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The use of analytic hierarchy process in the selection of suitable excavation machine for Dez - Qomroud water conveyance tunnel (lot 1&2), Iran

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Abstract
Qomroud water conveyance tunnel (lot 1&2) with the length of 16 kilometers is considered as one of the greatest development and national projects in Iran. Since about 2 kilometers of tunnel pass through alluvium and the rest of the tunnel pass through various types of geological units, and due to the complexity of geological condition and variety of effective criteria, suitable selection of excavation machine is crucial. In this respect, application of a suitable method which can select the best, according to the consideration of these entire criteria would be so important. One of the best decision making methods is Analytic Hierarchy Process (AHP) which has a strong theoretical basis. Using this method, this paper selects the most suitable excavation machine for Qomroud water conveyance tunnel. The results show that the EPB TBM Single Shield is the best alternative.

Keywords: *Excavation machine; analytic hierarchy process; Qomroud tunnel.*

1. Introduction
Most of Iran water resources, which are located in western, south western and north of Iran and provide long term drinkable water for central regions of Iran, are in need of inter-transmission of water in the mentioned regions. One of these projects is the water transfer from Dez region tributaries to the center of Iran where excavation water conveyance tunnel from Enuj River to Qomroud is the main part of the project.
To cope with various geological conditions, several construction methods have been developed for tunneling. Those methods can be categorized in two types: drill and blast (traditional) method; and mechanized excavation methods.
Considering the length of tunnel and also existing complexity of geological conditions and low speed of drilling and blasting methods, the possibility of using traditional method was rejected for this project.
Mechanization is becoming widespread in excavation operations today. Mechanized excavation methods are faster and more reliable than the conventional methods. So this study considers the mechanized excavation method. Along with technology development, tunnel excavation machines have also developed remarkably. Selection of a suitable mechanized excavation machine is very important since it affects the duration and cost of the project.
Tunnel excavation machines can be classified by the methods for excavation (full face or partial face), the types of cutter head (rotation or non-rotation), and by the methods of securing reaction force (from gripper or segment).

Careful and comprehensive analysis should be made to select proper machine for tunneling. That is, its reliability, safety, cost efficiency and the working conditions should be taken into account.
Optimizing models have been considered by mathematicians since the Second World War and the main emphasis of such models is to have an objective function or a measurable criteria. In order to make correct decisions, effective methods are required in many operation processes. In recent decades multiple-criteria decision making is presented for complex decision makings in which there are multiple measuring criteria. The general tendency of the studies is towards multiple attributes decision-making (MADM) and multiple objective decision making (MODM) methods. While MADM is based on determining the most appropriate alternative from the options considering multiple and conflicting criteria for realizing only one aim, MODM tries to determine the most appropriate option for realizing a set of conflicting aims.
In this study a new method is recommended for the most suitable selection of a mechanized excavation machine for the above mentioned tunnel on the bases of AHP.

2. Study area description

The area of implementation of project is a part of the Dez tributaries catchments area located in Lorestan province and Qomroud region located in Isfahan and Markazi provinces. From the geographical point of view the project lies in the geographical coordinates of 49º 13′ to 49º 53′ of eastern longitude and 33º 02′ to 33º 18′ of northern latitude. The construction site of tunnel is located in Lorestan province in 20 kilometer of south eastern of Aligoodarz city (Figure 1).

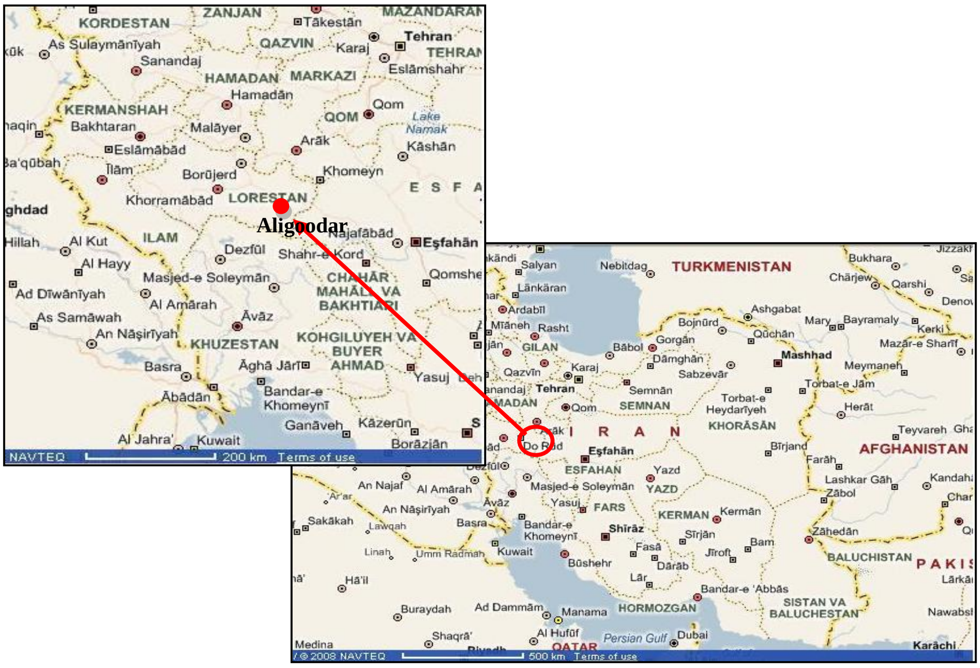

Figure 1. Location of Dez – Qomroud water conveyance tunnel project

Based on the geological division of Iran, the path of water conveyance tunnel of Enuj to Qomroud is located in Sanandaj-Sirjan region. The important feature of this region is thermal and movement metamorphosis of Mesozoic age. Metamorphosis rocks of this region, which are particularized with amphibolites, gneiss, and amphibolites schist and marble, are actually regarded to Precambrian. Geometry and rock mechanics properties of Qomroud water conveyance tunnel are shown in Table 1 [1].

Table 1. Geometry and rock mechanics properties of Dez-Qomroud water conveyance tunnel [1]

Parameter	Value
Slope (%)	0.13
Diameter(m)	4.69
Length(m)	15750
Shape	Circle
Depth(m)	60-220
Underground water level(m)	30-40
Tensile strength(MPa)	1.5-7
Discontinuities spacing(mm)	50-400

3. Analytic Hierarchical Process Method

The Analytic Hierarchy Process (AHP) is a structured technique for helping people deal with complex decision makings. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It is used throughout the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education. The AHP helps organize the rational analysis of the problem by dividing it into its single parts; the analysis then supplies an aid to the decision makers who, by making several pairwise comparisons, can appreciate the influence of the considered elements in a hierarchical structure.

The procedure for using the AHP can be summarized as [2]:

a. Model the problem as a hierarchy containing the decision goal, the criteria for evaluating the alternatives and the alternatives for reaching the goal.

b. Establish the priorities among the elements of the hierarchy by making a series of judgments based on pairwise comparisons of the elements.

c. Synthesize these judgments to yield a set of overall priorities for the hierarchy.

d. Check the consistency of the judgments.

e. Come to a final decision based on the results of this process.

Step b is the most important part of the process which calls for the collection of idea and judgments of professionals in the study area. In this step by forming pairwise comparison matrices at first, the relative importance of each criterion with respect to reaching the goal is evaluated and then the relative strength of each alternative in meeting the requirement of each criterion are determined.

4. Selection of a suitable excavation machine for Dez - Qomroud water conveyance tunnel

4.1. Modeling the problem as a hierarchy

The first step in the AHP is modeling the problem as a hierarchy. In doing so, participants explore the aspects of the problem at levels from general to detailed, then express it in the multileveled way that the AHP requires. It consists of an overall goal, a group of factors or criteria that relate the alternatives to the goal and a group of options or alternatives for reaching the goal. The criteria can be further broken down into subcriteria, sub-subcriteria, and so on, in as many levels as the problem requires.

To select the most suitable excavation machine in this region first the effective criteria in tunnel excavation was studied. Generally 4 criteria were introduced including C_1: geological parameters and features of rock mass, C_2 : tunnel geometrical parameters, C_3: machine parameters and C_4: price as the effective criteria in this process. Tunnel geometrical parameters, geological parameters and features of rock mass and machine parameters have sub-criteria which are depicted in Figure 2.

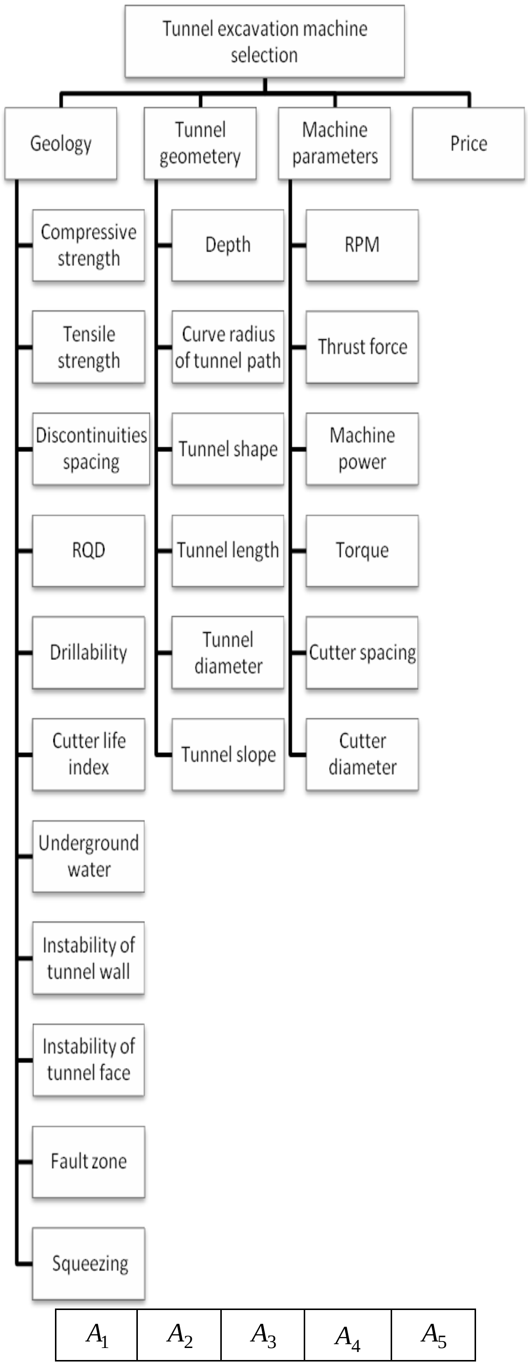

Figure 2. Hierarchical structure for Selection of suitable excavation machine

After investigating the different available alternatives, 5 options including A_1: Road header, A_2: EPB TBM single shield, A_3: Double shield TBM, A_4: Single shield TBM and A_5:Open TBM were finally suggested.

4.2. Formation of pairwise comparison matrix for each level with respect to the higher levels

The ''principle of pairwise comparison'' lies in giving a weight to each cluster to demonstrate the importance of each level in the hierarchy. Each single element is evaluated using a pairwise comparison. The comparisons are made on a 9-point scale, so-called ''fundamental scale of Saaty'', which is represented in Table 2.

Table 2. Saaty's fundamental scale

Value	Definition
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6,8	Intermediate judgment values

In comparison of each element i with itself obviously, the elements are equally preferable. So the principal diagonal of all the pairwise comparison matrices is always composed of values that are equal to one. The matrices are reciprocal and a value from 1 to 9 is used for comparison between the element i and the element j, the reciprocal value corresponds to the comparison between j and i [3-5].

4.3. Determination of relative weights for pairwise comparison matrices

There are several methods for computation of relative weights with regard to the pairwise comparison matrices. The most important of which are least squares method, logarithmic least squares method, eigenvector method and approximated methods. Among these methods, eigenvector method is considered to be the most precise one. In this method W_i would determine in a manner that we have the following equation:

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

Where λ and W are orderly eigenvalue and eigenvector of a pairwise comparison matrix [4]. In this research the relative weights were reached through Matlab software for each of these matrices. The pairwise comparison matrices and relative weights of each matrix are shown in Tables 3-30.

Table 4. Comparison of the sub-criteria of geology with respect to their importance in achieving the goal

	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{110}	C_{111}	Weight
C_{11}	1	2	1	1/3	1/3	2	1/3	2	1/2	1	1/2	**0.0605**
C_{12}	1/2	1	1/2	1/4	1/4	1	1/4	1	1/3	1/2	1/3	**0.0356**
C_{13}	1	2	1	1/3	1/3	2	1/3	2	1/2	1	1/2	**0.0605**
C_{14}	3	4	3	1	1	4	1	4	2	3	2	**0.1711**
C_{15}	3	4	3	1	1	4	1	4	2	3	2	**0.1711**
C_{16}	1/2	1	1/2	1/4	1/4	1	1/4	1	1/3	1/2	1/3	**0.0356**
C_{17}	3	4	3	1	1	4	1	4	2	3	2	**0.1711**
C_{18}	1/2	1	1/2	1/4	1/4	1	1/4	1	1/3	1/2	1/3	**0.0356**
C_{19}	2	3	2	1/2	1/2	3	1/2	3	1	2	1	**0.1035**
C_{110}	1	2	1	1/3	1/3	2	1/3	2	1/2	1	1/2	**0.0605**
C_{111}	2	1/3	2	1/2	1/2	3	1/2	3	1	2	1	**0.0949**

Table3. Comparison of the main criteria with respect to their importance in achieving the goal

	C_1	C_2	C_3	C_4	Weight
C_1	1	6	4	5	**0.6042**
C_2	1/6	1	1/3	1/2	**0.0744**
C_3	1/4	3	1	2	**0.2007**
C_4	1/5	2	1/2	1	**0.1207**

Table 5. Comparison of sub-criteria of tunnel geometry with respect to their importance in achieving the goal

	C_{21}	C_{22}	C_{23}	C_{24}	C_{25}	C_{26}	Weight
C_{21}	1	5	4	4	1/2	1	**0.2293**
C_{22}	1/5	1	1/2	1/2	1/6	1/5	**0.0432**
C_{23}	¼	2	1	1	1/5	1/4	**0.0671**
C_{24}	¼	2	1	1	1/5	1/4	**0.0671**
C_{25}	2	6	5	5	1	2	**0.3639**
C_{26}	1	5	4	4	1/2	1	**0.2293**

Table 6. Comparison of sub-criteria of machine parameters with respect to their importance in achieving the goal

	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	C_{36}	Weight
C_{31}	1	1	3	3	1	4	**0.2382**
C_{32}	1	1	3	3	1	4	**0.2382**
C_{33}	1/3	1/3	1	1	1/3	2	**0.0895**
C_{34}	1/3	1/3	1	1	1/3	2	**0.0895**
C_{35}	1	1	3	3	1	4	**0.2382**
C_{36}	1/4	1/4	1/2	1/2	1/4	1	**0.0532**

Table 7. Comparison of alternatives with respect to compressive strength

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/7	1/6	1/7	3	**0.0545**
A_2	7	1	2	1	9	**0.3476**
A_3	6	1/2	1	1/2	8	**0.2206**
A_4	7	1	2	1	9	**0.3476**
A_5	1/3	1/9	1/8	1/9	1	**0.0297**

Table 8. Comparison of alternatives with respect to tensile strength

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/6	1/8	1/6	1	**0.0426**
A_2	6	1	1/3	1	6	**0.2163**
A_3	8	3	1	3	8	**0.4821**
A_4	6	1	1/3	1	6	**0.2163**
A_5	1	1/6	1/8	1/6	1	**0.0426**

Table 9. Comparison of alternatives with respect to discontinuities spacing

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/6	1/3	1/6	3	**0.0662**
A_2	6	1	4	1	8	**0.3822**
A_3	3	1/4	1	1/4	5	**0.1348**
A_4	6	1	4	1	8	**0.3822**
A_5	1/3	1/8	1/5	1/8	1	**0.0346**

Table 10. Comparison of alternatives with respect to RQD

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/4	1/7	1/4	2	**0.0601**
A_2	4	1	1/4	1	5	**0.1832**
A_3	7	4	1	4	8	**0.5327**
A_4	4	1	1/4	1	5	**0.1832**
A_5	1/2	1/5	1/8	1/5	1	**0.0409**

Table 11. Comparison of alternatives with respect to drillability

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/4	1/2	1/2	2	**0.1063**
A_2	4	1	3	3	5	**0.4589**
A_3	2	1/3	1	1	3	**0.1844**
A_4	2	1/3	1	1	3	**0.1844**
A_5	1/2	1/5	1/3	1/3	1	**0.066**

Table 12. Comparison of alternatives with respect to cutter life index

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/3	1/4	1/3	1/3	**0.0698**
A_2	3	1	1/2	1	1	**0.1916**
A_3	4	2	1	2	2	**0.3554**
A_4	3	1	1/2	1	1	**0.1916**
A_5	3	1	1/2	1	1	**0.1916**

Table 13. Comparison of alternatives with respect to underground water

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/5	1/5	1/5	5	**0.077**
A_2	5	1	1	1	9	**0.2984**
A_3	5	1	1	1	9	**0.2984**
A_4	5	1	1	1	9	**0.2984**
A_5	1/5	1/9	1/9	1/9	1	**0.0278**

Table 14. Comparison of alternatives with respect to instability of tunnel wall

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/5	1/5	1/5	5	**0.077**
A_2	5	1	1	1	9	**0.2984**
A_3	5	1	1	1	9	**0.2984**
A_4	5	1	1	1	9	**0.2984**
A_5	1/5	1/9	1/9	1/9	1	**0.0278**

Table 15. Comparison of alternatives with respect to instability of tunnel face

	A_1	A_2	A_3	A_4	A_5	Weight
A_1	1	1/9	1/3	1/3	1	**0.0508**
A_2	9	1	7	7	7	**0.6364**
A_3	3	1/7	1	1	3	**0.129**
A_4	3	1/7	1	1	3	**0.129**
A_5	1	1/7	1/3	1/3	1	**0.0548**

Table 16. Comparison of alternatives with respect to fault zone

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/5	1/4	1/3	5	**0.0868**
A_2	5	1	2	3	9	**0.4279**
A_3	4	1/2	1	2	8	**0.2764**
A_4	3	1/3	1/2	1	7	**0.1791**
A_5	1/5	1/9	1/8	1/7	1	**0.0298**

Table 17. Comparison of alternatives with respect to squeezing

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/3	3	1/3	1/3	**0.1025**
A_2	3	1	7	1	1	**0.2907**
A_3	1/3	1/7	1	1/6	1/6	**0.0423**
A_4	3	1	6	1	1	**0.2823**
A_5	3	1	6	1	1	**0.2823**

Table 18. Comparison of alternatives with respect to depth

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/3	1/3	1/3	1/3	**0.0769**
A_2	3	1	1	1	1	**0.2308**
A_3	3	1	1	1	1	**0.2308**
A_4	3	1	1	1	1	**0.2308**
A_5	3	1	1	1	1	**0.2308**

Table 19. Comparison of alternatives with respect to curve radius of tunnel path

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	4	5	4	2	**0.4352**
A_2	1/4	1	2	1	1/3	**0.1093**
A_3	1/5	1/2	1	1/2	1/4	**0.0657**
A_4	1/4	1	2	1	1/3	**0.1093**
A_5	1/2	3	4	3	1	**0.2804**

Table 20. Comparison of alternatives with respect to tunnel shape

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/2	1/2	1/2	1/2	**0.1111**
A_2	2	1	1	1	1	**0.2222**
A_3	2	1	1	1	1	**0.2222**
A_4	2	1	1	1	1	**0.2222**
A_5	2	1	1	1	1	**0.2222**

Table 21. Comparison of alternatives with respect to tunnel length

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/5	1/5	1/5	1/5	**0.0476**
A_2	5	1	1	1	1	**0.2381**
A_3	5	1	1	1	1	**0.2381**
A_4	5	1	1	1	1	**0.2381**
A_5	5	1	1	1	1	**0.2381**

Table 22. Comparison of alternatives with respect to tunnel diameter

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/3	1/3	1/3	1/3	**0.0769**
A_2	3	1	1	1	1	**0.2308**
A_3	3	1	1	1	1	**0.2308**
A_4	3	1	1	1	1	**0.2308**
A_5	3	1	1	1	1	**0.2308**

Table 23. Comparison of alternatives with respect to tunnel slope

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/2	1/2	1/2	1/3	**0.098**
A_2	2	1	1	1	1/2	**0.1843**
A_3	2	1	1	1	1/2	**0.1843**
A_4	2	1	1	1	1/2	**0.1843**
A_5	3	2	2	2	1	**0.3491**

Table 24. Comparison of alternatives with respect to RPM

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/3	1/4	1/3	1/3	**0.0698**
A_2	3	1	1/2	1	1	**0.1916**
A_3	4	2	1	2	2	**0.3554**
A_4	3	1	1/2	1	1	**0.1916**
A_5	3	1	1/2	1	1	**0.1916**

Table 25. Comparison of alternatives with respect to thrust force

	A_5	A_4	A_3	A_2	A_1	**Weight**
A_1	1	1/2	1/3	1/2	1/2	**0.098**
A_2	2	1	1/2	1	1	**0.1843**
A_3	3	2	1	2	2	**0.3491**
A_4	2	1	1/2	1	1	**0.1843**
A_5	2	1	1/2	1	1	**0.1843**

Table 26. Comparison of alternatives with respect to machine power

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/2	1/3	1/2	1/2	**0.098**
A_2	2	1	1/2	1	1	**0.1843**
A_3	3	2	1	2	2	**0.3491**
A_4	2	1	1/2	1	1	**0.1843**
A_5	2	1	1/2	1	1	**0.1843**

Table 27. Comparison of alternatives with respect to torque

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/3	1/3	1/3	1/3	**0.0769**
A_2	3	1	1	1	1	**0.2308**
A_3	3	1	1	1	1	**0.2308**
A_4	3	1	1	1	1	**0.2308**
A_5	3	1	1	1	1	**0.2308**

Table 28. Comparison of alternatives with respect to cutter spacing

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/3	1/5	1/5	1/5	**0.0505**
A_2	3	1	1/3	1/3	1/3	**0.107**
A_3	5	3	1	1	1	**0.2808**
A_4	5	3	1	1	1	**0.2808**
A_5	5	3	1	1	1	**0.2808**

Table 29. Comparison of alternatives with respect to cutter diameter

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	1/5	1/5	1/5	1/5	**0.0476**
A_2	5	1	1	1	1	**0.2381**
A_3	5	1	1	1	1	**0.2381**
A_4	5	1	1	1	1	**0.2381**
A_5	5	1	1	1	1	**0.2381**

Table 30. Comparison of alternatives with respect to price

	A_1	A_2	A_3	A_4	A_5	**Weight**
A_1	1	4	6	3	2	**0.4201**
A_2	1/4	1	3	1/2	1/3	**0.1026**
A_3	1/6	1/3	1	1/4	1/5	**0.0484**
A_4	1/3	2	4	1	1/2	**0.1638**
A_5	1/2	3	5	2	1	**0.2652**

4.4. Determination of the overall rating of each alternative

The overall rating of each alternative is computed by adding the product of the relative priority of each criterion and the relative priority of the alternative considering the corresponding criteria.

For example overall rating of alternative A_1 is computed as:

0.6042 × [(0.0545 × 0.0605)+(0.0426 × 0.0356)+(0.0662 × 0.0605)+(0.0601 × 0.1711)+(0.1063 × 0.1711)+(0.0698 × 0.0356)+(0.077 × 0.1711)+(0.077 × 0.0356)+(0.0508 × 0.1035)+(0.0868 × 0.0605)+(0.1025 × 0.0949)]+0.0744 × [(0.0769 × 0.2293)+(0.4352 × 0.0432)+(0.1111 × 0.0671) +(0.0476 × 0.0671)+(0.0769 × 0.3639)+ (0.098 × 0.2293)] +0.2007 × [(0.0698 × 0.2382)+(0.098 × 0.2382)+(0.098 × 0.0895)+(0.0769 × 0.0895)+(0.0505 × 0.2382)+(0.0476 × 0.0532)] + [(0.4201 × 0.1207] = 0.1187

Table 31 gives the overall rating of each alternative. It is seen from the Table 31 that alternative A_2 (EPB TBM single shield) with a rating 0.2745 is most preferred and is followed by alternatives A_3 (Double shield TBM), A_4 (Single shield TBM), A_5 (Open TBM) and A_1 (Road header).

Table 31. Priorities of alternatives

Priority	Excavation Machine Type	Total Weight
1	A_2 : EPB TBM single shield	0.2744
2	A_3 : Double shield TBM	0.2482
3	A_4 : Single shield TBM	0.2210
4	A_5 :Open TBM	0.1377
5	A_1 : Road header	0.1187

4.5. Computation of inconsistency ratio

AHP consistency is known as the consistency ratio (CR). This consistency ratio simply reflects the consistency of the pair-wise judgments. For example, judgments should be transitive in the sense that if A is considered more important than B, and B more important than C, then A should be more important than C. If, however, the user rates A is as important as C, the comparisons are inconsistent and the user should revisit the assessment [6].

The inconsistency ratio (I.R) which is defined as:

$$I.R = \frac{I.I}{R.I.I} \quad (2)$$

where I.I is called the inconsistency index and R.I.I the random inconsistency index. I.I is defined as:

$$I.I = \frac{\lambda_{\max} - n}{n-1} \quad (3)$$

Where $\lambda_{\max}$ maximum or principal eigen value and n is the size of the pair-wise matrix. Random Consistency Index (RI) is obtained from Table 32. If the value of CR is smaller or equal to 10%, the inconsistency is acceptable. If the CR is greater than 10%, we need to revise the subjective judgment [8]. In this problem, relative

Weights, λ_{max}, I.I, R.I.I and R.I for various matrices are represented in Table 33.

Table 32. Random Consistency Index [7]

n	1	2	3	4	5	6	7	8	9	10
R.I.I	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 33. Relative Weights, λ_{max}, I.I, R.I.I for various matrixes

	Weight	λ_{max}	I.I	R.I.I	I.R
Goal	1.0000	4.0658	0.0219	0.9000	0.0244
Geological parameters	0.6042	11.0018	0.0002	1.5100	0.0001
Geometry parameters	0.0744	6.0787	0.0157	1.2400	0.0127
Machine parameters	0.2007	6.0275	0.0055	1.2400	0.0044
Price	0.1207	5.0988	0.0247	1.1200	0.0220
Compressive strength	0.0605	5.1359	0.0340	1.1200	0.0303
Tensile strength	0.0356	5.1065	0.0266	1.1200	0.0238
Discontinuities spacing	0.0605	5.1745	0.0436	1.1200	0.0390
RQD	0.1711	5.1544	0.0386	1.1200	0.0345
Drillability	0.1711	5.0567	0.0142	1.1200	0.0127
Cutter life index	0.0356	5.0198	0.0050	1.1200	0.0044
Underground water	0.1711	5.1297	0.0324	1.1200	0.0290
Instability of tunnel wall	0.0356	5.1297	0.0324	1.1200	0.0290
Instability of tunnel face	0.1035	5.1598	0.0399	1.1200	0.0357
Fault zone	0.0605	5.1893	0.0473	1.1200	0.0423
Squeezing	0.0949	5.0177	0.0044	1.1200	0.0039
Depth	0.2293	5.0000	0.0000	1.1200	0.0000
Curve radius of tunnel path	0.0432	5.0531	0.0133	1.1200	0.0119
Tunnel shape	0.0671	5.0000	0.0000	1.1200	0.0000
Tunnel length	0.0671	5.0000	0.0000	1.1200	0.0000
Tunnel diameter	0.3639	5.0000	0.0000	1.1200	0.0000
Tunnel slope	0.2293	5.0100	0.0025	1.1200	0.0022
RPM	0.2541	5.0198	0.0050	1.1200	0.0044
Thrust force	0.2541	5.0100	0.0025	1.1200	0.0022
Machine power	0.0909	5.0100	0.0025	1.1200	0.0022
Torque	0.0909	5.0000	0.0000	1.1200	0.0000
Cutter spacing	0.2541	5.0420	0.0105	1.1200	0.0094
Cutter diameter	0.0560	5.0000	0.0000	1.1200	0.0000

5. Conclusions

AHP is one of the most important methods in decision making. It provides an objective way for reaching an optimal decision for both individual and group decision makers. In this research the suitable excavation machine was recommended for excavation of Dez - Qomroud water conveyance tunnel by the aforementioned method. At first the relative weights of parameters were obtained using pairwise comparison matrices. At later steps, the total weights were calculated for each alternative. According to the relative weights, geological parameters are the most important criteria in machine selection and orderly machine parameters, price and geometrical parameters are in the next priorities.

Comparing the achieved inconsistency ratio for all pair-wise comparison of the criteria or alternatives with the reference number of Saaty (0.10) reveals that the presented judgments about all pairwise comparison of criteria and alternatives are logical.

In this research all achieved numbers for relative and final weights were normalized and finally among alternatives, the EPB TBM Single Shield was recommended for excavation.

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