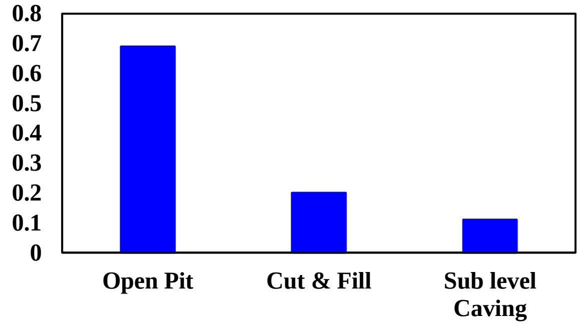

Figure 5. Life of mine

Table 10. Comparison of paired a_5

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	4.00	6.00	0.69
Cut & Fill	0.25	1.00	2.00	0.20
Sublevel Caving	0.17	0.50	1.00	0.11

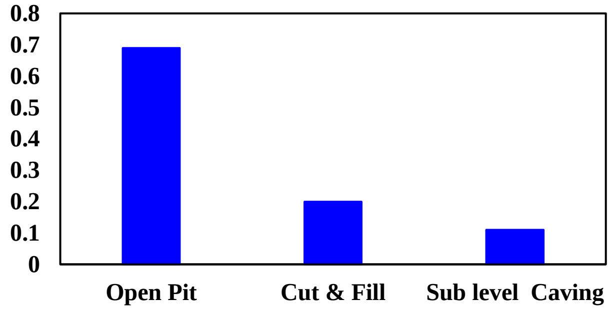

Figure 6. Minimum time access to mineral

Table 11. Comparison of paired a_6

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	5.00	9.00	0.72
Cut & Fill	0.20	1.00	3.00	0.20
Sublevel Caving	0.11	0.33	1.00	0.08

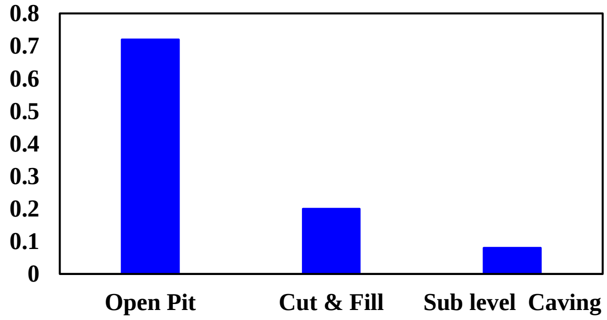

Figure 7. Capital cost

Table 12. Comparison of paired a_7

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	6.00	8.00	0.75
Cut & Fill	0.17	1.00	2.00	0.16
Sublevel Caving	0.13	0.50	1.00	0.09

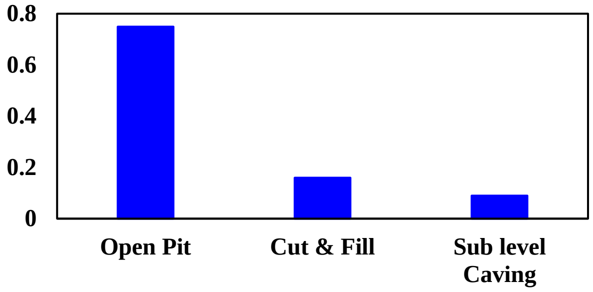

Figure 8. Operational cost

Table 13. Comparison of paired a_8

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	4.00	5.00	0.66
Cut & Fill	0.25	1.00	2.00	0.22
Sublevel Caving	0.20	0.50	1.00	0.12

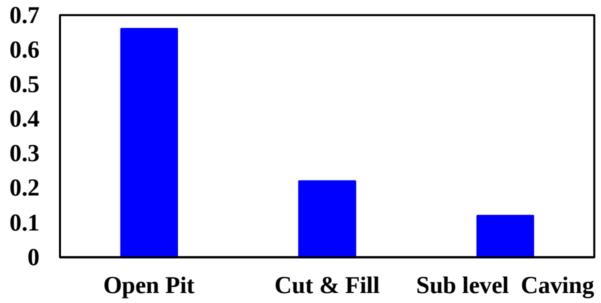

Figure 9. Revenue and net present method

Table 14. Comparison of paired a_9

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	3.00	4.00	0.61
Cut & Fill	0.33	1.00	2.00	0.25
Sublevel Caving	0.25	0.50	1.00	0.14

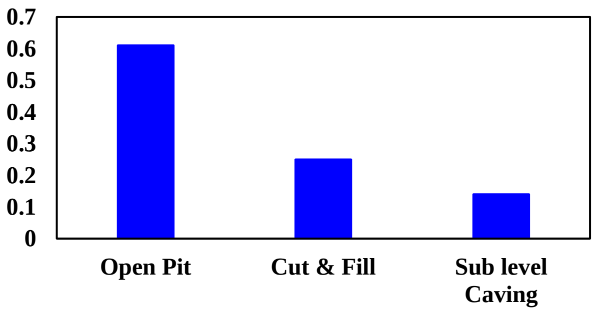

Figure 10. Minimum return on investment and internal rate of return method

Table 15. Comparison of paired a_{10}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	0.14	0.11	0.05
Cut & Fill	7.00	1.00	4.00	0.51
Sublevel Caving	9.00	0.25	1.00	0.44

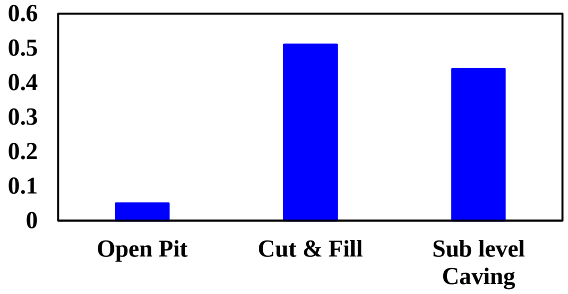

Figure 11. The impact of each method on the environment

Table 16. Comparison of paired a_{11}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	5.00	3.00	0.64
Cut & Fill	0.20	1.00	0.50	0.12
Sublevel Caving	0.33	2.00	1.00	0.24

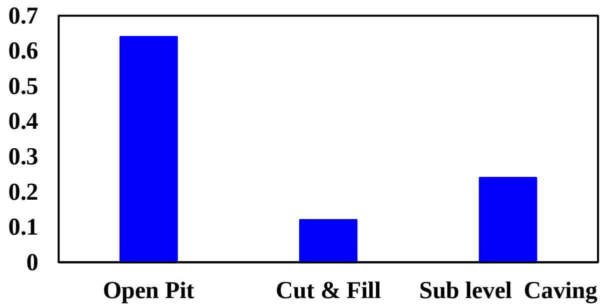

Figure 12. Potential capital lost in each method

Table 17. Comparison of paired a_{12}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	6.00	8.00	0.73
Cut & Fill	0.17	1.00	3.00	0.20
Sublevel Caving	0.13	0.33	1.00	0.07

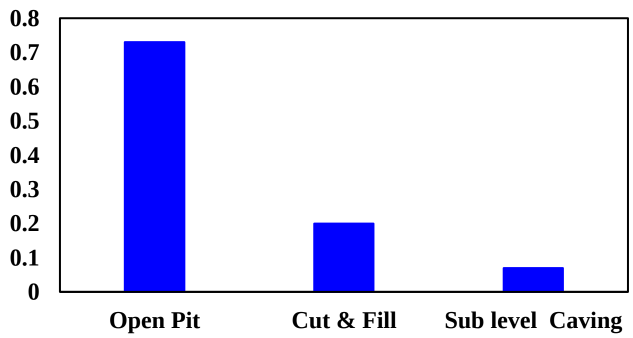

Figure 13. Loss in case of failure of the project and the strategy set

Table 18. Comparison of paired a_{13}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	7.00	6.00	0.74
Cut & Fill	0.14	1.00	0.50	0.09
Sublevel Caving	0.17	2.00	1.00	0.17

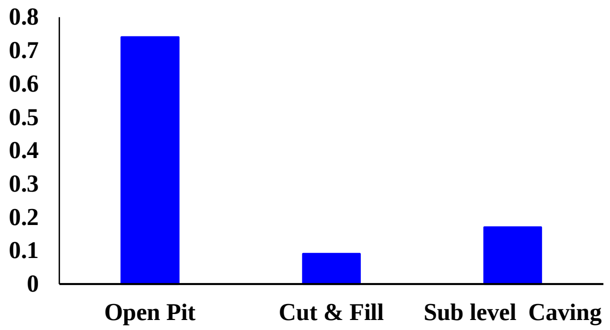

Figure 14. Efficient use of financial human resources facilities

Table 19. Comparison of paired a_{14}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	4.00	3.00	0.61
Cut & Fill	0.25	1.00	0.50	0.14
Sublevel Caving	0.33	2.00	1.00	0.25

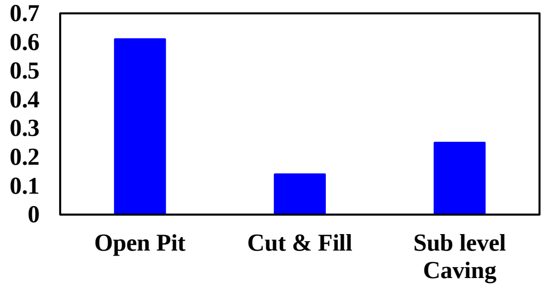

Figure 15. Willingness to invest in each method

Table 20. Comparison of paired a_{15}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	7.00	5.00	0.73
Cut & Fill	0.14	1.00	0.50	0.09
Sublevel Caving	0.20	2.00	1.00	0.18

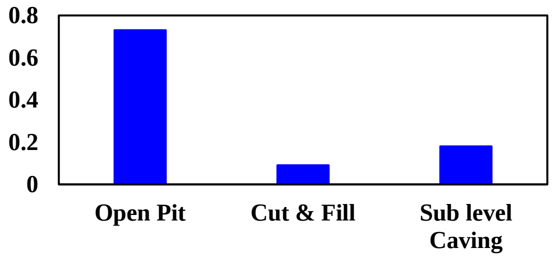

Figure 16. Absorption or non-absorption of labor and skilled labor supply conditions

Table 21. Comparison of paired a_{16}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	7.00	5.00	0.73
Cut & Fill	0.14	1.00	0.50	0.09
Sublevel Caving	0.20	2.00	1.00	0.18

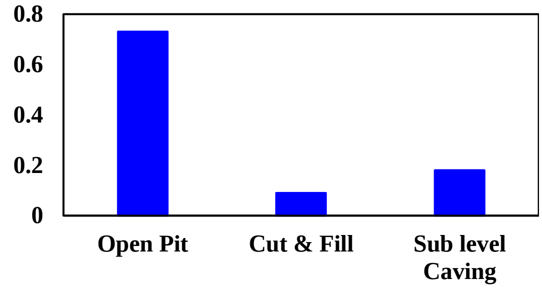

Figure 17. Having a machine of any of the company

Table 22. Comparison of paired a_{17}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	6.00	4.00	0.65
Cut & Fill	0.17	1.00	0.33	0.09
Sublevel Caving	0.25	3.00	1.00	0.26

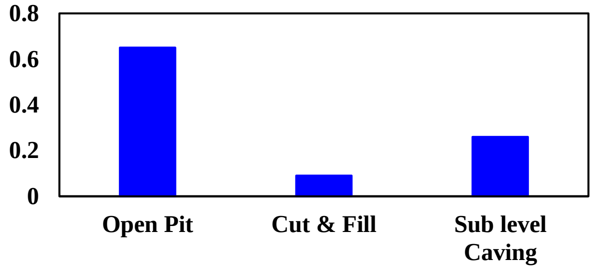

Figure 18. Empirical technology and the ability to participate in each method

Table 23. Comparison of paired a_{18}

	Open Pit	Cut & Fill	Sublevel Caving	Weight
Open Pit	1.00	6.00	4.00	0.65
Cut & Fill	0.17	1.00	0.33	0.09
Sublevel Caving	0.25	3.00	1.00	0.26

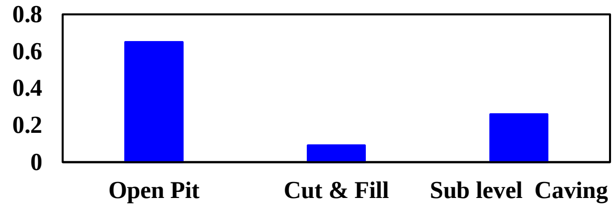

Figure 19. Having the human resources of each of the company

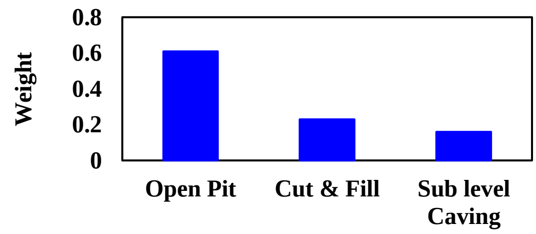

Figure 20. Appropriate extraction method with AHP method

Table 24. Calculate the final weight of the options

Parameters	Weight	Open Pit	Cut & Fill	Sublevel Caving
a_1	0.0714	0.32	0.57	0.11
a_2	0.0706	0.60	0.29	0.11
a_3	0.0499	0.70	0.22	0.08
a_4	0.0414	0.69	0.20	0.11
a_5	0.0597	0.69	0.20	0.11
a_6	0.0444	0.72	0.20	0.08
a_7	0.0395	0.75	0.16	0.09
a_8	0.1162	0.66	0.22	0.12
a_9	0.0923	0.61	0.25	0.14
a_{10}	0.0683	0.05	0.51	0.44
a_{11}	0.0420	0.64	0.12	0.24
a_{12}	0.0400	0.73	0.20	0.07
a_{13}	0.0235	0.74	0.09	0.17
a_{14}	0.0345	0.61	0.14	0.25
a_{15}	0.0540	0.73	0.09	0.18
a_{16}	0.0672	0.73	0.09	0.18
a_{17}	0.0547	0.65	0.09	0.26
a_{18}	0.0303	0.65	0.09	0.26
Ultimate Weight		0.6061	0.2295	0.1644

Table 25. Values λ_{max}, *I.I.*, *R.I.I.* and *I.R.* for different matrices

$$I.R. = Ave(I.I./R.I.I) = 0.0025$$

	Weight	λ_{max}	$I.I.$	$R.I.I.$	$I.R.$
a_1	0.0714	3.0092	0.0046	0.9900	0.0046
a_2	0.0706	3.0000	0.0000	0.9900	0.0000
a_3	0.0499	3.0000	0.0000	0.9900	0.0000
a_4	0.0414	3.0182	0.0091	0.9900	0.0091
a_5	0.0597	3.0000	0.0000	0.9900	0.0000
a_6	0.0444	3.0092	0.0046	0.9900	0.0046
a_7	0.0395	3.0000	0.0000	0.9900	0.0000
a_8	0.1162	3.0092	0.0046	0.9900	0.0046
a_9	0.0923	3.0000	0.0000	0.9900	0.0000
a_{10}	0.0683	3.0000	0.0000	0.9900	0.0000
a_{11}	0.0420	3.0182	0.0091	0.9900	0.0091
a_{12}	0.0400	3.0000	0.0000	0.9900	0.0000
a_{13}	0.0235	3.0000	0.0000	0.9900	0.0000
a_{14}	0.0345	3.0000	0.0000	0.9900	0.0000
a_{15}	0.0540	3.0092	0.0046	0.9900	0.0046
a_{16}	0.0672	3.0000	0.0000	0.9900	0.0000
a_{17}	0.0547	3.0000	0.0000	0.9900	0.0000
a_{18}	0.0303	3.0182	0.0091	0.9900	0.0091

Table 26. Normalized decision matrix used in the TOPSIS method

Criteria	Open Pit	Cut & Fill	Sublevel Caving
a_1	0.425	0.425	0.150
a_2	0.519	0.191	0.290
a_3	0.555	0.249	0.196
a_4	0.567	0.323	0.110
a_5	0.567	0.323	0.110
a_6	0.631	0.281	0.155
a_7	0.631	0.232	0.137
a_8	0.542	0.318	0.142
a_9	0.471	0.358	0.171
a_{10}	0.043	0.294	0.663
a_{11}	0.625	0.237	0.138
a_{12}	0.625	0.138	0.237
a_{13}	0.713	0.148	0.139
a_{14}	0.696	0.191	0.114
a_{15}	0.713	0.148	0.139
a_{16}	0.713	0.148	0.139
a_{17}	0.661	0.187	0.152
a_{18}	0.661	0.187	0.152

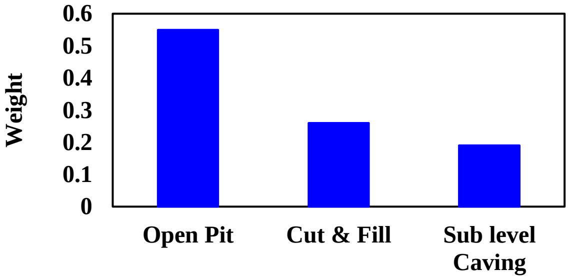

Figure 21. Proper extraction method with TOPSIS method

5. CONCLUSIONS

This research endeavored to address the limitations inherent in previous models. Initially, guided by the characteristics of three Gol Gohar Iron Nous deposits and employing numerical scoring methods, three extraction methods - Open Pit, Cut & Fill, and Sublevel Caving - were selected as the primary alternatives. These extraction methods were subsequently ranked using the chosen decision-making models AHP and TOPSIS, with management indicators taken into consideration. Both the AHP and TOPSIS models designated the Open Pit extraction method as the most suitable for this mine.

Significantly, in the AHP model, the difference in scores between the optimal extraction method (Open Pit) and the other methods was substantial, based on the paired comparison. Given the successful and profitable extraction currently being achieved using the Open Pit method, and studies indicating that the employment of other methods could not yield comparable profits, it can be posited that for the selection of the extraction method, models based on paired comparisons, such as AHP, exhibit greater effectiveness than the TOPSIS model.

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