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Selection of Optimum Tunnel Support System Using Aggregated Ranking of SAW, TOPSIS and LA Methods

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Abstract The selection of optimum support system is a key step in the successful design operation of tunneling, rock mass stabilization and minimization of plastic zone extension around a tunnel. In this context, it is not sufficient to rely only on the experiences of design engineers, but taking all effective measures and parameters is necessary to do a proper choice. In this paper, multi attribute decision making (MADM) methods including simple additive weighting (SAW), technique for order preference by similarity to ideal solution (TOPSIS), and linear assignment (LA) are used for selection of a proper support system for Beheshtabad water transporting tunnel from among the six proposed support systems by considering the attributes of cost, safety factor, applicability, installation time, displacement and capable of mechanization. Aggregating the results of ranking by the ranks mean, borda and copland techniques led to the suggestion of a support system of injectional rock-bolt 3 m in length with 1.5×1.5 m distance together with shotcrete by 10 cm in thickness.

Keywords: Saw, Topsis, Linear Assignment (La), Support Systems, Aggregated Methods.

1 Introduction

Today, along with the increasing development of underground structures and their new and diverse applications, especially the inter-city and intra-city transport network, studying the resistance of these structures against static and dynamic loads in the design of such structures in terms of safety and cost has been attended. According to the obtained experiences, on the one hand, the design and construction of such structures in different environments are based on the special principles and methods. For example, rock mass is own used instead of conventional engineering materials in the construction of underground structures, so naturally followed by some uncertainty on some properties of rock and underground water. In order to deal with these uncertainties, it is necessary to perform a proper and flexible designing and also observe the safety in implementation. On the other hand, engineers often deal with situations in which they should select the appropriate option among the available alternatives. In the past, selecting the appropriate alternative was based on engineers' experiences and in accordance with existing laws, but such work today is possible with higher confidence degree by using the Multi Attribute Decision Making (MADM) methods. Several research about the

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issues related to mining, tunneling and underground spaces have been carried out using MADM methods that some of the most important of them are presented in Table 1.

As can be seen in Table 1, the methods such as Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) alone or in combination with fuzzy logic have been used in most performed research to select the appropriate alternative (extraction method, transport system, loading, transportation, mining, maintenance, etc.) for underground structures.

Table 1 Some of the mining and tunneling studies with different methods of MADM

Topic	Method	Authors	Year	Reference
Selection of the appropriate monitoring system for drilling an open pit mine	AHP	Dessureault and Scoble	2000	[1]
Underground mining method selection	AHP-Yager	Karadogan et al.	2001	[2]
Selection of the transport system of mineral resources	PROMETHEE I	Elevli et al.	2002	[3]
Selection of the transport system in coal mine	AHP-Yager	Kesimal and Bascetin	2002	[4]
Surface mine equipment selection	AHP	Bascetin	2004	[5]
Selection of the transport system of mineral resources	PROMETHEE II	Elevli and Demirci	2004	[6]
Mining method selection	FAHP	Bitarafan and Ataei	2004	[7]
Selection of the rock bolt system for underground mine	AHP	Kazakidis et al.	2004	[8]
Location of cement plant	AHP	Ataei	2005	[9]
Open pit mining method selection	PROMETHEE II	De Almeida et al.	2005	[10]
Choose an appropriate method of tunnel excavation	AHP	Bottero, Peila	2005	[11]
Coal mining method selection	AHP	Uysal and Demirci	2006	[12]
Selection of the transport system in open pit mine	AHP-Yager	Bascetin et al	2006	[13]
Choosing drilling machine in tunneling operations.	AHP-Yager	Acaroglu et al	2006	[14,15]
Selection of the product type of mining company	AHP	Wu et al.	2007	[16]
Selection of the system of loading and transportation in open pit mine	AHP-TOPSIS	Aghajani, Osanloo	2007	[17]
Selection of the method for extracting a platinum mine	AHP	Musingwini and minnitt	2008	[18]
Underground mining method selection	AHP-TOPSIS	Ataei et al.	2008	[19,20]
Underground mining method selection	FAHP	Zare Naghadehi et al.	2008	[21]
Selection of the support system in main tunnels of underground mine	AHP	Yavuz et al. (2008)	2008	[22]
Underground mining method selection	FAHP	Karadogan et al.	2008	[23]
Underground mining method selection	AHP-Yager	Alpay, Yavuz	2009	[24]
Selection of the support system in an underground mine access tunnel	AHP	Oraee et al.	2009	[25]
Mining method selection	FAHP	Azadeh et al.	2009	[26]
Location of beneficiation plant	AHP	Safari et al.	2009	[27]
Selection of the tunnel support system	AHP-TOPSIS	Oraee et al.	2010	[28]
Fire risk assessment system for underground mining of coal	AHP	Lang and Fu-bao	2010	[29]
Mining method selection	FAHP	Azadeh et al.	2010	[30]
Selection of the bench height in open pit mining	VIKOR	Soltanmohammadi et al.	2010	[31]

Topic	Method	Authors	Year	Reference
Selection of the surface mine equipment	VIKOR	Aghajani Bazzazi et al.	2011	[32]
Evaluation of tunnel boring methods	FAHP-TOPSIS	Golestanifar et al.	2011	[33]
Risk assessment of tunneling projects	Fuzzy TOPSIS	Fouladgar et al.	2012	[34]
Selection of the Tunnel Boring Machine (TBM)	Fuzzy TOPSIS-FAHP	Yazdani-Chamzini and Haji Yakhchali	2012	[35]
Risk management of underground mining projects	AHP	Badri et al.	2013	[36]
Choosing the best ventilation system	FAHP	Mirhedayatian et al.	2013	[37]
Choosing the best ventilation system	VIKOR-SWARA	Hashemkhani Zolfani et al.	2013	[38]
Surface mine equipment selection	FNAP-TOPSIS	Rahimi Ghazikalayeh et al.	2013	[39]

Because on the one hand, there are several technical and economic criteria in selecting a proper support system for tunnels and on the other hand, methods that are used for designing the support system generally are based on the preferences of designers and their work experience, possibility of a careful choice of an appropriate support system in terms of technical, economic and safety is difficult. Therefore, proposing an appropriate method seems necessary in this context.

In current work, proper support system is selected for Beheshtabad water transporting tunnel using SAW, TOPSIS and LA methods by considering of effective attributes. Finally, the optimum support system is suggested using aggregating techniques that is economically and safety suitable.

2 Multi-Attribute Decision Making Methods (MADM)

In MADM problems, any alternative is evaluated by several attributes and selecting an alternative is performed by determining the desired level for the criteria or pair-wise comparison of criteria and alternatives. The best alternative in the multi attribute models will be an alternative which provides the most preferable value of each existing feature. Base of modeling is creating and establishing the contingency table [40].

Among the most common MADM methods we can point out to Simple Additive Weighting (SAW), TOPSIS and Linear Assignment (LA). First, the performance of alternatives must be evaluated in terms of attributes in all three methods.
Therefore, decision matrix is generated as follows:

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \cdots & \cdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

in which x_{ij} is the performance of alternative i $(i=1,2,\ldots,m)$ in related to the attribute j $(j=1,2,\ldots,n)$.

On the use of SAW, TOPSIS and LA, determining the relative importance of existing attributes is an effective step in problem solving process. Therefore, we can use methods such as using the expert opinions, Shannon entropy and eigenvector method [41]. After formation of the decision matrix and determination of the importance coefficient of attributes, the methods used are as follows:

2.1 SAW method

This method, also called the weighted linear combination method was suggested in 1981 by Hwang and Yoon. In this way, the matrix's arrays are considered as mean of elements, and weights of attributes are considered as the weight of these numbers. Using this method rely on the assumption of preference independence and being separated of attributes from each other, and is done during the following steps [42]:

- Normalization of decision matrix is done by linear method for positive and negative attributes is done respectively with the following equations:

$$r_{ij} = \frac{x_{ij}}{\max_i \{x_{ij}\}} \tag{2}$$

$$r_{ij} = \frac{\min_i \{x_{ij}\}}{x_{ij}} \tag{3}$$

- Determination of the weight vector of criteria which are defined according to importance coefficient of different criteria in decision making as $[w_1, w_2, \dots, w_n]$.
- Selection of the best option that is determined from the following equation:

$$A^* = \{A_i | \max_i \frac{\sum_{j=1}^{m} w_j r_{ij}}{\sum_{j=1}^{m} w_j} \} \tag{4}$$

By assumption of the total weight of the attribute equal to 1:

$$A^* = \{A_i | \max_i \sum_{j=1}^{m} w_j r_{ij} \} \tag{5}$$

2.2 TOPSIS method

In this technique, the positive (A^+) and negative (A^-) ideal solutions are defined on Euclidean space, and then distances of alternative i from these solutions are computed. The base of alternatives ranking is farness from A^- and closeness to A^+. On the detection of positive and negative ideal solutions, it is important to note that appropriateness of each attribute should be steadily increasing (or decreasing) and in this case, the best present value of an attribute is representative its positive ideal and the worst value belongs to its negative one [42]. Steps of TOPSIS method are as follows:

- Normalization of decision matrix using Euclidean norm by the following equation:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{6}$$

in which, the attribute i and j are indicators of desired alternative and attribute, respectively.

- Creating a weighted normalized decision matrix (V) as the product of the normalized decision matrix in weight vector of attributes:

$$v_{ij} = w_j r_{ij} \qquad j = 1, \dots, n ; i = 1, \dots, m. \tag{7}$$

- Identifying the positive and negative ideal solutions as follows:

$$A^+ = \{ v_1^+, v_2^+, \dots, v_j^+, \dots, v_n^+ \} \tag{8}$$

$$A^- = \left\{ v_1^-, v_2^-, \dots, v_j^-, \dots, v_n^- \right\} \tag{9}$$

which v_j^+ and v_j^- are respectively the best and worst value of attribute *j* of all the alternatives. The alternatives cited in A^+ and A^-, respectively indicating better and worse alternatives.

- Calculating the relative distance from A^+ and A^- by the following equations:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(V_{ij} \quad V_j^+\right)^2} \tag{10}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_j^-\right)^2} \tag{11}$$

- Calculating the relative closeness attribute by the following equation:

$$C_i^+ = \frac{S_i}{S_i^+ + S_i} \tag{12}$$

The value of this attribute changes between 0 and 1. Whatever desired alternative is more similar to ideal, distance would be much farther away from zero and its relative closeness attribute would be closer to one.

- Ranking alternatives based on highest value of relative closeness attribute.

2.3 LA method

Multi-attribute decision making methods are used to select the most appropriate choice among *m* available alternatives, and a distinctive feature of them is the presence of a few countable predetermined alternatives. The best alternative in a multi-attribute model is an alternative which provides the most preferred value from each available feature. Modeling is based on the development and formation of consistency table [40].

One of the most important methods in order to select the most appropriate option among m available alternatives is the linear assignment method. Ranking in linear assignment method is based on scores of assumed alternatives of each attribute in a special problem and the final rank of the alternatives is determined by a linear compensation process. In this method, based on the simplex property of solution space, while considering all the arrangements implicitly, optimal solution is extracted within a convex simplex space. In addition, the compensatory feature of attributes obtained from exchange between the alternatives and ranks, although the attribute weight vector is obtained based on expert's opinions. The main advantage of this MADM method is taking advantage of both hard and soft (hybrid) techniques. In soft decision-making techniques, describing the model is based on a contingency table, while in hard decision-making techniques, the model is defined based on mathematical equations system. Apparently, the hybrid decision-making techniques follow the logic of soft techniques, and are defined based on the contingency table but take advantage of mathematical equations system practically in the solution process; therefore, they have strengths of both hard and soft techniques. On the one hand, this method causes exchange between attributes using a simple raking for the alternatives and lacks complicated calculations, and on the other hand, there is no requirement for assimilating measurement scales, and the attributes can be of any scale [43].

The stages of applying this ranking method are as follows [43]:

- Determining the rank of any risk for each attribute: formation of a matrix (m × m), which its row and column indicates the rank and attribute respectively.

- Forming the allocation matrix or gamma matrix (γ): formation of a square matrix ($m \times m$) with line as i showing risk and column as k showing rank. Components of γ matrix (γ_{ik}) are the total weight of the attributes which its *i*th risk has *k*th rank. Gamma matrix is an allocation matrix that its optimal answer can be obtained using any of the allocation methods (transport, Hungarian method, grid method and linear programming method (0,1)). The most common solution method in linear assignment method is the Linear Programming method.
- Ranking by linear programming: Ranking is done according to the following models.

$$Max\ Z = \sum_{i=1}^{m}\sum_{k=1}^{m}\gamma_{ik}h_{ik} \tag{13}$$

$$\sum_{k=1}^{m} h_{ik} = 1 \qquad , i = 1, 2, \ldots\ldots, 25 \tag{14}$$

$$\sum_{i=1}^{m} h_{ik} = 1, \quad k = 1, 2, \ldots, 25, \quad h_{ik} = 0\ or\ 1 \tag{15}$$

where h_{ik} is a binary variable which means risk factor i takes k rank when be equal 1.

3 Aggregation techniques of MADM

With various MADM techniques, there is the possibility of different ranking for the same issue. In this case, it is possible to use aggregating techniques such as ranks mean, Borda, and Copland in order to assemble different ranks for obtaining the final value [40], [41].

3.1 Ranks mean technique

In this technique, the alternatives are prioritized based on the achieved arithmetic mean of ranks from different MADM methods [41]. Obviously the alternatives with the highest arithmetic mean will be in preference.

3.2 Borda technique

This technique is based on majority rule, and rank of each pair in different ranking ways is compared with each other. If the preferences of alternative K is on alternative L be more than the preferences of alternative L on alternative K, it means win (M) and if the former be less than or equal to the later, it means lost (X). In this condition, priority attribute for each alternative is considered as the summation of their win (Ms) [41].

3.3 Copland technique

This technique can be called correction of previous techniques, since, in addition to Ms, the numbers of Xs are also considered in prioritization. In other words, the score of each alternative in Copeland technique is calculated based on the difference of the number of wins and losts in accordance with the following equation [40]:

$$T_i = \sum M_i - \sum X_i \tag{16}$$

4 Case study: Beheshtabad Water Transporting Tunnel
4.1 Geomechanical properties of area

Beheshtabad Water Transporting Tunnel with a length of approximately 65 km and a diameter of 6 m and horseshoe cross-section which is one of the biggest projects for remedying the lack of water supplies in the sectors of drinking, industrial and agricultural in the central plateau of Iran, with an estimate of 1070 million cubic meters per year. The tunnel in northeast-southwest direction is located near the Ardal town of Isfahan province [44]. The geotechnical characteristics of the area are presented in Table 1.

Table 1 Geomechanical properties of Beheshtabad Tunnel [44]

$\rho(kg/cm^3)$	2720
$E(Pa)$	1×10^9
$G_m(Pa)$	4.038×10^8
$\phi(\circ)$	30
$C(Pa)$	1.5×10^6
ν	0.3

4.2 Tunnel geometry

Beheshtabad tunnel excavation is done by blasting method in several stages because of weakness of its site. The purpose of this drilling plan is reducing the spread of the plastic zone and enhancing the performance of the operation. To analyze the stability of the tunnel, numerical software Flac2D was used due to continuous environment. Figures 2 and 3 indicate the process of model constructing in the mentioned software according to excavation stages. In figures 4 and 5, the vertical stress (*Syy*) and vertical displacement around the tunnel after excavation are also shown. For the constructed model, six types of support system are considered in Table 2 [44].

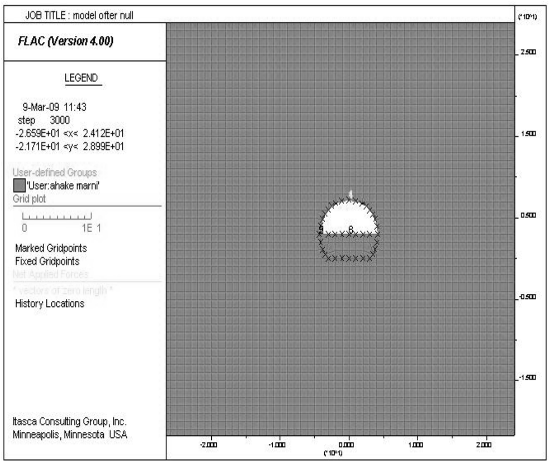

Fig. 2 The first step of tunnel excavation

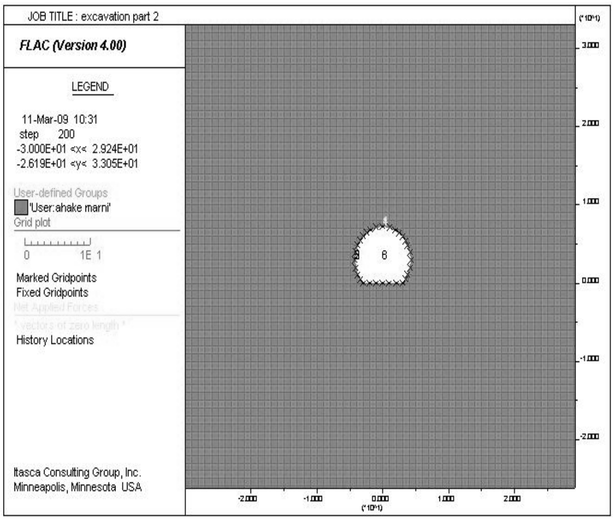

Fig. 3 The second step of tunnel excavation

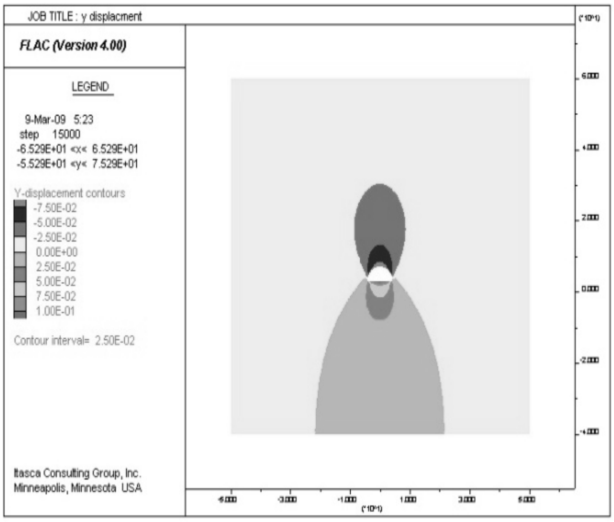

Fig. 4 Stress and displacement around the tunnel at the first phase of excavation

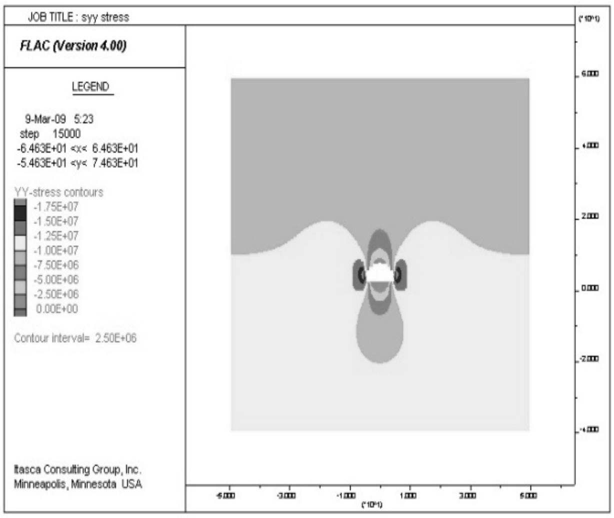

Fig. 5 Stress and displacement around the tunnel at the second phase of excavation

Table 2 Proposed support systems for Beheshtabad tunnel

Support system	Definitions
A	The combination of Shotcrete by 25 cm in thickness together with IP_{180}
B	The combination of Shotcrete by 30 cm in thickness together with IP_{160}
C	The combination of Shotcrete by 20 cm in thickness together with wire mesh
D	The combination of Shotcrete with steel fiber by 20 cm in thickness
E	Application of Injectional rock-bolt 3 m in length with 1.5 × 1.5 distance together with Shotcrete by 10 cm in thickness
F	Application of injectional rock-bolt 3 m in length with 2 × 2 distance together with Shotcrete by 20 cm in thickness

5 Optimum support system selection

Selection is done based on the obtained results from numerical studies and expert's opinions.

5.1 Decision matrix

In this study, six attributes including cost (C_1), safety factor (C_2), applicability of support system (C_3), installation time (C_4), displacement (C_5) and the capability of mechanization (C_6) have been considered in selection of tunnel support system. The selection process of support system in this study includes 6 attributes and 6 alternatives that its hierarchical structure is shown in Figure 6.

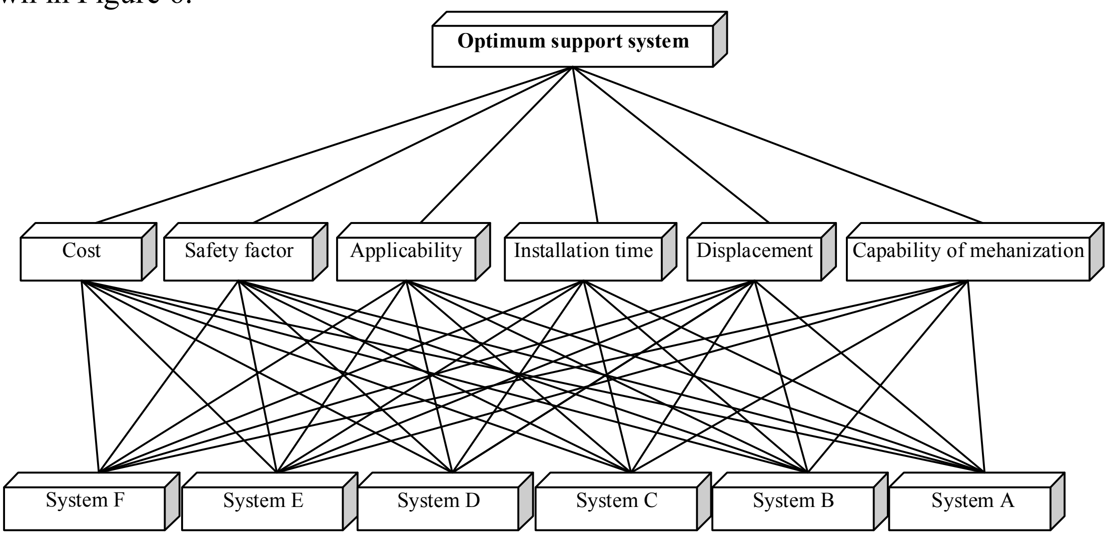

Fig. 6 Hierarchy design for the tunnel support selection

In order to determine important coefficient of attributes, their pair-wise comparisons 6×6 matrix are formed and using the eigenvector method, the weight of each of them is obtained, as shown in Table 3.

Table 3 Final weight of attributes

Attributes	Weight	Attributes	Weight	Attributes	Weight
Cost	0.27	Applicability	0.19	Displacement	0.11
Safety factor	0.23	Installation time	0.16	Capability of mechanization	0.04

The quantitative attributes of cost, safety factor and displacement are obtained through the economic analysis and numerical modeling. Therefore, their quantitative amounts in the decision matrix will be directly set in related cells. The applicability, installation time and the capability of mechanization attributes are qualitative that are evaluated by qualitative terms such as very low, low, medium, high and very high. In table 4, the initial decision matrix is presented, including quantitative and qualitative arrays.

Table 4 Initial decision matrix (quantitative and qualitative)

Support system	Cost (Rials)	Safety factor	Applicability	Time	Displacement (m)	Mechanization
A	15100900	1.572	Low	High	0.0197	Low
B	13926000	1.64	Very low	Very high	0.0187	Low
C	11598610	1.51	High	Low	0.0208	Low
D	10760000	1.71	High	Very low	0.0210	Very high
E	5939820	2.037	Very high	Medium	0.0224	High
F	6304900	1.3	Very high	Medium	0.0220	Medium

For the purpose of quantifying the qualitative attributes, bipolar scale has been used. Therefore, instead of terms very low, low, medium, high and very high, the numbers 1, 3, 5, 7 and 9 are used respectively. The final decision matrix is presented in Table 5. In this matrix, the attributes of cost, installation time, and displacement have negative aspects, while safety factor, applicability and capability of mechanization attributes have positive aspects. It should be noted that all these attributes are independent of each other.

Table 5 Final decision matrix (quantitative)

Support system	Cost (Rials)	Safety factor	Applicability	Time	Displacement (m)	Mechanization
A	15100900	1.572	3	7	0.0197	3
B	13926000	1.64	1	9	0.0187	3
C	11598610	1.51	7	3	0.0208	3
D	10760000	1.71	7	1	0.0210	9
E	5939820	2.037	9	5	0.0224	7
F	6304900	1.3	9	5	0.0220	5

5.2 Prioritization of alternatives by SAW method

In this way, the decision matrix is normalized using a linear method (equations 2 and 3) at first that the results are shown in Table 6.

Table 6 The normalized decision matrix in SAW method

Support system	C_1	C_2	C_3	C_4	C_5	C_6
A	0.393	0.772	0.333	0.143	0.949	0.333
B	0.427	0.805	0.111	0.111	1	0.333
C	0.512	0.741	0.778	0.333	0.899	0.333
D	0.552	0.839	0.778	1	0.930	1
E	1	1	1	0.2	0.835	0.778
F	0.942	0.638	1	0.2	0.850	0.556

Then, the weighted decision matrix is calculated from multiplying the importance coefficient of each attribute by the corresponding cells in the normalized decision matrix, in accordance with Table 7. The final weight of the alternatives is obtained by summing the rows of weighted decision matrix which the results are provided in Table 8.

Table 7 The weighted decision matrix in SAW method

Support system	C_1	C_2	C_3	C_4	C_5	C_6
A	0.106	0.177	0.063	0.023	0.104	0.013
B	0.115	0.185	0.021	0.018	0.110	0.013
C	0.138	0.170	0.148	0.053	0.099	0.013
D	0.149	0.193	0.148	0.160	0.102	0.040
E	0.270	0.230	0.190	0.032	0.092	0.031
F	0.254	0.147	0.190	0.032	0.094	0.031

Table 8 The final weight of alternatives based on SAW method

Support system	A	B	C	D	E	F
Final weight	0.488	0.462	0.622	0.792	0.845	0.729

5.3 Prioritization of alternatives by TOPSIS method

In this procedure, using equations 6 and 7, respectively, the normalized and the weighted decision matrix are composed according to Tables 9 and 10. Thereafter, the ideal positive and negative solutions are calculated for each attribute respectively using equations 8 and 9, respectively (Table 11). Alternative distances from the ideal positive and negative solutions and also relative closeness attribute of each alternative are presented in Table 12.

Table 9 The normalized decision matrix in TOPSIS method

Support system	C_1	C_2	C_3	C_4	C_5	C_6
A	0.552	0.391	0.183	0.508	0.389	0.222
B	0.509	0.407	0.061	0.653	0.370	0.222
C	0.424	0.375	0.426	0.218	0.411	0.222
D	0.394	0.425	0.426	0.073	0.397	0.667
E	0.217	0.506	0.548	0.363	0.443	0.519
F	0.231	0.323	0.548	0.363	0.435	0.371

Table 10 The final weight of alternatives based on TOPSIS method

Support system	C_1	C_2	C_3	C_4	C_5	C_6
A	0.149	0.090	0.035	0.081	0.043	0.009
B	0.138	0.094	0.012	0.104	0.041	0.009
C	0.115	0.086	0.081	0.035	0.045	0.009
D	0.106	0.098	0.081	0.012	0.044	0.027
E	0.059	0.116	0.104	0.058	0.049	0.021
F	0.062	0.074	0.104	0.058	0.048	0.015

Table 11 The ideal positive and negative solutions for each attribute

	C_1	C_2	C_3	C_4	C_5	C_6
Ideal positive solution	0.059	0.116	0.104	0.012	0.041	0.027
Ideal negative solution	0.149	0.074	0.012	0.104	0.049	0.009

Table 12 Alternative distances and their relative closeness attribute

Support system	Si-	Si+	Ci
A	0.137	0.037	0.211
B	0.156	0.024	0.134
C	0.074	0.105	0.587
D	0.056	0.127	0.693
E	0.047	0.144	0.752
F	0.064	0.135	0.678

5.4 Prioritization of alternatives by LA method

In this method, according to the decision matrix, the rank of each alternative is determined for each of existing attributes. Accordingly, in accordance with Table 13, a 6×6 matrix has been constructed which its rows and columns indicate rank and attribute, respectively.

Table 13 Determine the rank of alternatives per attribute

Rank	C_1	C_2	C_3	C_4	C_5	C_6
1	E	E	E	D	B	D
2	F	D	F	C	A	E
3	D	B	C	E	D	F
4	C	A	D	F	C	A
5	B	C	A	A	F	B
6	A	F	B	B	E	C

The next step in LA method is forming the allocation matrix (Table 14) that is a 6×6 matrix and its row and column indicate *i* alternative (support system) and *k* rank, respectively. Components of the matrix are the summation of the weight of attributes where their *i*th alternative has *k*th rank. Thereafter, the final rank of each alternative has been calculated by solving the linear programming model of equation 13 using LINGO software.

Table 14 Allocation matrix in LA method

Support System	R1	R2	R3	R4	R5	R6
A	0	0.11	0	0.27	0.35	0.27
B	0.11	0	0.22	0	0.31	0.35
C	0	0.16	0.19	0.38	0.23	0.04
D	0.2	0.23	0.38	0.19	0	0
E	0.69	0.04	0.16	0	0	0.11
F	0	0.46	0.04	0.16	0.11	0.23

5.5 Final prioritization of alternatives

Ranking of the alternatives (support systems) is proposed according to the SAW, TOPSIS, and LA method in the first three columns of Table 15. As can be seen, the ranks of some alternatives are different in three desired methods. For aggregating the obtained ranks, Ranks Mean, Borda and Copland techniques were used which results are provided in the last three columns of Table 15. According to the obtained results, support system E has been taken the first rank in all aggregating methods and D, F, C, A and B systems have been gained the second to the sixth ranks respectively. Thus, the system E is recommended as a proper support system for the tunnel.

Table 15 Ranking of support systems and aggregating results

Support system	Ranking by MADM methods			Final ranking by aggregating techniques		
	SAW	TOPSIS	LA	Ranks Mean	Borda	Copland
A	5	5	5	5	5	5
B	6	6	6	6	6	6
C	4	4	4	4	4	4
D	2	2	3	2.3	2	2
E	1	1	1	1	1	1
F	3	3	2	2.7	3	3

6 Conclusion

The selection of proper support system for tunnel depends on the consideration of numerous effective factors. It is impossible by numerical methods properly. MADM Methods are appropriate scientific solutions for dealing with such engineering problems. In current study, the most important MADM methods including SAW, TOPSIS, and LA have been used in the selection of support system in Beheshtabad tunnel and six of cost, safety factor, time, displacement, capability of mechanization and applicability attributes have been studied. Aggregating the obtained results of ranking by Ranks Mean, Borda and Copland techniques, among the six support systems, injectional rock-bolt 3 m in length with 1.5×1.5 m distance with shotcrete by 10 cm in thickness is proposed as a proper support system.

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