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The Best Transportation System Selection with Fuzzy Multi-Criteria Decision Making (Fuzzy MADM) Case Study: Iran Persian Gulf Tunnel

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Abstract: Transportation system selection is one of the most important decisions in tunnel advancement and development. A lot of can have a roll in tunnel transportation system selection, such as technical factors, e.g. production, haulage distance, ground condition, flexibility, utilization and economical factors, operational cost, investment and development and Safety. Thus fuzzy set theory, with considering the usable transportation system, e.g., truck, rail and belt conveyer, is using for a proper method selection. In this research used the fuzzy analytic hierarchy process, for calculating weight criteria and alternative ranking. In the end of assessment, truck transportation system, with the highest membership grade, 0.3877, is selected as the best transportation system for tunnel boring.

Keywords: Fuzzy AHP, fuzzy set theory, persian gulf tunnel, transportation system

INTRODUCTION

Transportation system selection for material handling is a significant function in the mine and civil planning (Chan, 2001). Using suitable Transportation system can increase the yield process, provide efficient employment of manpower, increase production, and enhance system flexibility. The significance of Transportation system selection cannot be overlooked (Chan, 2001). Because material handling cost surround between 15 and 70% of the total operating cost. On the other hand, material handling, waste disposal, stones, stuffs, instruments, equipment are the parts of transportation system. Transporting mined material from face and support segments transmissions to its installation position have an important role in tunnel advancement. However, with the wide range of Transportation system valid today, resolution of the best Transportation system alternative for a given yield scenario is not an easy task (Chan, 2001). There are various studies focusing on transportation system design, during Persian Gulf construction. These studies provide the possible of mined material transportation, concert segments and the other instrument in both going and coming route with a simple manner and a unity system with lowest cost and most effectiveness. Consequently, an optimum transportation system is a system which can deal with different conditions and have the most effectiveness. There are the various types of transportation system selection; such as technical parameters (utilization, useful life, flexibility,) cost and Safety parameters. Each of these parameters can be useful in the last choice selection. Although, yet, engineering judgment and experiments is used in transportation system selection, but we need scientific and systematic research for more partial analysis. According to the above concepts, this paper developed a method with calculating the complexity and subject requirement based on multiple attribute decision making. Fuzzy AHP is used for alternative ranking. In the literature, there are different studies concentrations on the solution of the complicated problem of material handling equipment and transportation system selection. Chan (2001) described the development of an intelligent material handling equipment system called Material Handling Equipment Selection Advisor (MHESA) (Chan, 2001). Kulak *et al*. (2004) developed a decision support system called FUMAHES-fuzzy multi-attribute material handling equipment selection (Kulak *et al*., 2004). Chakraborthy and Banik (2006) focused on the application of the AHP technique in selecting the optimal transportation system (Chakraborthy and Banik, 2006). Aghagani *et al*. (2008) selected the optimal open pit mining equipment using fuzzy multiple attribute decision making approach (Aghajani *et al*., 2007). Gumus (2009) evaluated the hazardous waste transportation corporation by using a two step fuzzy-AHP and TOPSIS methodology (Gumus, 2009). Bascetin (2004) discussed about application of the analytic hierarchy process in equipment selection at Orhaneli open pit coal mine (Bascetin, 2004). Aielli *et al*. (2002) about an integrated method to the facilities and material handling system design researched (Aielli *et al*., 2002). Celebi (1998) presented an article for equipment selection and cost analysis system for open pit coal mines (Celebi, 1998). Denby and Schofield (1990) focused on

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the application of expert systems in equipment selection for surface design (Denby and Schofield, 1990). Bandopadhyay and Venkatasubramanian (1987) selected surface mine equipment by Expert systems as decision aid (Bandopadhyay and Venkatasubramanian, 1987). In this paper, the selection of transportation system is handled. First of all, transportation system detailed. Then the fuzzy AHP methodology structure described. Then, after description of case study information, suitability and performance of the methodology presented.

Transportation system:

Truck transportation: Usually, truck transportation is used for constructing big section tunnels with high slope. Various trucks are used for transportation during project accomplishment. Maybe in transportation, trucks traverse beside each other so for a safe passing; a safe distance should be described between two trucks. This safe distance is assigned based on trucks speed. Because of constraint of road width and different size of trucks, this project can't use many of trucks, in spite of their high pay load. On the other hand, there is no space in tunnel for trucks whirl, so we should use a circular ground for trucks whirl. Consequently, in spite of width constraint, there is a length constraint too; length shouldn't be longer than 9 m.

Rail transportation: Mined material transportation and support system of concrete segments transmission of the lowest slope tunnels that constructed by shield, done with rail transportation. If we use rail system for Persian Gulf project, possibility of mined material transportation, concrete pre-constructed segments transmission and other instruments, required stuff and staff transmission, will be provided by unity system on both side. In this system for mined material transportation and concrete segments transmission, we should use freight wagons and for simple movement of these wagons we should use a locomotive.

Belt conveyer: Belt conveyors, because of their simplicity and universality, have quickly become indispensable in the layout of a storage facility (Anon, 1980). If we use belt conveyer for mined material transportation, because of humidity and gummy form of mined material we will design an indiscriminate belt conveyer. Also in draw point, we devise some equipment for cleaning the belt conveyer. The most important factors are speed and width of belt conveyer. Width of the belt follows the speed of belts. It means that, if the width of belt increased the permissive speed of belt will be increased. Wide parts of investment spend in devised and design of belt conveyer. This cost follows the width and tensile strength of belt. So we use the maximum speed of belt, will be decreased. There for the cost will be decreased. The best integration of width and speed lead us to an optimum selection of speed and width.

METHODOLOGY

The AHP model has been proposed by Saaty. The AHP structure the decision problem in levels which mach to one s understanding of situation: goals, criterion, sub-criterion, and alternatives. By breaking the problem into levels, the decision maker can focus on smaller set of decisions (Bascetin, 2004). In this study, we nominate Chang (1996) extent analysis method because the steps of this method are easier than the other fuzzy-AHP approaches (Fuzzy sets and AHP are not detailed here because of being famous applications). The steps of Chang (1996) extent analysis approach are as follows: Let $X = \{x_1, x_2, ..., x_n\}$ be an object set, and $U = \{u_1, u_2, ..., u_m\}$ be a goal set. According to the method of Chang (1996) extent analysis, each object is taken and extent analysis for each goal is executed, respectively (Chang, 1996). Therefore, m extent analysis values for each object can be obtained, with the following signs (Dag˘deviren, Yüksel, & Kurt, in press) (Zare *et al*., 2009):

$$M^{I}_{gi}, M^{2}_{gi}, \ldots, M^{m}_{gi} \quad i = 1, 2, ..., n \tag{1}$$

where, all the M^{j}_{gi} (j = 1, 2, . . . , m) are triangular fuzzy numbers. The steps of Chang's extent analysis can be given as in the following Chang (1996) and Zare *et al*. (2009):

Step 1: The value of fuzzy synthetic extent with respect to the i^th^ object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^{m} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{m}\right]^{-1} \tag{2}$$

To determineOTE $\sum_{j=1}^{m} M_{gi}^{m}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that Chang (1996) and Zare *et al*. (2009):

$$\sum_{j=1}^{m} M_{gi}^{m} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} i\right. \tag{3}$$

And to determine $\left[\sum_{j=1}^{n}\sum_{j=1}^{m}\sum_{gi}^{m}\right]$,perform the fuzzy edition operation of m extent analysis values for a particular matrix such that Chang (1996) and Zare *et al*. (2009):

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{m} = \left(\sum_{i=1}^{n} l_j, \sum_{i=1}^{n} m_j, \sum_{i=1}^{n} u_j\right) \tag{4}$$

And then obtain the opposite of the vector in Eq. (4) such that Chang (1996) and Zare *et al*. (2009):

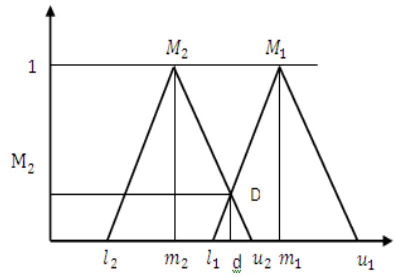

Fig. 1: The junction between M_1 and M_2 (Chang, 1996)

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{m}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_j}, \frac{1}{\sum_{i=1}^{n} m_j}, \frac{1}{\sum_{i=1}^{n} I_j}\right) \quad (5)$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as Chang (1996) and Zare *et al*. (2009):

$$V\,(M_2 \geq M_1) = \sup\left\lfloor \min(\mu_{M_1}(x), \mu_{M_2}(y)) \right\rfloor \quad (6)$$

And can be equivalently proposed as follows Chang (1996) and Zare *et al*. (2009):

$$V\,(M_2 \geq M_1) = hgt(M_2 \cap M_1) = \mu_{M2}(d) = \begin{cases} 1 & if\ m_2 \geq m_1 \\ 0 & if\ I_2 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases} \quad (7)$$

where, d is the ordinate of the highest junction point D between μ_{M1} and μ_{M2} (Fig. 1).

To compare M_1 and M_2, both the values of V $(M_2 \geq M_1)$ and V $(M_2 \geq M_1)$ are needed.

Step 3: The degree probability for a convex fuzzy number to be greater than convex fuzzy numbers M_i (i = 1, 2, ...,k) can be defined by Chang (1996) and Zare *et al*. (2009):

$$V\,(M_2 \geq M_1, M_2, \ldots, M_k)$$

$$V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and } \ldots,(M \geq M_1)] \quad (8)$$
$$\min V(M \geq M_i),\ i = 1, 2, \ldots, k.$$

Assume that Chang (1996) and Zare *et al*. (2009):

$$d'(A_i) = \min V(S_i \geq S_k) \quad (9)$$

For k = 1, 2, ..., n; k ≠ i. Then the weight factor is given by Chang (1996) and Zare *et al*. (2009):

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T \quad (10)$$

where, A_i (i = 1, 2, ...,n) are n elements Chang (1996) and Zare *et al*. (2009).

Step 4: Via normalization, the normalized weight vectors are Chang (1996) and Zare *et al*. (2009):

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T \quad (11)$$

where, W is a non-fuzzy number (Chang, 1996; Zare *et al*., 2009).

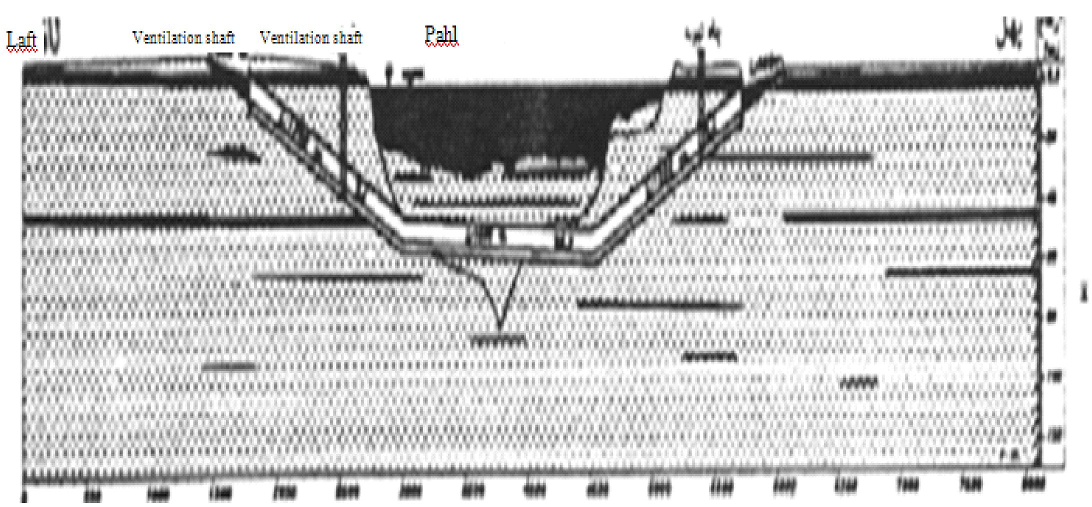

Fig. 2: Linear profile of Persian gulf tunnel route

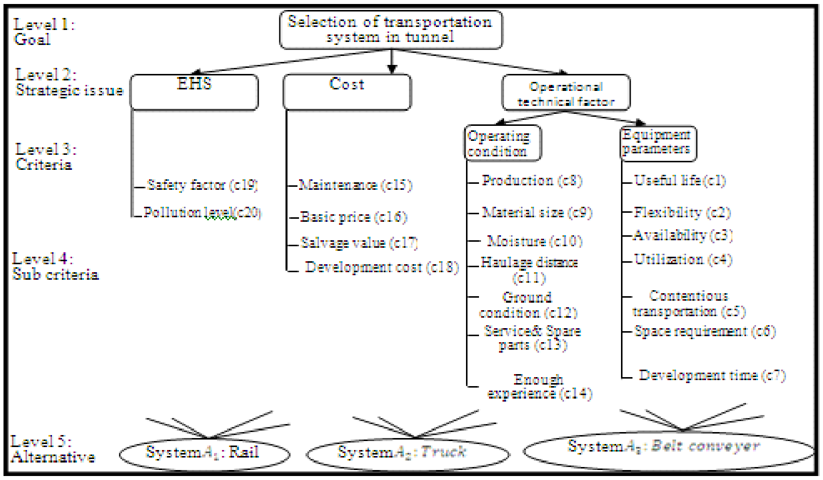

Fig. 3: AHP model for transportation system

Case study:

Persian gulf tunnel: Persian Gulf tunnel is a land way to connect the Gheshm Island to Iran. It is locate in Pahl-Laft region. The diameter of this tunnel is 12 m and the length of it is 6250 m. route of tunnel is consist of three pieces: 1st; north shore route (Pahl) with 3% slope and 2450 m length, 2nd; middle piece with 0.003% slope and 1200 m length, 3rd; southern shore route (Laft) with 2% slope and 2600 m length (Fig. 2). Structure of tunnel is consist of: Marl thick layers and sandy thin mid-layers. So by depth increasing percentage of sandy layers will be decreased.

Usage of fuzzy AHP in Persian gulf tunnel: For optimum transportation system selection, 20 criterion and 3 alternatives is used. Problem structure is shown in Fig. 3 based on AHP model.

Goal is an optimum transportation system selection, which can response the required production. This goal is located in the first level of structure. There are 3 strategic factors in 2nd level; Environmental Health and Safety (EHS), cost and operational technical factors. 3rd level is consisting of criteria and 4th level is consist of sub-criteria. Finally, the last level is consist of alternative or proposed transportation system for this tunnel.

Determination of the weights of criteria: Different people have rolls in mining and tunnel constructing project. Each of these persons has a different idea about transportation system selection, based on assumed design and goals. So that different people may have a different opinion on the significance of a specific criterion.

Therefore 4 decision makers with different technical knowledge have been selected for criteria evaluation.

FAHP has been proposed for decision makers to evaluate the judgment precision, and reduce the doubt

Table 1: Pair-wise comparison scale (Saaty, 1980)

Comparison index	Score
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equal	1
Intermediate values between the two adjacent judgments	2, 4, 6, 8

value and ambiguity. Table 1 (Saati, 1980) has been proposed to form a pair-wise comparison matrix till decision makers can have a unit criteria for their evaluation. Based on this basis, each decision maker provides a pair-wise comparison matrix. Then a comprehensive pair-wise comparison matrix devised, based on Eq. (12) (Table 2):

$$(\tilde{x}_{ij}) = (a_{ij}, b_{ij}, c_{ij})$$
$$l_{ij} = \min_k \{a_{ijk}\} m_{ij} = \frac{1}{k}\sum_{k=1}^{k} b_{ijk}, u_{ij} = \max_k \{ci_{jk}\} \tag{12}$$

After forming Table 2, based on FAHP method, by Eq. (4), S_i will be computed:

S_1 = (16.40.38.68, 73.5) ⊗ (1/861.57,1/447, 264, 1/2 41.928) = (0.0190, 0.0864, 0.3038)

Rest of the computation will be done like this and listed in Table 3.

According to Eq. (9) and by fuzzy comparison, we will have:

$v(S_1 \geq S_2) = 1$, $v(S_1 \geq S_3) = 1$, $v(S_1 \geq S_4) = 1$, $v(S1 \geq S_5) = 1$
$v(S_1 \geq S_6) = 1$, $v(S_1 \geq S_7) = 1$, $v(S_1 \geq S_8) = 1$, $v(S_1 \geq S_9) = 1$
$v(S_1 \geq S_{10}) = 1$, $v(S_1 \geq S_{11}) = 1$, $v(S_1 \geq S_{12}) = 1$, $v(S_1 \geq S_{13}) = 1$
$v(S_1 \geq S_{14}) = 1$
$v(S_1 \geq S_{15}) = 1$, $v(S_1 \geq S_{16}) = 1$, $v(S_1 \geq S_{17}) = 1$, $v(S_1 \geq S_{18}) = 1$,

Table 2: Comprehensive pair-wise comparison matrix

goal	c_1	c_2	c_3	c_4	c_5
c_1	(1, 1, 1)	(1, 2.33, 4.5)	(1, 2.33, 4.5)	(1, 2.33, 405)	(0.6, 1.67, 3.5)
c_2	(0.22, 0.43, 1)	(1, 1, 1)	(0.55, 1, 1.8)	(0.55, 1, 1, 1.8)	(0.33, 0.71, 21.4)
c_3	(0.22, 0.43, 1)	(0.55, 1, 1.8)	(1, 1, 1)	(0.55, 1, 1, 1.8)	(0.33, 0.71, 1.4)
c_4	(0.22, 0.43, 1)	(0.55, 1, 1.8)	(0.55, 1, 1.8)	(1, 1, 1)	(0.33, 0.71, 1.4)
c_5	(0.29, 0.6, 1.67)	(0.711.4, 3)	(0.71, 1.4, 3)	(0.71, 1.4, 3)	(1, 1, 1)
c_6	(0.29, 0.6, 1.67)	(0.71, 1.43)	(0.71, 14, 3)	(0.71, 1.4, 3)	(0.43, 1, 2.33)
c_7	(0.29, 0.6, 1.67)	(0.71, 1.43)	(0.71, 1.4, 3)	(0.71, 1.4, 3)	(0.43, 1, 2.33)
c_8	(0.22, 0.33, 0.71)	(0.55, 0.78, 1.29)	(0.55, 0.78, 1.29)	(0.55, 0.78, 1.29)	(0.33, 0.55, 1)
c_9	(0.29, 0.6, 1.67)	(0.71, 1.43, 0.71)	(0.71, 1.4, 3)	(0.71, 1.4, 3)	(0.43, 1, 2.33)
c_{10}	(0.29, 0.6, 1.67)	(0.71, 1.43, 0.71)	(0.71, 1.4, 3)	(0.71, 1.4, 3)	(0.43, 1, 2.33)
c_{11}	(0.4, 1, 2.5)	(1, 2.34, 4.5)	(1, 2.34, 4.5)	(1, 2.336, 4.5)	(0.6, 1.67, 3.5)
c_{12}	(0.29, 0.6, 1.67)	(1, 2.34, 45)	(1, 2.336, 4.5)	(0.71, 1.4, 5)	(0.6, 1.67, 3.5)
c_{13}	(0.22, 0.33, 0.71)	(0.71, 1.4,3)	(0.71, 1.4, 5)	(0.55, 0.78, 1.29)	(0.43, 1, 2.33)
c_{14}	(0.22, 33, 0.71)	(0.55, 0.78, 1.29)	(0.55, 0.78, 1.29)	(0.55, 0.78, 1.8)	(0.33, 0.55, 1)
c_{15}	(0.22, 33, 0.71)	(0.71, 0.78, 1.29)	(0.71, 0.78, 1.29)	(0.55, 1, 1.8)	(0.33, 0.55, 1)
c_{16}	(0.29, 0.6, 1.67)	(0.55, 1, 1.8)	(0.55, 1, 1.8)	(0.71, 1, 4.3)	(0.33, 0.71, 1.4)
c_{17}	(0.22, 0.43, 1)	(0.71, 1.4, 3)	(0.5, 5, 1, 1.8)	(0.5, 1, 1.8)	(0.439, 1, 2.33)
c_{18}	(0.29, 0.6, 1.67)	(0.55, 1, 1.8)	(0.71, 1.4, 3)	(0.71, 1.4, 3)	(0.33, 0.71, 1.4)
c_{19}	(0.29, 0.6, 1.67)	(0.71, 1.4, 3)	(0.71, 1.4, 3)	(0.71, 1.4, 3)	(0.43, 1, 2.33)
c_{20}					(0.43, 1, 2.3)
	c_6	c_7	c_8	c_9	c_{10}
c_1	(0.6, 1.67, 3.5)	(0.6, 1.67, 3.5)	(0.6, 1.67, 3.5)	(1.4, 3, 4.5)	(0.6, 1.67, 3.5)
c_1	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)	(0.78, 1.29, 1.8)	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)
c_2	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)	(0.78, 1.29, 1.8)	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)
c_3	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)	(0.77, 1.29, 1.8)	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)
c_4	(0.43, 1, 2.33)	(0.43, 1, 2.33)	(1, 1.8, 3)	(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_5	(1, 1, 1)	(0.43, 1, 2.33)	(1, 1.8, 3)	(0.43, 1, 2.33)	(0.431, 1, 2.33)
c_6	(0.431, 2.33)	(1, 1, 1)	(1, 1.8, 3)	(0.43, 1, 2.33)	(0.431, 1, 2.33)
c_7	(0.33, 0.55, 21)	(0.33, 0.55, 1)	(1, 1, 1)	(0.33, 0.55, 1)	(0.33, 0.55, 1)
c_8	(0.43, 1, 2.33)	(0.43, 1, 2.33)	(1, 1.83)	(1, 1, 1)	(0.43, 1, 2.33)
c_9	(0.43, 12.33)	(0.43, 1, 2.33)	(1, 1.83)	(0.43, 1, 2.33)	(1, 1, 1)
c_{10}	(0.6, 1.67, 3.5)	(0.6, 1.67, 3.5)	(1, 4, 3, 4.5)	(0.6, 1.67, 3.5)	(0.6, 1.67, 3.5)
c_{11}	(0.6, 1.67, 3.5)	(0.43, 1, 2.33)	(1, 1.8, 1)	(0.43, 1, 2.33)	(0.6, 1.67, 3.5)
c_{12}	(0.5, 1, 2.33)	(0.33, 0.55, 1)	(0.78, 1, 1.29)	(0.33, 0.55, 1)	(0.43, 1, 2.33)
c_{13}	(0.33, 0.555, 1)	(0.33, 0.55, 1)	(0.78, 1, 1.29)	(0.33, 0.71, 1.4)	(0.33, 0.551)
c_{14}	(0.33, 0.55, 1)	(0.33, 0.71, 1.4)	(0.78, 0.29, 1.8)	(0.43, 1, 2.33)	(0.33, 0.55, 1)
c_{15}	(0.33, 0.71, 1.4)	(0.431, 2.33)	(1, 1.83)	(0.33, 2.51, 1.4)	(0.33, 0.71, 1.4)
c_{16}	(0.5, 1, 2.33)	(0.33, 0.71, 1.4)	(0.78, 1.29, 1.83)	(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_{17}	(0.33, 0.71, 1.4)	(0.43, 1, 2.33)	(1, 1.8, 3)	(0.43, 1, 2.33)	(0.33, 0.71, 1.4)
c_{18}	(0.5, 1, 2.33)	(0.43, 1, 2.33)		(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_{19}	(0.43, 1, 2.3)				(0.43, 1, 2.33)
c_{20}					
	c_6	c_7	c_8	c_9	c_{10}
c_1	(0.4, 1, 2.5)	(0.4, 1, 2.5)	(0.6, 1.67, 3.5)	(1.4, 3, 4.5)	(1. 4, 3, 4.5)
c_2	(0.22, 0.43, 1)	(0.22, 0.43, 1)	(0.33, 0.71, 1.4)	(0.78, 1.29, 1.8)	(0.78, 1.29, 1.8)
c_3	(0.22, 0.43, 1)	(0.22, 0.43, 1)	(0.33, 0.71, 1.4)	(0.78, 1.29, 1.8)	(0.78, 1.29,1.8)
c_4	(0.22, 0.43, 1)	(0.22, 0.43, 1)	(0.33, 0.71.4)	(0.78, 1.29, 1.8)	(0.78, 1.29, 1.8)
c_5	(0.29, 0.6, 1.67)	(0.29, 0.6, 1.67)	(0.43, 1, 2.33)	(1, 1.8, 3)	(1, 1.8, 3)
c_6	(0.29, 0.6, 1.67)	(0.29, 0.6, 1.67)	(0.43, 1, 2.33)	(1, 1.8, 3)	(1, 1.8, 3)
c_7	(0.29, 0.6, 1.67)	(0.29, 0.6, 1.67)	(0.43, 1, 2.33)	(1, 1.8, 3)	(1, 1.8, 3)
c_8	(0.29, 0.33, 0.71)	(0.29, 0.33, 0.71)	(0.33, 0.55, 1)	(0.78, 1, 1.29)	(0.78, 1, 1.29)
c_9	(0.29, 0.6, 1.67)	(0.29, 0.6, 1.67)	(0.43, 1, 2.33)	(1, 1.8, 3)	(1, 1.8, 3)
c_{10}	(0.29, 0.6, 1.67)	(0.29, 0.6, 1.67)	(0.43, 1, 2.33)	(1, 1.8, 3)	(1, 1.8, 3)
c_{11}	(1, 1, 1)	(0.4, 1, 2.5)	(0.6, 1.67, 3.5)	(1, 4.3, 4.5)	(1.4.3, 4.5)
c_{12}	(0.4, 1, 2.5)	(1, 1, 1)	(0.6, 1.67, 3.5)	(1, 4.3, 4.5)	(1.4.3, 4.5)
c_{13}	(0.29, 0.6, 1.67)	(0.29, 0.6, 1.67)	(1, 1, 1)	(1, 1.8, 3)	(1, 1.8, 3)
c_{14}	(0.29, 0.33, 0.71)	(0.29, 0.33, 0.71)	(0.33, 0.55, 1)	(1, 1, 1)	(0.78, 1, 1.29)
c_{15}	(0.22, 0.33, 0.71)	(0.22, 0.33, 0.71)	(0.33, 0.55, 1)	(0.78, 1, 1.3)	(1, 1, 1)
c_{16}	(0.22, 0.43, 1)	(0.22, 0.43, 1)	(0.33, 0.71, 1.4)	(0.78, 1.29, 1.8)	(0.78, 1.29, 1.8)
c_{17}	(0.23, 0.6, 1.67)	(0.23, 0.6, 1.67)	(0.43, 1, 2.33)	(1, 1.8, 3)	(1, 1.8, 3)
c_{18}	(0.22, 0.43, 1)	(0.22, 0.43, 1)	(0.33, 0.71, 1.4)	(0.78, 1.29, 1.8)	(0.78, 1.29, 1.8)
c_{19}	(0.29, 0.6, 1.67)	(0.29, 0.6, 1.67)	(0.43, 1, 2.33)	(1, 1.8, 3)	(1, 1.8, 3)
c_{20}	(0.29, 0.6, 1.67)	(0.29, 0.6, 1.67)	(0.43, 1, 2.33)	(1, 1.8, 3)	(1, 1.8, 3)
	c_2	c_2	c_3	c_4	c_5
c_1	(1, 2.33, 4.5)	(0.6, 1.67, 3.5)	(1, 2.33, 4.5)	(0.6, 1.67, 3.5)	(0.6, 1.67, 3.5)
c_2	(0.55, 1, 1.8)	(0.33, 0.71, 1.4)	(0.55, 1, 1.8)	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)

Table. 2: (continue)

c_3	(0.55, 1, 1.8)	(0.33, 0.71, 1.4)	(0.55, 1, 1.8)	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)
c_4	(0.55, 1, 1.8)	(0.33, 0.71, 1.4)	(0.55, 1, 1.8)	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)
c_5	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.71, 1.4,3)	(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_6	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.71, 1.43)	(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_7	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.71, 1.43)	(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_8	(0.55, 1, 1.4, 3)	(0.33, 0.55, 1)	(0.55, 0.78, 1.3)	(0.33, 0.55, 1)	(0.33, 0.55, 1)
c_9	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_{10}	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.71, 1.43)	(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_{11}	(1, 2.33, 4.5)	(0.6, 1.67, 3.5)	(1, 2.33, 4.5)	(0.6, 1.67, 3.5)	(0.6, 1.67, 3.5)
c_{12}	(1, 2.33, 4.5)	(0.6, 1.67, 3.5)	(1, 2.33, 4.5)	(0.6, 1.67, 3.5)	(0.6, 1.67, 3.5)
c_{13}	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.43, 1, 2.33)
c_{14}	(0.55, 0.78, 1.3)	(0.33, 0.55, 1)	(0.55, 0.78, 1.3)	(0.33, 0.55, 1)	(0.33, 0.55, 1)
c_{15}	(0.55, 0.78, 1.3)	(0.33, 0.55, 1)	(0.55, 0.78, 1.3)	(0.33, 0.55, 1)	(0.33, 0.55, 1)
c_{16}	(1, 1, 1)	(0.33, 0.71, 1.4)	(0.55, 1, 1.8)	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)
c_{17}	(0.71, 1.4, 3)	(1, 1, 1)	(0.71, 1.4, 3)	(0.431, 2.33)	(0.43, 1, 2.33)
c_{18}	(0.55, 1, 1.8)	(0.33, 0.71, 1.4)	(1, 1, 1)	(0.33, 0.71, 1.4)	(0.33, 0.71, 1.4)
c_{19}	(0.71, 1.43)	(0.43, 1, 2.33)	(0.71, 1.4, 3)	(1, 1, 1)	(0.43, 1, 2.33)
c_{20}	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(0.71, 1.4, 3)	(0.43, 1, 2.33)	(1, 1, 1)

Table 3: Computed S_i in FAHP method

S_1	(0.0190, 0.0864, 0.3038)	S_6	(0.0137, 0.0518, 0.2011)	S_{11}	(0.0106, 0.0345, 0.1195)	S_{16}	(0.0104, 0.0287, 0.0874)
S_2	(0.0190, 0.0865, 0.3037)	S_7	(0.0106, 0.0410, 0.1207)	S_{12}	(0.0106, 0.0370, 0.1207)	S_{17}	(0.0137, 0.0518, 0.2011)
S_3	(0.0104, 0.0287, 0.0874)	S_8	(0.0288, 0.0518, 0.1928)	S_{13}	(0.0137, 0.0518, 0.2011)	S_{18}	(0.0137, 0.0518, 0.2011)
S_4	(0.0108, 0.0292, 0.0858)	S_9	(0.0137, 0.0518, 0.2011)	S_{14}	(0.0137, 0.0518, 0.2011)	S_{19}	(0.0190, 0.0865, 0.3037)
S_5	(0.0106, 0.0345, 0.1195)	S_{10}	(0.0106, 0.0370, 0.1207)	S_{15}	(0.0134, 0.0518, 0.1948)	S_{20}	(0.0137, 0.0518, 0.1928)

Table 4: Criteria weighting by FAHP method

Criteria weight (W)							
c_1	0.0051	c_6	0.057	c_{11}	0.040	c_{16}	0.068
c_2	0.059	c_7	0.046	c_{12}	0.057	c_{17}	0.054
c_3	0.035	c_8	0.065	c_{13}	0.021	c_{18}	0.022
c_4	0.067	c_9	0.062	c_{14}	0.027	c_{19}	0.046
c_5	0.031	c_{10}	0.033	c_{15}	0.041	c_{20}	0.019

Table 5: Usage of the FAHP model to transportation system selection of the Persian Gulf tunnel

		Alternatives					
		A_1		A_2		A_3	
Criteria	Global weights	M_3	Score (s_3)	M_2	Score (s_2)	M_1	Score (s_1)
c_1	0.055	0.35	0.0192	0.40	0.0220	0.24	0.0132
c_2	0.064	0.25	0.0160	0.40	0.0256	0.35	0.0224
c_3	0.040	0.25	0.0100	0.40	0.0160	0.35	0.0140
c_4	0.073	0.25	0.0182	0.35	0.0255	0.40	0.0292
c_5	0.036	0.25	0.0090	0.35	0.0126	0.40	0.0144
c_6	0.062	0.35	0.0217	0.25	0.0155	0.35	0.0217
c_7	0.051	0.31	0.0158	0.38	0.0193	0.31	0.0158
c_8	0.070	0.35	0.0245	0.40	0.0280	0.25	0.0175
c_9	0.067	0.44	0.0294	0.48	0.0321	0.08	0.0053
c_{10}	0.038	0.39	0.0148	0.44	0.0167	0.17	0.0064
c_{11}	0.045	0.53	0.0238	0.47	0.0211	0	0
c_{12}	0.062	0.25	0.0155	0.35	0.0217	0.40	0.0248
c_{13}	0.026	0.40	0.0104	0.25	0.0065	0.35	0.0091
c_{14}	0.032	0.25	0.0080	0.40	0.0128	0.35	0.0112
c_{15}	0.046	0.25	0.0115	0.35	0.0161	0.40	0.0184
c_{16}	0.073	0.33	0.0240	0.21	0.0153	0.41	0.0299
c_{17}	0.059	0.35	0.0206	0.40	0.0236	0.25	0.0147
c_{18}	0.027	0.26	0.0070	0.46	0.0124	0.29	0.0078
c_{19}	0.051	0.14	0.0071	0.55	0.0280	0.32	0.0163
c_{20}	0.024	0.33	0.0079	0.43	0.0103	0.24	0.0057
Total scores	……	…….	0.3144	…….	0.3814	..…..	0.2878
Renormalized scores	……	…….	0.3196	…….	0.3877	…….	0.2926

$v(s1 \geq S_{19}) = 1,\ v(S_1 \geq S_{20}) = 1$

Rest of the computation will be done like this. According to Eq. (10) we will have:

$d'(c_1) = \min(1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1) = 1$

Rest of the computation will be done like this. According to Eq. (11) we will have:

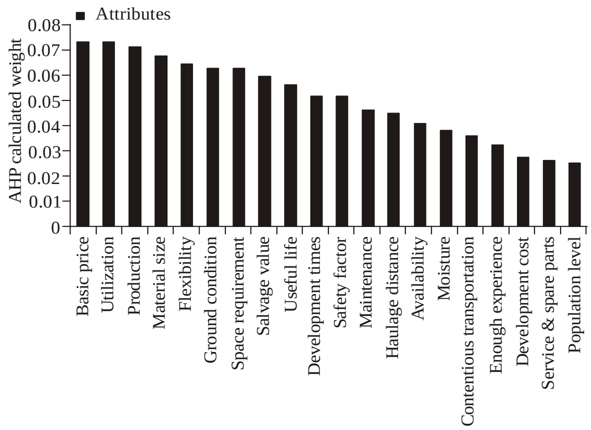

Fig. 4: Global weights of the evaluation attributes calculated FUZZY AHP method

w′ = (1, 0.67, 0.67, 0.67, 0.84, 0.84, 0.84, 0.31, 0.84, 0.84, 1, 1, 0.68, 0.31, 0.54, 0.66, 0.84, 0.43, 0.83, 0.84)

Finally, by normalized W′, the ultimate weights of criteria will be listed in Table 4.

DISCUSSION

Transportation system selection: Three alternatives have been proposed for transportation system in Persian Gulf tunnel. In this step, alternatives should be compared with each criterion to form the Pair-Wise Comparison Judgment Matrix (PCGM). In Table 5, column M_1, M_2 and M_3 will be devised respectively by the values of s_1‘ $s_2$ands$_3$ multiply to weigth's of criteria. Grades of A_1‘ A_2 and A_3 alternatives are achieved separately by adding the column M_1, M_2 and M_3. Rank of the alternatives (A_1, A_2, A_3) has been achieved by normalized them 0.3196, 0.3877, 0.2926, respectively.

An investor has a special view to parameters, such as; primary investment, basic price of related equipments and project utilization for big and small projects. It is obvious that this project do this act. And according to other projects, our project has the highest significant coefficient rate, basic price criteria, utilization and production (Fig. 4). Truck transportation system has been selected among 3 available transportation systems, during Persian Gulf tunnel constructing, based on computation (Fig. 5).

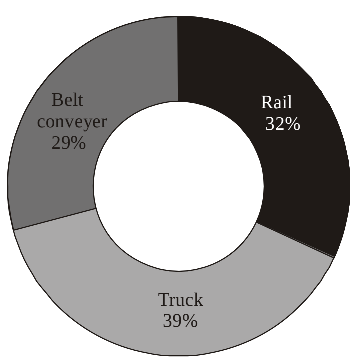

Fig. 5: Fuzzy AHP ranking

CONCLUSION

The transportation system selection is a strategic issue and has significant impact to the tunnel boring. So has been tried that the best transportation system has been selected. The best system is a system without any problem or minimum problem. So this case should be considered in economical, Safety, technical, operation aspects, so that the lowest problem and operation cost, and highest safety factors, compatibility with different ground conditions, most flexibility and effective life time.

In this study we try, to select the best transportation system based on mentioned condition and other criteria among 3 proposed alternatives. It is necessary to say that, such selection, done by one or some person's ideas in past and in terms of different criteria. But, here we try to select the best alternative, based on factual mathematics model with the help of several expert's idea and important and effective criteria.

On the other hand, human always opine in a problem, quality. They can not express an exactly quantity. This disability causes an un-crispy in expert's opinion.

To solve this problem, we use FUZZY AHP to determine the degree of importance of the effective factors in the model. Finally, according to Fig. 5, truck is selected as the best transportation system, during the Persian Gulf construction with the highest membership grade.

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