Choosing shaft sinking method by using the combination of Fuzzy AHP &Fuzzy TOPSIS approaches

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Abstract

Shaft sinking is one of the main parts in underground mine planning. Shaft has various applications in underground mines e.g. minerals exiting flow, gases entrance or exit way, stope developments for exploitation etc. Considering that this section requires an abundance of expenses, management always following the election is the way that both terms have the technical considerations, economic constraints are also considered. Therefore, selecting shaft sinking method is one of the biggest concerns of underground mines management. There are some methods for this purpose including Delphi, ELECTRE, TOPSIS and AHP. This paper intends to use the combination AHP and TOPSIS methods under fuzzy environment in order to choose a ventilation shaft sinking method for Parvade mine located in coal zone of Tabas. The results indicate that RBM method is the most preferable approach, and drilling-blasting, Alimac, and SBM methods are preferred respectively.

Keywords: Shaft sinking, Tabas Parvade mine, Fuzzy AHP, Fuzzy TOPSIS

1-Introduction

Shafts are the most important of the deep ore bodies' openings which are used to have access to ore bodies and serve the underground operations. In addition to sink new shafts, deepening available shafts is also desirable in this field. Various shaft applications in underground mines has made shaft sinking one of the most essential parts in underground planning and it is one of the major concerns of mine designers and mangers to decide on an appropriate method for shaft sinking. The most desirable method is one which considers all technical and environmental issues and has the minimum cost. Decision making on choosing the best shaft sinking method gets more complicated as all quantitative and qualitative criteria impact on the sinking method selection and these criteria are often in contrast with each other.

Multi attribute decision making methods like AHP (Analytical hierarchy process) and TOPSIS (Technique for order performance by similarity to ideal solution) are two beneficial approaches in decision making problems which can evaluate quantitative and qualitative criteria and sort the preferences (See table-1). On the other hand, due to uncertainties in data collection, these uncertainties should be used therefore fuzzy theory must also be used in making decisions. Therefore, this paper has tried to apply fuzzy AHP and fuzzy TOPSIS in order to help decision making on the type of shaft sinking of Parvade mine in Tabas coal zone. For this purpose, FAHP has evaluated criteria weight and then fuzzy TOPSIS has prioritized the alternatives.

1 .Member of Student Researcher Club

2-Fuzzy theory

This theory has been first introduced by Lotfi A. Zadeh (1965). This theory works under uncertain conditions. This theory can change concepts, variables and systems which are vague and imprecise to mathematical forms and this can provide background for reasoning, inference, control and decision making in uncertainty conditions.

3-FAHP

AHP method has been introduced by Saaty [12]. This method enables decision makers to determine all interaction simultaneous impacts of many complicated situations. This system uses analyzing a problem into some detailed ones to solve the complicated problems.

The first level is devoted to the purpose and the second level is the criteria in AHP. If any detailed criteria, they are in lower levels. AHP method was compounded with Fuzzy one in 1996 by Chang [13]. The following covers the steps in this approach.

Step 1- Forming fuzzy decision matrix: $S_{k,}$ which is a fuzzy triangle number in each matrix paired comparison that as follow:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \tag{7}$$

Where:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right), \sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right), \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{8}$$

Where "g" shows the row number, and "i" and "j" show the alternatives and criteria respectively.

Step 2- Finding the degree of possibility S_g. If M_1 and M_2 are two fuzzy triangle numbers, the degree of possibility of M_1 to M_2 is shown by $V(M_1 \geq M_2)$ and they are defined as:

$$\begin{cases} V(M_1 \geq M_2) = 1, & M_1 \geq M_2 \\ V(M_1 \geq M_2) = 0, & M_1 \leq M_2 \\ V(M_1 \geq M_2) = hgt(M_1 \geq M_2), & otherwise \end{cases} \tag{9}$$

Also:

$$hgt(M_1 \geq M_2) = \frac{u_1 - l_2}{(u_1 - l_2) + (m_2 - m_1)} \tag{10}$$

Step 3- Finding the degree of possibility of one fuzzy triangle number from "k" of another fuzzy number. The following equation can be used to determine the degree of greatness:

$$V(M_1 \geq M_2, \ldots, M_k) = \min[(M_1 \geq M_2), \ldots, (M_1 \geq M_k)] \tag{11}$$

Criteria weight is calculated as follows:

$$w'^{(x_i)} = \min\{V(S_i \geq S_k\}, k = 1,2, \ldots n \qquad k \neq i \tag{12}$$

The paired matrix comparison and the criteria resultant will be as the below:

$$w' = [w'(c_1), w'(c_2), \ldots, w'(c_n)]^T \tag{13}$$

3-Fuzzy TOPSIS

This method was offered by Hwang and Yoon in 1981 [14]. This theory asserts that the selected alternative should be in the shortest distance with the positive ideal solution (the best case), and in the biggest distance with the negative ideal solution (the worst case). The following six steps are to solve Fuzzy TOPSIS problems.

Step 1- At first the alternatives should be scored considering different criteria, qualitative concepts should be used to weigh each criterion.

Step 2- This stage establishes a normal weighting fuzzy matrix.

Step 3- Determining the positive ideal solution (A^+) and negative ideal solution (A^-): these positive and negative ideal solutions are defined as the below:

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \tilde{v}_3^+, ..., \tilde{v}_n^+) = \left\{ \max_i \ v_{ij} \middle| (i = 1, 2, ..., n) \right\} \quad (14)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \tilde{v}_3^-, ..., \tilde{v}_n^-) = \left\{ \min_i \ v_{ij} \middle| (i = 1, 2, ..., n) \right\} \quad (15)$$

Step 4- Determining the distance of each alternative to positive and negative ideals. This distance of each option from positive ideal (d_j^+) and the distance of each alternative to negative ideal (d_j^-) are calculated as the following:

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+) \quad , \ i = 1, 2, \ldots, m \quad (16)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \quad , i = 1, 2, ..., m \quad (17)$$

Step 5- Determining relative closeness (CL^*) of one alternative to ideal solution can be calculated as the following formula:

$$CL^* = \frac{d_i^-}{d_i^- + d_i^+} \quad (18)$$

6) Sorting the alternatives: the bigger CL is the better.

4- Fuzzy Member Function

The decision maker should compare the alternatives with the criteria and give them a weight. To serve this purpose, some verbal terms can be used. Table 2 illustrates the importance of these verbal terms.

5-Parvade mine (Tabas coal zone)

Tabas coal zone is located in the east of Iran. This zone divided on three parts; Parvade, Nayband and Mezino areas. Nayband and Parvade coals are coke ones And Mezino coal is the thermal one. The area of this zone is 30,000 square meters and Iran's biggest resources are reaching to billions tons are located in this zone. Parvade is 1200 square kilometers. Parvade located on 70 kilometers far from Tabas in the geographical area of 33 and 5 to 32 and 50 and the geographical length is 57 and 15 to 76 and 45. The height of this area is 850 meters above the sea level. Parvade is located between Rostam and Ghoori Chay faults. Some faults with north east tendency and south west ones divide this area into districts I, II, III, IV and eastern.

6- Selection of the shaft sinking method

There are many criteria for determining the most appropriate method for shaft sinking. According to comments of experts, the most important criteria for selection one of the sinking methods Raise Boring Machine (A1), Shaft Boring Machine (A2) and Alimac (A3), and common methods as Drilling and Blasting (A4), have been chosen. Table 3 demonstrates indicators, symbols, and the way that each parameter influence choosing the shaft sinking methods for Parvade mines. The approach in this paper is using FAHP to obtain the weight of each criterion. Then Fuzzy TOPSIS sorts the alternatives. The criteria have been weighed by 13 experts. On the first FAHP matrix is obtained then Importance degree of each S over other S_i has been calculated.

Greatness of each fuzzy triangular number compared to other fuzzy triangular numbers and the final weight of FAHP have been shown in table 4. After that importance of each criterion to each alternative is weighed by experts. Normalized weighed fuzzy matrix has been mentioned in table 5. Finally, alternatives have been sorted according to their relative closeness . As it has been indicated in table 6, RBM is the first which means to be the most appropriate method for ventilation shaft sinking applied in Parvade coal mine. Blasting, Alimak and SBM have next ranks respectively.

7- Results

Selection the shaft sinking method is one of fundamental decisions in underground mines that influences designing and planning. There are many methods for decision making which have relative advantages and disadvantages. A combinational method can be used to have the most of advantages and achieve better results. On the other hand, due to uncertainty in decision making has necessitated Fuzzy method. This paper has tried to use a combinational method of Fuzzy AHP and Fuzzy TOPSIS to find out the best method for shaft sinking in Parvade coal mine located inside Tabas coal area. The results indicated that RBM is the best and most appropriate method. Drilling-Blasting, Alimak and SBM have the other ranks.

Table-1: sample of multiple attribute decision making approach

Proposed by	Method used	Year	Application areas
C. Yu, C. Li	Fuzzy AHP	2001	Plant location selection problem[2]
Z. Jiang et al	Fuzzy AHP	2009	Partner Selection and Evaluation for Aeronautical Subcontract Production[3]
M. Ataei et al	AHP	2008	Mining method selection[4]
M. Ataei et al	TOPSIS	2008	Suitable mining method[5]
M. Z. Naghadehi et al	FAHP	2009	Selection of optimum underground mining method[6]
S. Alpay , M. Yavuz	AHP, FMADM	2009	Underground mining method selection[7]
T.Chen, C. Tsao	Fuzzy TOPSIS	2008	The interval-valued fuzzy TOPSIS method and experimental analysis[8]
H. Wu et al	TOPSIS, SAW,	2009	evaluating banking performance based on Balanced Scorecard[9]
Yavuz et al	AHP	2008	The optimum support design selection[10]
A. Aghajani & M. Osanloo	AHP-TOPSIS	2007	Loading – Haulage Equipment Selection in Open Pit Mines[11]

Table 2: verbal terms for fuzzy rates

Linguistic terms	Corresponding Fuzzy Number
Very bad	(0,0,1)
Bad	(0,1,3)
Medium bad	(1,3,5)
Medium	(3,5,7)
Medium good	(5,7,9)
Good	(7,9,10)
Very good	(9,10,10)

Table 3: Effective criteria in choosing the method

Criteria	Water penetration	Advance rate	Rock mechanic features	Shaft length	Shaft diameter	Safety	Operation cost	Capital cost
Symbol	C1	C2	C3	C4	C5	C6	C7	C8
effect	-	+	+	+	+	+	-	-

Table4- final weight obtained of FAHP

	Local Weight	Global Weight
V(S1>S2,S3,S4,S5,S6,S7,S8)	0.662	0.0979
V(S2>S1,S3,S4,S5,S6,S7,S8)	0.692	0.103
V(S3>S1,S2,S4,S5,S6,S7,S8)	0.975	0.1443
V(S4>S1,S2,S3,S5,S6,S7,S8)	0.785	0.1161
V(S5>S1,S2,S3,S4,S6,S7,S8)	0.896	0.1326
V(S6>S1,S2,S3,S4,S5,S7,S8)	0.746	0.1104
V(S7>S1,S2,S3,S4,S5,S6,S8)	0.999	0.1478
V(S8>S1,S2,S3,S4,S5,S6,S7)	1	0.148

Table 5- Normalized weighed fuzzy matrix

	A1			A2			A3			A4		
C1	0.065	0.081	0.098	0.046	0.07	0.092	0.026	0.04	0.059	0	0.009	0.023
C2	0.067	0.083	0.097	0.054	0.072	0.085	0.012	0.025	0.044	0	0.009	0.019
C3	0	0.035	0.072	0.006	0.021	0.075	0.067	0.064	0.11	0.08	0.11	0.145
C4	0	0.009	0.014	0.025	0.038	0.048	0.07	0.081	0.092	0.091	0.102	0.117
C5	0	0.027	0.046	0.057	0.079	0.104	0.083	0.101	0.119	0.099	0.108	0.133
C6	0.088	0.101	0.111	0.076	0.086	0.092	0.034	0.046	0.06	0	0.016	0.027
C7	0.094	0.111	0.148	0.089	0.108	0.13	0.042	0.081	0.092	0	0.015	0.035
C8	0	0.007	0.016	0.018	0.033	0.042	0.055	0.064	0.076	0.12	0.133	0.149

Table 6- final ranking of alternatives

Ranking	CL_i	d^-_i	d^+_i	Alternative
4	0.060250063	0.4836388	7.5435529	SBM
1	0.067037	0.537782	7.4843801	RBM
3	0.065938	0.528522	7.486919	Alimac
2	0.066573	0.5340034	7.487368	Drilling- Blasting

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