Research Article

SUPPLIER EVALUATION AND SELECTION FOR A CONSTRUCTION COMPANY

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ABSTRACT

In recent years, supply chain management has taken attention to both business and academic areas. Notably, the selection of the best supplier is one of the most crucial problems in the supply chain. That is why studies on supplier selection problem increase day by day. The aim of this study to determine the best supplier selection for a construction firm. Multi-criteria decision-making methods are the best approach for solving problems, including many selection criteria. For this reason, it is proposed a two-stage multi criteria decision making model in this paper. In the first stage, Fuzzy AHP is used to find the weight of the criteria. At the second stage, the TOPSIS method is used to rank the cement supplier. The presented model is applied to a construction company from Somali. The results support the decision process of managers.

Keywords: Supplier selection, Fuzzy AHP, TOPSIS.

BİR İNŞAAT FİRMASI İÇİN TEDARİKÇİ DEĞERLENDİRMESİ VE SEÇİMİ

ÖZET

Son yıllarda, tedarik zinciri yönetimi hem iş hem de akademik alanlarda dikkat çekmektedir. Özellikle en iyi tedarikçinin seçimi tedarik zincirindeki en önemli problemlerden biridir. Bu nedenle, tedarikçi seçim problemi ile ilgili çalışmalar her geçen gün artmaktadır. Bu çalışmanın amacı bir inşaat firması için en iyi tedarikçiyi tespit etmektir. Çok kriterli karar verme yöntemleri, bir çok seçim kriterini içeren problemler için en iyi seçenektir. Bunun için, bu makalede iki aşamalı bir model önerilmektedir. İlk aşamada, kriterlerin ağırlığını bulmak için Bulanık AHP kullanılır. İkinci aşama TOPSIS yöntemi, taşeronları kapsamak için kullanılır. Önerilen model Somali'den bir inşaat şirketine uygulanmıştır. Sonuçlar yöneticilerin karar alma sürecini desteklemektedir.

Anahtar Kelimeler: Tedarikçi seçimi, Bulanık AHP, TOPSIS

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1. INTRODUCTION

In recent years the construction industry has undergone tremendous development. Population growth and urbanization led to an increasing need for shelter developments. Similarly, the material used in the building has been developed and increased.

Many materials are used for construction purposes, but generally, they are classified as naturally occurring substances such as sand and rocks, while many are human-made products such as cement and glass (Safa et al. 2014) state that the cost of material amounts to almost 50-60% of the overall project cost and their management affects 80% of the project schedule. It indicates that project success depends on the success of the right choice of a material supplier.

Cement is one of the most critical materials used in construction (Schneider, 2011). It is used as a binder or substance which sets hardens and adheres to other materials to bind them together. It is rarely used alone but somewhat mixed with fine aggregate to produce mortar for masonry or with sand and gravel to produce concrete. Construction companies are mostly organizations established for-profit; therefore, they aim to reduce the total construction cost as much as possible and increase profit in the projects they undertake. The supplier selection decision is one of the most important decisions that companies should make. According to Aretoulis et al. (2010), supplier selection plays a critical role in the success or failure of construction projects.

This paper aims to provide a solution for supplier selection of cement in Alburuuj Construction Company. The problem of the cement supplier is a multi-criteria decision-making problem since it associated with multiple alternatives and criteria which consist of numerical and non-numerical criteria in its structure. For this study first, three Turkish cement manufacturers selected. To evaluate the suppliers, five criteria which are cost, quality, delivery, service, and supplier profile, are selected. The Fuzzy-AHP method is used to determine the weights of each criterion, extracted from the subjective judgments of the decision-makers. TOPSIS method is applied for the ranking of the supplier.

This article is organized as follows; in the second part, a literature review related to the selection of suppliers is given. In the third section, information about the multi-criteria decision-making methods, Fuzzy AHP, and TOPSIS methods to be used in the application are explained. In the fourth section, the application was made. In the last section part, the result of the study is discussed.

2. LITERATURE REVIEW

Supplier selection is one of the most common problems that MCDM methods are applied. Also, it is defined as the comparison of suppliers using multiple criteria and selecting the most appropriate one. The selection of the best suitable supplier is based on assessing supplier capabilities (Shih et al. 2004). In most cases, the problem of supplier evaluation and selection deals with more than one supplier, and the supplier selection is made by multiple decision-makers, who have different points of view (Plebankiewicz and Kubek 2016).

Construction professionals still tend to select their suppliers based on past experiences rather than objective and systematic approaches Flanagan, (2009). In today's competitive market, the supplier evaluation and selection process are the best methods off purchasing. One of the essential tasks at the purchasing function is the selection of the right suppliers and thereby, the acquisitions of required material (Monczka et al. 2011).

There are many types of research in the literature related to supplier evaluation and selection methods, which are carried out in different sectors in recent years. Erdebilli et al. (2018) used the TOPSIS method combined with an intuitionistic fuzzy set (IFS) to solve the problem of site selection in a wind energy plant in Turkey. For this purpose, four alternative locations that can build wind power plant had been identified.to evaluate alternatives ten criteria in four dimensions that are cost, location, wind potential, and social benefits are selected. The TOPSIS method is used to rank the alternatives, while IFS is used to reflect approval, rejection, and hesitation of decision-makers by dealing with real-life uncertainty, imprecision, vagueness, and human linguistic decisions. Cengiz (2017) was implemented an extensive questionnaire survey to the construction companies, universities, and governmental institutions. According to the results of the study, the most commonly mentioned criteria were cost, quality, and delivery.

Rezaie and Ramiyani (2014) evaluated the performance of 27 Iranian cement firms in the Tehran stock exchange market for two years (2008 and 2009) separately. They gathered the financial ratio of the firm's performance. Fuzzy AHP was used to determine the weight of criteria from a subjective judgment of decision-makers and VIKOR method used for ranking the firms. In another study, Guan et al. (2013) examined the material Suppliers' selection process. They proposed the fuzzy substance-element model and fuzzy AHP methods for this process; the proposed approach is demonstrated on the problem of choosing a cement supplier for the National Highway project in the Republic of Congo. In the case study, three cement suppliers were evaluated according to 10 evaluation criteria. Alternatives are listed according to the results of the evaluation. Chai (2013)'s study reveals that the most widely used method is AHP, followed by Linear Programming, TOPSIS, and ANP, respectively.

Time is one of the most critical factors in construction operations and has significant legal consequences. Since the project owner sets the rigid beginning and ending dates for the construction process. (Polat and Arditi 2005) states that the absence of the right materials in the right quantities and quality on-site is one of the most commonly experienced causes of delays in construction projects.

Radziszewska (2010) solved the problem of subcontractor selection in the construction sector by using the ELECTRE III method. Selection criteria were cost distribution, adaptability to market changes, mutual relations, communication method, information sharing, solution conflicts, standards-codes of conduct, frequency of communication, reliability, and quality control service status.

Ho et al. (2010) examined 78 articles about supplier selection published between 2000 and 2008. Data Envelopment Analysis was the most used method. When they examined the integrated methods, they found that AHP-GP (Goal Programming) combination was used the most. In that studies, they also listed the criteria used most in selecting suppliers. The most frequently used criterion was Quality, Delivery, and Cost criteria, respectively. Shengbin and Chunsheng (2009) developed a multi-purpose programming model by using quality, delivery, cost, and service criteria in supplier selection of a company that operates in the aviation industry.

Chen et al. (2006) proposed the Fuzzy TOPSIS approach to evaluate and select suppliers in the supply chain method. They used their proposed approach to select the supplier of the materials to be used in the final products of a high-tech company. In the method, they worked with three decision-makers and evaluated five alternative suppliers according to 5 criteria. Soner & Önüt (2006) solved the problem of supplier selection of a company that produces ventilation and air conditioning by using AHP and ELECTRE methods together. First, they determine the weights of 7 criteria that would use to evaluate the suppliers by using the AHP method and then, using these weights, they ranked five alternative suppliers with the ELECTRE method.

Kahraman et al. (2003) proposed the Fuzzy AHP method for the solution of supplier selection problems. The proposed approach is shown as a case study on the supplier selection problem of a company in the white goods manufacturing sector; three alternative suppliers were evaluated according to 11 criteria by using the Fuzzy AHP method for ranking. When a company chooses to work with a supplier who offers the lowest price, it is exposed to several risks. The main problems caused by building materials can be summarized as follows: failure to order on time, delivery at the wrong time, errors in quantity take-off, obtaining incorrect materials from distribution to output, and dual handling (Flanagan, 2009). The selection supplier aims are to determine the suppliers that can supply the demands of an enterprise continuously at an appropriate price, on-time delivery, in the desired quantities, and of good quality (Güner, 2005).

3. MULTI CRITERIA DECISION-MAKING METHODS

Multi-criteria decision making (MCDM) methods are utilized to analyze and evaluate decision processes where multiple criteria are combined when studies related to supplier selection and evaluation. Although MCDM methods may be widely diverse many of them have certain aspects in common (Chen and Hwang, 1991), which are alternatives more than one and criteria used to evaluate those alternatives.

Nowadays, there are many mathematical methods used in solving multi-criteria decision-making problems. One of the major topics using MCDM methods is the selection of the best supplier among alternatives.

Ho et al. (2010) examined studies on supplier selection between 2008 and 2012. In that study, they reviewed 123 articles and defined 26 different decision-making methods. In the studies they examined, the most commonly used methods were AHP method (24.39%), L.P. (Linear Programming, 15.44%), TOPSIS (14.63%), ANP (12.20%), DEA (Data Envelopment Analysis, 10.57%) and purposeful optimization (10.57%). In these methods, Fuzzy AHP and TOPSIS methods will be explained step by step approach.

3.1. Fuzzy Ahp

The fuzzy analytical hierarchy process (FAHP) is a beneficial method for multi-criteria decision making in fuzzy environments. The literature was used many times in different applications. The first study on FAHP was conducted by Van Laarhoven and Pedrytcz (1983). There are many different Fuzzy AHP algorithms in the literature. In this paper, Buckley's proposed approach to the Fuzzy AHP method is used (Buckley, 1985). The steps of FAHP are as follows.

Step 1: The hierarchy of the problem is established as in the AHP approach.

Step 2: A binary comparison matrix is created. Decision-makers are asked to evaluate the criteria relative to each other and the alternatives for each criterion. Evaluation should be done according to the AHP evaluation scale. These comparisons are then blurred using the triangular fuzzy values shown in Table 1. (Anagnostopoulos et al., 2007). If there is more than one decision-maker, the geometric mean is used to combine the results.

Table 1. Linguistic variables for the importance weights of the criteria.

Linguistic Variables	Crisp AHP Scale	Fuzzy AHP Scale	
		TFNs	Reciprocal TFNs
Equally Importance	1	(1, 1, 1)	(1, 1, 1)
Moderately Importance	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Strongly Importance	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Very Strongly Importance	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Extremely Importance	9	(8, 9, 9)	(1/9, 1/8, 1/8)
Intermediate values	2	(1, 2, 3)	(1/3, 1/2, 1)
	4	(3, 4, 5)	(1/5, 1/4, 1/3)
	6	(5, 6, 7)	(1/7, 1/6, 1/5)
	8	(7, 8, 9)	(1/9, 1/8, 1/7)

Step 3: Once the binary comparison matrices are obtained in a fuzzy manner, the criteria have weightings relative to each other, and alternatives have weight according to each criterion. The formula below is used first to find significant weights.

$$\tilde{r} = (\tilde{c}_{i1} \times \tilde{c}_{i2} \times \ldots . \times \tilde{c}_{in})^{\frac{1}{n}} \quad (1)$$

The values in the binary comparison matrix $\tilde{c}_{ij}$ in the formula represent the alternative number n. So, first of all, the geometric mean of each row of the binary comparison matrix is taken. Then the sum of the columns of each column of the $\tilde{r}$ obtained is calculated. The significance weights are then calculated using the below formula.

$$\widetilde{W} = \left(\frac{r_l}{\sum r_u}, \frac{r_m}{\sum r_m}, \frac{r_u}{\sum r_l}\right) = (\mathrm{w_l}, \mathrm{w_m}, \mathrm{w_u}) \quad (2)$$

In the formula, r_l represents the values of the fuzzy matrix r found in the previous formula, $\mathrm{r_m}$ and $\mathrm{r_u}$ respectively represent the m and u values of the fuzzy matrix r. The significance weight (w) found by the above formula is in the form of a triangular fuzzy function. Actual weight values are obtained by defuzzification, followed by normalization. Rinsing is performed using the field center formula (Sun, 2010). The formula is given below.

$$\mathrm{w_i} = \frac{(\mathrm{l_1}+\mathrm{m_1}+\mathrm{u_1})}{3} \quad (3)$$

The values found are divided by the column total. Thus, normalization of the values is provided. The values obtained after the normalization process are the significance of weight values.

Step 4: After calculating the significance weights, the consistency of the matrices is checked. Consistency Ratio (C.R.) value should be less than 0.1 as in the AHP method.

3.2. TOPSIS

The TOPSIS (Technique for Order by Similarity Ideal Solution) was first developed by Hwang and Yoon 1980 (reference). It is based on the concept that the chosen alternative should be the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. While solving many criterion decision problems where negative ideal solutions are consisting of the combination of the worst values and positive ideal solutions consisting of the combination of all the best values of the criteria. Zhongyou (2012) describes the steps of the TOPSIS method as follows.

Step 1: The Decision Matrix (D) is created. In the decision matrix, there are i, i = 1,2,…, m for alternatives, and in the columns, j, j = 1, 2,…, n criteria. Matrix D is the data matrix generated by the decision-maker. The decision matrix is shown as follows:

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ & & . & \\ a_{n1} & a_{n2} & \cdots & a_{nm} \end{bmatrix} \tag{4}$$

Step 2: Normalized decision matrix (R). There are different methods for carrying out the normalization process. The most commonly used are vector normalization, linear normalization, and non-monotonous normalization. After the decision matrix is created, the values of each a_{ij} values are taken from the sum of these values. The resulting column totals are obtained and each a_{ij} value (a_{11}, a_{21}, a_{31}... a_{m1}) is divided by the square root of the column total to which the normalization process is performed.

$$R_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \tag{5}$$

The matrix R is obtained as follows:

$$N_{ij} = \begin{bmatrix} r_{11} & r_{11} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ . & . & . & . \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} \tag{6}$$

Step 3: Weighted normalized decision matrix (Y) is generated. Weight values (wi) for evaluation factors are determined first. After the weighting is done according to the importance of the criteria. The weights obtained are the only subjective parameter of the TOPSIS method. The point to be considered at this stage is w_i value sums equal to (1). The weights of the criteria were determined by the FAHP method,

$$V = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_m r_{1m} \\ w_1 r_{21} & w_2 r_{12} & \cdots & w_m r_{2m} \\ . & & & . \\ w_1 r_{n1} & w_2 r_{n2} & \cdots & w_m r_{nm} \end{bmatrix} \tag{7}$$

Step 4: Create Positive Ideal (A^+) and Negative Ideal (A^*) solutions. To create the ideal solution set, the largest of the weighted criteria in the Y matrix (i.e., the smallest if the relevant criterion is minimized) is selected. The maximum values indicate ideal positive solution values, while the minimum values indicate ideal negative solution values. Generally the A^+ made up of all the best scores that the criteria produce and the A^* are all the lowest possible results in the criteria (Krohling and Campanharo, 2011).

The solution of a positive ideal solution set is shown in the equation.

$$A^+ = \{v_1{}^+, v_2{}^+, \dots, v_n{}^+\} = \{(\max v_{ij} \mid \in I), (\min v_{ij} \mid J \in J^+)\} \quad (8)$$

The set of negative ideal solutions is formed by selecting the smallest of the weighted criteria in the Y matrix; on another side, the smallest of the column values (the largest if the corresponding evaluation factor is maximized). Finding the negative ideal solution set is provided by the formula shown in the equation

$$A^* = \{v_1{}^-, v_2{}^-, \dots, v_n{}^-\} = \{(\min v_{ij} \mid \in I), (\max v_{ij} \mid J \in J^-)\} \quad (9)$$

Step 5: Calculate the distances of each alternative to the positive ideal solution and the negative ideal solution. In the TOPSIS method, Euclidian Distance Approach is used to determine the distance of the criterion value for each alternative from the set of positive ideal and negative ideal solutions. The distance values for the alternatives obtained here are called Distance to Positive Ideal Solution ($\boldsymbol{s_i}^+$) and Distance to Negative Ideal Solution ($\boldsymbol{s_i}^*$).

The calculation of the distance to the positive ideal solution ($\boldsymbol{s_i}^+$) is presented in the equation.

$$\boldsymbol{s_i}^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j{}^+)^2} \quad (10)$$

The calculation of the distance to the negative ideal solution ($\boldsymbol{s_i}^*$) is as in the equation.

$$\boldsymbol{s_i}^* = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j{}^*)^2} \quad (11)$$

When making calculations, there will be $\boldsymbol{s_i}^+$ and $\boldsymbol{s_i}^-$ values as much as the number of decision points.

Step 6: Calculate proximity to the ideal solution. Positive and negative ideal criteria are used to calculate the relative proximity of each alternative to the ideal solution. The criterion used here is the ratio of the distance from the negative ideal solution to the sum of the distance from the positive ideal solution to the value of the range to the negative ideal solution. It is presented in the equation for calculating the relative proximity value to the ideal solution.

$$C_i{}^* = \frac{s_i{}^-}{s_i{}^- + s_i{}^+} \quad (12)$$

Where $C_i{}^*$ value takes value in the range $0 \leq C_i{}^* \leq 1$ and $C_i{}^* = 1$ indicates that the relevant alternative is at the positive ideal solution point, $C_i{}^* = 0$ indicates that the relevant alternative is at the negative ideal solution point.

4. APPLICATION

Alburuuj Construction Company was established in 2009 to provide construction services in Somalia and Djibouti. Alburuuj decided to buy cement from Turkish cement manufacturers Companies. In this study, it will analyze which cement manufacturer will be suitable for the order.

Construction companies have a purchasing department that is responsible for the supplying process. In this situation, decision-making was made by the team of decision-makers. Three decision-makers from (procurement manager, assistant-procurement manager, and civil engineer) asked to evaluate in terms of criteria compare and supplier rating. Numerous criteria can be found in the literature and publications to evaluate suppliers. Chou and Chang (2008) emphasize that the main task for the purchasing department is to determine the principal competitive factors in their industry during the criteria formulation stage and translate these measurements with their scales into supplier selection criteria. As a result of the interviews with the decision-makers, the criteria to be used in the selection of suppliers were determined, five criteria will take into account the selection of suppliers. The chosen criteria are Quality (C1), Cost (C2), Delivery (C3), Service (C4), and Supplier profile (C5). The number of suppliers participates in the evaluation was reduced to three suppliers. The names of suppliers are not mentioned due to confidentiality. So instead of that, A1, A2, and A3 have been used. As a result of the subjective judgments of the decision-maker, five main criteria and 3 alternative suppliers have been determined for the evaluation of the supplier.

4.1. Fuzzy AHP (FAHP) Method For Determination of Criteria Weights

FAHP method was used to determine the weights of the criteria to determine the weights of all criteria, a team of 3 decision-makers from the purchasing department and construction engineer of the company was consulted. Experts were asked to evaluate the criteria by asking paired comparison questions. At this stage, the 1-9 scale of Saaty was used. Since there are 3 decision-makers, a geometric mean is used to get one value. Buckley (1985) is used to determine the weight the procedure that I explain step by step in chapter 3 as follows.

Step1: For the solution with the Fuzzy AHP method, firstly, a hierarchy of the problem is established.

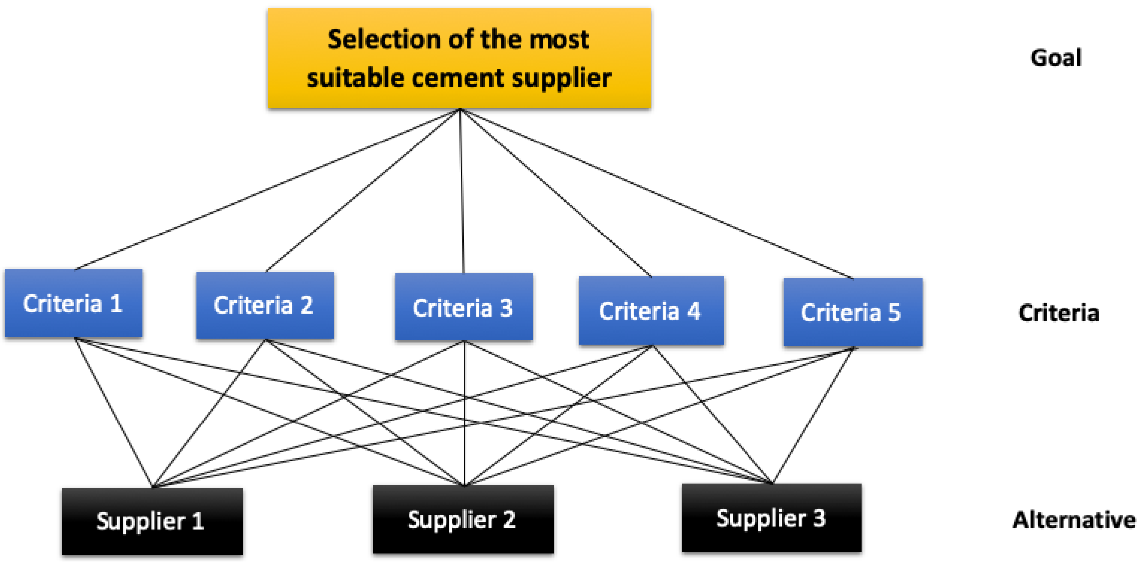

Figure.1. Decision hierarchy to use in supplier selection problem.

Step 2: firstly, the data obtained from the survey were blurred. Blurring was performed using Table 1, as described in Fuzzy AHP steps. The blurred states of binary comparison matrices are shown in Table 2.

Table 2. Fuzzy binary comparison matrix comparing criteria.

DM1	C1	C2	C3	C4	C5
C1	(1, 1, 1)	(0.333, 0.5, 1)	(2, 3, 4)	(3, 4, 5)	(0.333, 0.5, 1)
C2	(1, 2, 3)	(1, 1, 1)	(3, 4, 5)	(4, 5, 6)	(3, 4, 5)
C3	(0.20, 0.333, 0.5)	(0.20, 0.25, 0.333)	(1, 1, 1)	(2, 3, 4)	(4, 5, 6)
C4	(0.20, 0.25, 0.333)	(0.166, 0.20, 0.25)	(0.20, 0.333, 0.5)	(1, 1, 1)	(0.20, 0.25, 0.333)
C5	(1, 2, 3)	(0.20, 0.25, 0.333)	(0.166, 0.20, 0.25)	(3, 4, 5)	(1, 1, 1)
DM2	C1	C2	C3	C4	C5
C1	(1, 1, 1)	(1, 2, 3)	(2, 3, 4)	(4, 5, 6)	(3, 4, 5)
C2	(0.333, 0.5, 1)	(1, 1, 1)	(1, 2, 3)	(3, 4, 5)	(2, 3, 4)
C3	(0.20, 0.333, 0.5)	(0.333, 0.5, 1)	(1, 1, 1)	(5, 6, 7)	(3, 4, 5)
C4	(0.166, 0.20, 0.25)	(0.20, 0.25, 0.333)	(0.142, 0.166, 0.20)	(1, 1, 1)	(0.20, 0.333, 0.5)
C5	(0.20, 0.25, 0.333)	(0.20, 0.333, 0.5)	(0.20, 0.25, 0.333)	(2, 3, 4)	(1, 1, 1)
DM3	C1	C2	C3	C4	C5
C1	(1, 1, 1)	(3, 4, 5)	(2, 3, 4)	(4, 5, 6)	(5, 6, 7)
C2	(0.20, 0.25, 0.333)	(1, 1, 1)	(0.20, 0.333, 0.5)	(4, 5, 6)	(3, 4, 5)
C3	(0.25, 0.333, 0.5)	(2, 3, 4)	(1, 1, 1)	(5, 6, 7)	(4, 5, 6)
C4	(0.166, 0.20, 0.25)	(0.166, 0.20, 0.25)	(0.142, 0.166, 0.20)	(1, 1, 1)	(0.333, 0.5, 1)
C5	(0.142, 0.166, 0.20)	(0.20, 0.25, 0.333)	(0.166, 0.20, 0.25)	(1, 2, 3)	(1, 1, 1)

The geometric mean of binary comparison matrices blurred because there is more than one decision-maker. The fuzzy evaluation matrix in Table 3 was obtained by taking the geometric mean of the binary comparisons of the five main criteria.

Table 3. Binary Comparison Matrix of Main Criteria.

	C1	C2	C3	C4	C5
C1	(1, 1, 1,)	(1, 1.58, 2.46)	(2, 3, 4)	(3.63, 4.64, 5.64)	(1.70, 2.28, 3.27)
C2	(0.40, 0.63, 1)	(1, 1, 1)	(0.84, 1.38, 1.95)	(3.63, 4.64, 5.64)	(2.62, 3.63, 4.64)
C3	(0.21, 0.333, 0.5)	(0.51, 0.72, 1.10)	(1, 1, 1,)	(3.68, 4.76, 5.80)	(3.63, 4.64, 5.64)
C4	(0.176, 0.215, 0.275)	(0.17, 0.21, 0.27)	(0.16, 0.21, 0.27)	(1, 1, 1)	(0.23, 0.34, 0.55)
C5	(0.30, 0.43, 0.56)	(0.2, 0.27, 0.38)	(0.17, 0.21, 0.27)	(1.81, 2.88, 3.91)	(1, 1, 1)

Step 3: Once the binary comparison matrices are obtained in a fuzzy manner to calculate the values of the criteria, firstly, the triangular fuzzy number values of each criterion must be obtained. For each criterion, there is an l <m <u relationship between the triangular number values, which means the lowest probability (l), the absolute value (m), and the highest probability (u).

According to criteria 1; Calculation of l, m and u values are as follows

$$l_{c1}=\sqrt[5]{1 \times 1 \times 2 \times 3.63 \times 1.70} = 1.653$$

$$m_{c1}=\sqrt[5]{1 \times 1.58 \times 3 \times 4.64 \times 2.28} = 2.187$$

$$u_{c1}=\sqrt[5]{1 \times 2.46 \times 4 \times 5.64 \times 3.27} = 2.829$$

The calculations of the other criteria are made the same procedure, and the values obtained as a result of the calculations are shown in Table 4.

Table 4. Fuzzy Number Values of Main Criteria

	C1	C2	C3	C4	C5
l	1.653	1.261	1.074	0.256	0.511
m	2.187	1.710	1.395	0.317	0.587
u	2.829	2.195	1.782	0.405	0.652

In the calculation of the total sum of fuzzy numbers, the amount of the triangular fuzzy number values of all the main criteria is taken.

$L = l_{c1} + l_{c2} + l_{c3} + l_{c4} + l_{c5} = 4.755$
$M = m_{c1} + m_{c2} + m_{c3} + m_{c4} + m_{c5} = 6.196$
$U = u_{c1} + u_{c2} + u_{c3} + u_{c4} + u_{c5} = 7.863$

The equation that I describe chapter 3 is used in the calculation of the inverse of the total $(\frac{1}{u}, \frac{1}{m}, \frac{1}{l})$. like this $(\frac{1}{7.863}, \frac{1}{6.196}, \frac{1}{4.755})$. The result obtained by calculation is (0.210; 0.161; 0.127) value was found in the vector.

C_1= (1.653; 2.187; 2.829) × (0.210; 0.161; 0.127) = (0.210; 0.352; 0.594)
C_2= (1.261; 1.710; 2.195) × (0.210; 0.161; 0.127) = (0.160; 0.275; 0.461)
C_3= (1.074; 1.395; 1.782) × (0.210; 0.161; 0.127) = (0.136; 0.225; 0.374)
C_4= (0.256; 0.317; 0.405) × (0.210; 0.161; 0.127) = (0.032; 0.051; 0.085)
C_5= (0.511; 0.587; 0.652) × (0.210; 0.161; 0.127) = (0.064; 0.094; 0.137)

Then, the Fuzzy weight of the criteria were calculated. Using add l, m and u values then divided the number of consist.

C_1= 0.210, 0.352, 0.594 = 0.385
C_2= 0.160, 0.275, 0.461 = 0.298
C_3= 0.136, 0.225, 0.374 = 0.245
C_4= 0.032, 0.051, 0.085 = 0.056
C_5= 0.064, 0.094, 0.137 = 0.098

The resulting weight vector; W' = (0.385, 0.298, 0.245, 0.056, 0.098). Found W' vector value is divided by the sum of the normalized matrix of the criteria. The sum of the probability values obtained with the normalized matrix must be equal to 1. As a result of this process, the weight of the criteria is obtained. Table 5 shows the exact weight values of the criteria.

Table 5. Weights of the Criteria.

Criteria	Weight
Quality	0.355
Cost	0.275
Delivery	0.226
Service	0.053
Supplier Profile	0.091

The most important criteria among the chosen criteria are quality, followed by cost, delivery, supplier profile, and service, respectively. It indicates that the quality of the products is more important than all the other criteria.

Step 4: After the significance weights were calculated, the consistency of the data was tested with the Consistency Ratio C.R. values and the fuzzy significance weight values of the relevant table under each table and the actual weight values obtained as a result of the rinsing process as a separate matrix.

Table 6. The group paired comparison matrix in which the criteria are compared.

	C1	C2	C3	C4	C5
C1	1	1.58	3	4.64	2.28
C2	0.63	1	1.38	4.64	3.63
C3	0.333	0.72	1	4.76	4.64
C4	0.215	0.21	0.21	1	0.34
C5	0.43	0.27	0.21	2.88	1
C.R.	0.06				

Consistency ratios (C.R.) of comparison matrices is 0.06, which is lower than 0.1. It shows that the validity of the comparison matrices is good.

4.2. Solution by TOPSIS Method

The TOPSIS method is used to select the best supplier of cement manufacturers. Decision-makers evaluate alternatives according to each criterion, using a very good - very bad scale since more than one decision-maker participates in the assessment the Arithmetic mean of decision-makers are used to create the decision matrix.

Table 7. Formation of Decision Matrix.

	C1	C2	C3	C4	C5
A1	5.67	6	5	4.67	6.33
A2	4.33	5.33	5	3.33	4.67
A3	3.67	4.33	4.67	3.67	4.33

Step 2: Create a normalized decision matrix. Vector for matrix (R) normalization formula is $R_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}}$, i = 1,2,…, m; j = 1,2,…, n. used.

Table 8. Normalized Decision Matrix.

	C1	C2	C3	C4	C5
A1	0.706	0.657	0.590	0.685	0.704
A2	0.539	0.584	0.590	0.489	0.520
A3	0.457	0.474	0.551	0.538	0.482

Step 3: A predominantly normalized decision matrix is created. The matrix is formed by multiplying the elements in each column of the R matrix by the corresponding wi value.

Table 9. Weighted Decision Matrix.

	C1	C2	C3	C4	C5
A1	0.251	0.181	0.133	0.035	0.063
A2	0.191	0.161	0.13	0.025	0.047
A3	0.162	0.130	0.124	0.027	0.043

Step 4: Positive Ideal (A^+) and Negative Ideal (A^*) solutions are created. For positive ideal solutions ($\max v_{ij} \mid \in I$), ($\min v_{ij} \mid J \in J^+$), for negative ideal solutions ($\min v_{ij} \mid \in I$), ($\max v_{ij} \mid J \in J^-$) formulas were used.

Table 10. Ideal (A^+) and Negative Ideal (A^*) Solution Sets.

A^+	0.251378	0.130905	0.13344	0.035452	0.063989
A^*	0.162708	0.181395	0.124633	0.025279	0.043771

Step 5-6: Calculate the distances of each alternative to the positive ideal solution and the negative ideal solution. For the calculation of positive ideal solutions $\boldsymbol{s_i}^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j{}^+)^2}$ for the calculation of negative ideal solutions $\boldsymbol{s_i}^* = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j{}^*)^2}$ equations are used.

The relative proximity to the ideal solution is calculated. $C_i{}^* = \frac{s_i{}^-}{s_i{}^- + s_i{}^+}$ The formula was applied for the calculation below Table 11 is given the result.

Table 11. The distances of suppliers from fuzzy positive and negative ideal solutions and the closeness coefficient.

	S^+	S^-	C_i	Rank
A1	0.0504	0.0919	0.6458	1
A2	0.0694	0.0368	0.3465	3
A3	0.0916	0.0505	0.3553	2

According to Table 11 C_i values, A1 “Supplier” which takes the greatest value is considered as the best alternative, and A2 “Supplier” which takes the lowest value is determined as the worst alternative.

5. RESULT

The selection of supplier process is one of the most critical problems in supply chain management. In the construction sector, the best selection of supplier affects the success of construction projects. To increase the business performance and to complete the project of Construction Companies, within the expected quality, budget and time, the right decisions in the selection of the supplier is getting higher importance.

This study is proposed a two-stage multi-criteria decision-making model in order to determine the best supplier selection for a construction firm. In the first stage, Fuzzy AHP is used to find the weight of the criteria. At the second stage, TOPSIS method is utilized to range the suppliers. The presented model is applied to Alburuuj Construction Company that operates in Somali and Djibouti. Three alternatives that are suitable for the company’s need were determined to participate in the contest. The solution shows us that the A1 alternative is the best, and the A2 alternative is the worst. As more than one department in the company participated in the assessment, the result is considered justified.

This study provides the purchasing department with a tool that facilitates the decision-making for an extremely critical process, such as the selection of steel, which directly affects the performance of the construction projects. In future studies, different multi-criteria decision-making methods can be applied while used both subjective and objective judgment of the decision-makers to obtain more accurate results.

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