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Contractor Selection Using Fuzzy Hybrid AHP-VIKOR

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ABSTRACT

In recent years, contractors play a major role in construction projects of buildings, roads, or waterworks under supervision of project owners or employers of these projects. So, that is why contractor selection is an important decision for employers. Contractor selection is a multi-criterion decision problem and resolving the problem of evaluation and although ranking the candidate contractors has become a key factor for firms and enterprises. In this article, the proposed a new hybrid AHP and VIKOR methodology is applied to select the best contractor. Because of dealing with uncertain values for the criteria, Fuzzy logic is used to solve this problem and the evaluation data for the alternatives have been expressed in linguistic terms. So, both AHP and VIKOR methods are performed under fuzzy environment. The fuzzy AHP is applied to form the structure of the contractor selection problem and also to obtain weights of the evaluation criteria, and fuzzy VIKOR method is used to determine final ranking. A numerical example is proposed to illustrate an application of the proposed method that demonstrates the effectiveness of the proposed model.

1. Introduction

Evaluation of the most eligible contractors is important for project performance and success in construction projects. An incapable contractor causes all kinds of problems such as delays, cost overruns, inappropriate work, disputes, or other major issues [1, 2]. The methods used for evaluating capable contractors in the construction industry are based on the principle of acceptance of the lowest bid price [1, 2]. On the other hand, the evaluation on lowest price basis is one of the major causes of project problems [3, 4]. One of the most important reasons of quality problems during completion of the project is to consider cost figures as the only effective criterion in the process of selection. On the other hand, explaining the rationale of the selection is difficult for employers when they select a contractor not according to the lowest bidder. In order to avoid arguments and protests from the potential bidders, using a multi-criteria method for evaluating contractors considering their experience, economic aspects, past performances, quality standards, current projects and other criteria may help solving this problem. First, the employer can determine and eliminate contractors with low

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capabilities by using a procedure called “prequalification”. Then the remaining bidders (contractors) are assessed for further consideration by evaluation of the criteria.
Most of the MADM methods enable the user to aggregate scores related with individual criteria and to rank the evaluated solutions [3]. Usually, because of the employer’s possible lack of experience or technical expertise, it’s difficult to select criteria weights and use it in the procedure of selection. So, by using experts' opinions as a decision maker, the problem may result in more effective and capable selection. In this paper, fuzzy sets, AHP and VIKOR methods are combined to rank the possible alternatives and to select the best contractor, which uses fuzzy AHP to determine the weights of evaluation criteria and then fuzzy VIKOR to obtain the final ranking order of the contractors. The remainder of this paper is organized as follows: Section 2 introduces the past researches available in the area of the contractor selection and fuzzy decision making approaches, specially AHP and VIKOR methods. In Section 3, fuzzy theory is presented. In Section 4, the proposed model is introduced, including selection of criteria, determination of importance weights of criteria, and evaluation of alternatives. In Section 5, a numerical example is expressed to illustrate an application of the proposed method that demonstrates the effectiveness of the proposed model. In Section 6, Conclusions are discussed.

2. Literature review

In this section, we will introduce the literature review of concepts in this paper, including contractor selection, Analytical Hierarchy Process (AHP) and VIKOR methodology which will be expressed later. We will also introduce literature consists of fuzzy AHP and VIKOR methods.
One of the most important tasks that a construction employer has to face to achieve an adequate project outcome is selecting a competent contractor [5, 6]. Traditional construction management has explored several studies different in ways of evaluating capable contractors in a bidding process [7, 8], as well as how to improve construction project performance [9, 10]. After the prequalification process, a limited number of the competent contractors are invited to tender. Then their tenders are evaluated on the basis of economic or technical criteria [11]. Several researchers [12–23] have introduced sets of criteria common to most projects and proposed methodologies for contractor selection or prequalification. Yasamis et al. [24] presented a contractor quality performance (CQP) evaluation model which can be used in a contractor prequalification or selection system.
Analytic Hierarchy Process (AHP) methodology is one of the most accepted methods to determine importance criteria or variants' evaluation that is used in many papers [25, 26, 27]. Turkis [6] initiated a multi-attribute contractor ranking method applying rules of dealing with qualitative, quantitative and verbal data. All kinds of methods are applied to solve the contractor selection problem. For example, Hatush and Skitmore [28] have created systematic multi-attribute decision analysis techniques for contractor selection and bid evaluation.
Analytical Hierarchy Process (AHP) was introduced primarily by Thomas Saaty [29] and is able to solve the decision making problems in many areas of construction project management. The AHP procedure consists of the three following stages: (i) decomposition of

the decision problem into a hierarchy of sub-problems, (ii) the matrix of pairwise comparisons of the criteria weights, and, (iii) calculating of criteria weights. Different fuzzy AHP methods are introduced by various authors. The first extensions of the AHP methodology were introduced by van Laarhoven and Pedrycz [30], Buckley [31], and Chang [32], where relative preferences were expressed by means triangular fuzzy numbers. In other words, these approaches apply a procedure to prioritize the criteria and also alternatives by using fuzzy set theory and hierarchical structure analysis. Hsieh et al. [33] used Buckley's method for selecting planning and design (P&D) tenders for public company constructions. But the proposed model does not allow group decision making because of being potentially appropriate for problems of contractor selection.

Some papers discussed the problems with fuzzy numbers in which the procedure of specifying weights or calculating vectors of priorities on the basis of pairwise comparison matrices is a complex problem. Methods such as fuzzy preference programming [34], fuzzy least squares method and lambda-max method [35] is used to solve this problem. In this paper, we have used Chang’s extent analysis method [32], because the steps of this method are more simple and uncomplicated comparing with the other fuzzy AHP techniques.

VIKOR methodology is one of the recent decision making techniques for obtaining a compromise solution for a problem with conflicting criteria and focuses on ranking and sorting a set of alternatives against different decision criteria. Opricovic [36, 37] developed VlsekriterijumskaOptimizacija I KompromisnoResenje (i.e. VIKOR) methodology for multi-criteria optimization of complex systems.

Chen and Wang [38] applied fuzzy VIKOR to evaluate outsourcing vendors. The method is very appropriate even if we use group decision making under a fuzzy environment and criteria weights are described in linguistic terms. Shemshadi et al. [39] used fuzzy VIKOR in supplier selection problem and determined data in linguistic terms. Then the weights of the criteria are obtained using entropy method by trapezoidal fuzzy numbers. Devi [40] used fuzzy VIKOR methodology in robot selection for material handling task. Kaya and Kahraman [41] used a hybrid AHP and VIKOR methodology to evaluate the alternative forestation areas. Then the authors specified criteria weights using a fuzzy AHP method. Kuo and Liang [42] used fuzzy VIKOR for service quality selection. The authors combined fuzzy VIKOR and GRA to initiate a new MCDM method for use problems with multiple requirements and fuzzy sets.

VIKOR counts on an aggregating function which expresses the measure of closeness to the ideal like some other MCDM methods such as TOPSIS. But VIKOR, unlike TOPSIS, describes the ranking index based on closeness to the ideal solution [43].

3. Fuzzy theory

In this section, to have a little acquaintance with fuzzy logic and also, to utilize this knowledge in the proposed methodology that consists of fuzzy AHP and fuzzy VIKOR, we are going to express a partial view of fuzzy theory. With due attention to different types of fuzzy numbers, it should be stated that trapezoidal fuzzy numbers (TFNs) are utilized in the proposed method and also in numerical example; because of their simple computation.

Zadeh[44] primarily initiated fuzzy set theory to express linguistic variables as numerical variables within decision making procedure. When the complexity of a problem increases, we may face the problem of uncertainty in data. So, fuzzy logic can be assumed as a methodology for solving problems where there are no sharp boundaries and certain values. Bellman and Zadeh [45] developed the definition of fuzzy sets to introduce Fuzzy Multi-Criteria Decision Making (FMCDM) methodology for solving the problem of uncertain data in criteria weights and ratings of alternatives.

A fuzzy set is general form of a crisp set that is characterized by a membership function which 1 addresses full membership and 0 expresses non-membership and this membership function assigns a grade of membership within the interval [0, 1] to each element that indicates to what degree that element is a member of the set [46].

Different types of fuzzy numbers can be used based on the situation. Often, triangular or trapezoidal fuzzy numbers (TFNs) are utilized because of their simple computation [47].

A fuzzy number is defined as a fuzzy set such that [46]:

$$M = \{(x), \mu_M(x), x \in R\} \tag{1}$$

where $\mu_M(x)$ is a continuous mapping from R to the closed interval [0, 1]. A Trapezoidal Fuzzy Number (TFN) can be expressed like $\{(m_1, m_2, m_3, m_4); m_1, m_2, m_3, m_4 \in R; m_1 \le m_2 \le m_3 \le m_4\}$ that indicates the smallest, the most promising, and the largest possible values that illustrate a fuzzy phrase. The membership function can be described as follows [39]:

$$\mu_M(x) = \begin{cases} (x - m_1)/(m_2 - m_1) & x \in [m_1, m_2] \\ 1 & x \in [m_2, m_3] \\ (m_4 - x)/(m_4 - m_3) & x \in [m_3, m_4] \\ 0 & otherwise \end{cases} \tag{2}$$

4. The proposed model

In this section, the proposed model is applied to rank and select the best contractor among candidate alternatives. This proposed model has been expressed in two phases as follows:

1. Identify the evaluation criteria and compute the importance weights of the criteria using fuzzy AHP method.
2. Obtain the final ranking of alternatives and select the best contractor using fuzzy VIKOR approach.

First, according to fuzzy AHP model, the decision making aim, alternatives (contractors) and the criteria are introduced and the decision hierarchy is constructed. In this model, the decision making goal, criteria and alternatives are respectively placed in the first, second and third level. Then pair-wise comparison matrices are constructed to compute the relative weights of the criteria. Next, decision maker establish linguistic terms for evaluation criteria in order to assign the values of the pair-wise comparison matrices elements by the introduced scale in Table 1.

In the second and last phase, the final ranking of alternatives is obtained and the best contractor is selected using the obtained values of Q in fuzzy VIKOR method. The scale used for express linguistic variables that have been applied for contractor evaluation is shown in Table 2. Also, the schematic flowchart of the proposed model is represented in Figure 1.

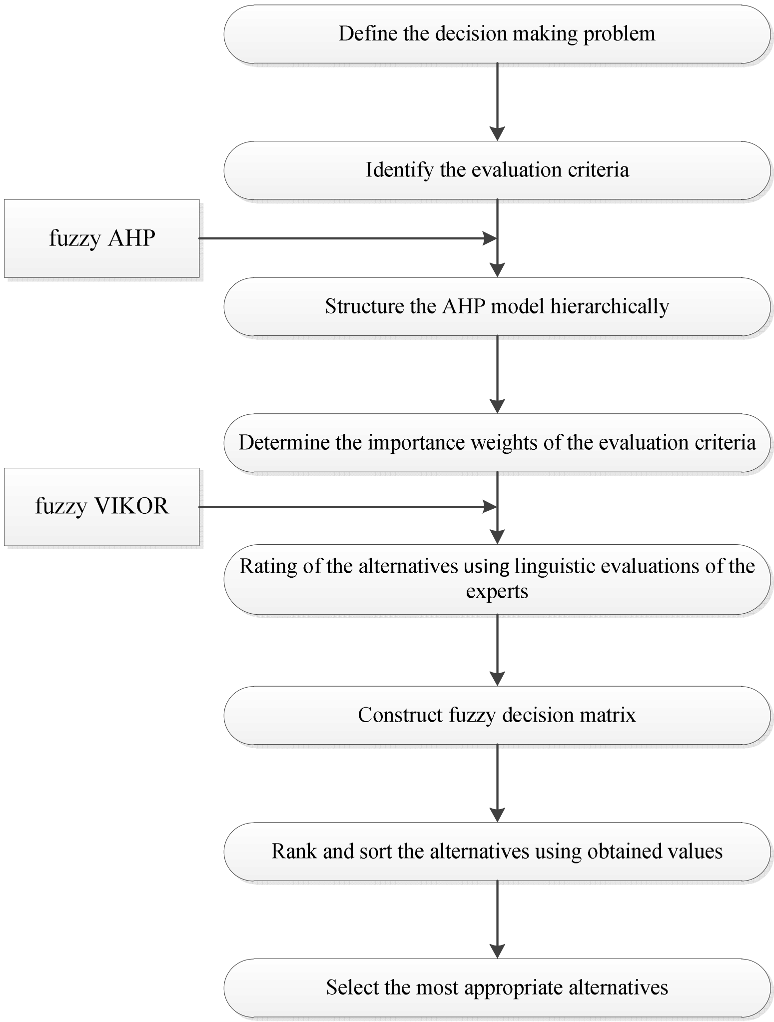

Figure 1. Schematic flowchart of the proposed model

4.1.Calculate importance weights of criteria by fuzzy AHP methodology

Firstly, we express fuzzy AHP method, particularly Chang's extent analysis method [32], because the steps of this method are more simple and uncomplicated comparing with the other fuzzy AHP techniques.

Let $X = \{x_1, x_2, ..., x_n\}$ be an object set and $U = \{u_1, u_2, ..., u_m\}$ be a goal set. Considering the method of Chang's extent analysis, each object is taken and extent analysis for each goal, *gi*, is performed, respectively. Thus, for each object, *m* extent analysis values can be determined, with the signs as follows:

$M_{gi}^1, M_{gi}^2, ..., M_{gi}^m, \ i = 1, 2, ..., n$

where all the $M_{gi}^j (j = 1, 2, ..., m)$ are TFNs [48].

The steps of Chang's extent analysis can be expressed as follows [32]:

Step 1. The value of fuzzy synthetic extent with respect to *i*th object is introduced as follows:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \tag{3}$$

To determine $\sum_{j=1}^{m} M_{gi}^{j}$, perform the fuzzy addition operation of *m* extent analysis values for a matrix such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = (\sum_{j=1}^{m} l_i, \sum_{j=1}^{m} m_i, \sum_{j=1}^{m} u_i) \tag{4}$$

And to determine $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$, perform the fuzzy addition operation of $M_{gi}^{j} (j = 1, 2, ..., m)$ values such that:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = (\sum_{i=1}^{m} l_i, \sum_{i=1}^{m} m_i, \sum_{i=1}^{m} u_i) \tag{5}$$

Then, calculate the inverse of the vector in Eq. (5) such that:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} = (\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}) \tag{6}$$

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 introduced as:

$$V(M_2 \geq M_1) = \sup_{y \geq x} [\min(\mu_{M1}(x), \mu_{M2}(y))] \tag{7}$$

And it can be identically determined as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M2}(d)$$

$$= \begin{cases} 1 & m_2 \geq m_1 \\ 0 & l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & otherwise \end{cases} \tag{8}$$

where *d* is the ordinate of highest intersection point *D* between μ_{M1} and μ_{M2}.

Step 3. The degree of possibility for a convex fuzzy number to be greater than *k* convex fuzzy numbers $M_i (i = 1, 2, ..., k)$ can be defined by:

$$V(M \geq M_1, M_2, ..., M_k) = V[(M \geq M_1) \& (M \geq M_2) \& ... \& (M \geq M_k)]$$

$$= \min V(M \geq M_i) \tag{9}$$

$$i = 1, 2, ..., k$$

Step 4,5. Assume that

$$d'(A_i) = \min V(S_i \geq S_k) \tag{10}$$

For $k = 1, 2, ..., n; k \neq i$. Then the importance weight vector is given by:

$$W' = \{d'(A_1), d'(A_2), ..., d'(A_n)\}^T \tag{11}$$

where $A_i (i = 1, 2, ..., n)$ are n elements.

Step 6. Finally, the normalized weight vectors after normalization are as follows:

$$W = \{d(A_1), d(A_2), ..., d(A_n)\}^T \tag{12}$$

where W is a non-fuzzy number.

4.2.Evaluate alternatives and determine final ranking by fuzzy VIKOR methodology

In the second phase, we describe the second part of the proposed model using fuzzy VIKOR method. The VIKOR methodology is one of the recent decision making techniques for obtaining a compromise solution for a problem with conflicting criteria and is widely used in the literature. In this paper, we propose fuzzy VIKOR based on fuzzy set theory to cope with the uncertainty in criteria weights and alternative data.

This method works on the principle that each alternative can be evaluated by each criterion function, and then, by comparing the degrees of closeness to the ideal alternative, the compromise ranking will be obtained [49]. We can continue implementing the steps of VIKOR after determining the weight vector by extent analysis [37, 43].

Step 7. Assuming that decision makers are K people, the ratings of alternatives can be calculated with considering each criterion as in Eq. (13) [50].

$$\tilde{x}_{ij} = \frac{1}{K}[\tilde{x}_{ij}^1 (+) \tilde{x}_{ij}^2 (+) ... (+) \tilde{x}_{ij}^K] \tag{13}$$

where $\tilde{x}_{ij}^K$ is the rating of the *K*th expert for *i*th alternative with respect to *j*th criterion.

Step 8. We can denote the fuzzy multi-criteria decision-making problem after determining the weights of criteria obtained by fuzzy AHP method and fuzzy ratings of alternatives considering each criterion in matrix format as follows:

$$\tilde{D} = \begin{pmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{pmatrix} \tag{14}$$

$$W = [w_1, w_2, ..., w_n], \quad j = 1, 2, ..., n \tag{15}$$

where $\tilde{x}_{ij}$ is the rating of alternative A_i with respect to Criterion j (i.e. C_j) and w_j denotes the importance weight of C_j that have been obtained by fuzzy AHP method.

Step 9. Next step is to calculate the fuzzy best value $(FBV, \tilde{f}_j^*)$ and the fuzzy worst value $(FWV, \tilde{f}_j^-)$ of each criterion function.

$$\tilde{f}_j^* = \max_i \tilde{x}_{ij}, \quad j \in B \tag{16}$$

$$\tilde{f}_j^- = \min_i \tilde{x}_{ij}, \quad j \in C \tag{17}$$

Step 10. After that, $\tilde{S}_i$ and $\tilde{R}_i$ should be calculated as follows:

$$\tilde{S}_i = \sum_{j=1}^{n} \tilde{w}_i (\tilde{f}_j^* - \tilde{x}_{ij}) / (\tilde{f}_j^* - \tilde{f}_j^-) \tag{18}$$

$$\tilde{R}_i = \max_j [\tilde{w}_i (\tilde{f}_j^* - \tilde{x}_{ij}) / (\tilde{f}_j^* - \tilde{f}_j^-)] \tag{19}$$

where $\tilde{S}_i$ refers to the separation measure of A_i from the fuzzy best value, and $\tilde{R}_i$ to the separation measure of A_i from the fuzzy worst value.

Step 11. In the next step, $\tilde{S}^*, \tilde{R}^*, \tilde{S}^-, \tilde{R}^-$ *and* $\tilde{Q}_i$ values are computed as follows:

$$\tilde{S}^* = \min_i \tilde{S}_i, \qquad \tilde{S}^- = \max_i \tilde{S}_i$$
$$\tilde{R}^* = \min_i \tilde{R}_i, \qquad \tilde{R}^- = \max_i \tilde{R}_i \tag{20}$$

$$\tilde{Q}_i = \upsilon(\tilde{S}_i - \tilde{S}^*)/(\tilde{S}^- - \tilde{S}^*) + (1-\upsilon)(\tilde{R}_i - \tilde{R}^*)/(\tilde{R}^- - \tilde{R}^*) \tag{21}$$

υ is the weight for the strategy of maximum group utility and (1- υ) is the weight of the individual regret of an opponent strategy, usually assumed to be 0.5.

Step 12. Next step is the defuzzification of the triangular or trapezoidal fuzzy number $\tilde{Q}_i$. Differentdefuzzification methods have been introduced in the literature. In this paper, we have used the graded mean integration method [51].

According to the graded mean integration method, a fuzzy number such as $\tilde{C} = (c_1, c_2, c_3, c_4)$ can be transformed into a crisp number for trapezoidal fuzzy numbers as follows [51]:

$$P(\tilde{C}) = C = (c_1 + 2c_2 + 2c_3 + c_4)/6 \tag{22}$$

Step 13. Finally, the best alternative with the minimum of Q_i is obtained and the alternatives will be ranked and sorted by values of Q in a decreasing order.

5. Illustrative example for the proposed method

In this section a numerical example is expressed to illustrate an application of the proposed method in the previous section.

In this study, five criteria will be used in contractor selection procedure that is expressed as follows:

Experience (C_1), economic stability (C_2), past performances (C_3), quality standards (C_4) and current projects (C_5) that all of these five criteria are the benefit type criteria.

Also, hierarchical structure of the contractor selection problem is given in Figure 2. After constructing the decision hierarchy and obtaining the evaluation criteria and alternatives, the weights of the importance criteria are calculated using fuzzy AHP method.

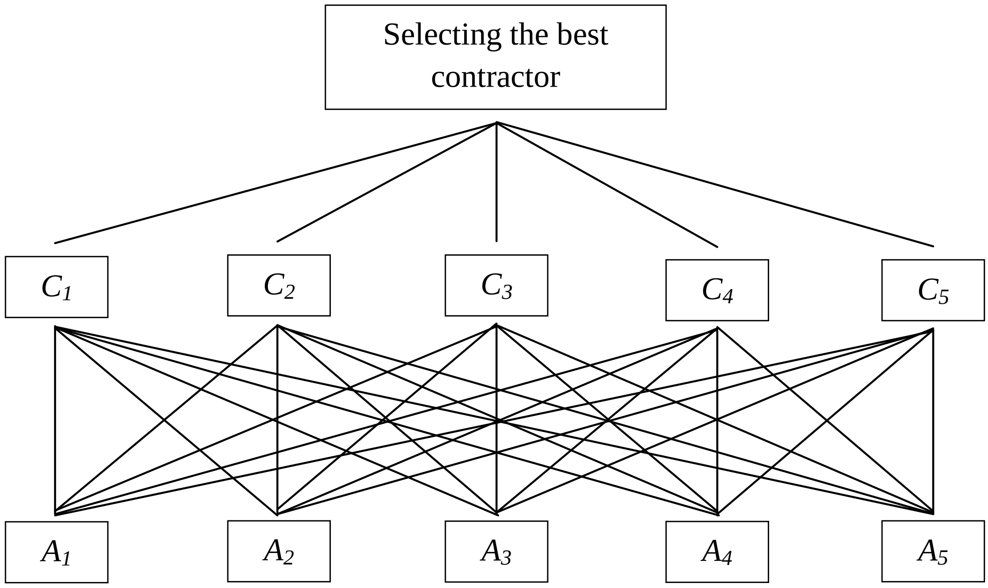

Figure. 2.The structure of decision.

In this phase, the pair-wise comparison matrix is formed using the scale denoted in Table 1, and then, the fuzzy evaluation matrix for the criteria weights is determined using Tables 2 that the results of the constructed pair-wise comparison matrix can be seen in Table 3.

Table 1. Linguistic terms for evaluation criteria

Just equal	(1, 1, 1, 1)
Weakly important	(2/3, 1, 1, 3/2)
Moderately important	(3/2, 2, 2, 5/2)
Strongly important	(5/2, 3, 3, 7/2)
Absolutely important	(7/2, 4, 4, 9/2)

Table 2. Linguistic terms for ranking the alternatives

Very poor (VP/VL)	(0.0, 0.0, 0.1,0.2)
Poor (P/LI)	(0.1, 0.2, 0.3, 0.4)
Medium poor (MP/BA)	(0.2, 0.3, 0.4, 0.5)
Fair (F/A)	(0.4, 0.5, 0.5, 0.6)
Medium good (MG/AA)	(0.5, 0.6, 0.7, 0.8)
Good (G/V)	(0.6, 0.7, 0.8, 0.9)
Very good (VG/VI)	(0.8, 0.9, 1.0, 1.0)

Table 3. Fuzzy pair-wise comparison matrix for the importance weights

	C_1	C_2	C_3	C_4	C_5
C_1	(1, 1, 1, 1)	(3/2, 2, 2, 5/2)	(3/2, 2, 2, 5/2)	(5/2, 3, 3, 7/2)	(5/2, 3, 3, 7/2)
C_2	(2/5, 1/2,1/2, 2/3)	(1, 1, 1, 1)	(3/2, 2, 2, 5/2)	(5/2, 3, 3, 7/2)	(5/2, 3, 3, 7/2)
C_3	(2/5, 1/2,1/2, 2/3)	(2/5, 1/2,1/2, 2/3)	(1, 1, 1, 1)	(3/2, 2, 2, 5/2)	(3/2, 2, 2, 5/2)
C_4	(2/7, 1/3,1/3, 2/5)	(2/7, 1/3,1/3, 2/5)	(2/5, 1/2,1/2, 2/3)	(1, 1, 1, 1)	(3/2, 2, 2, 5/2)
C_5	(2/7, 1/3,1/3, 2/5)	(2/7, 1/3,1/3, 2/5)	(2/5, 1/2,1/2, 2/3)	(2/5, 1/2,1/2, 2/3)	(1, 1, 1, 1)

Then, the values of fuzzy synthetic extent are calculated, and after that, the importance weight vector $W'$is obtained using priority weights. Finally, after the normalization of these values, the normalized weight vector W is determined. All of these results have shown in Table 4.

Table 4. The process of the determination of the weights using fuzzy AHP approach

	$\tilde{S}_j$	W'_j	W_j
C_1	(0.23,0.33,0.33,0.47)	1	0.446
C_2	(0.2,0.29,0.29,0.41)	0.78	0.348
C_3	(0.12,0.18,0.18,0.27)	0.21	0.094
C_4	(0.09,0.12,0.12,0.18)	0.14	0.063
C_5	(0.06,0.08,0.08,0.11)	0.11	0.049

In the second phase, the fuzzy VIKOR steps are used for obtaining the final ranking of alternatives and select the best contractor.

In the first step, fuzzy decision matrix of the criteria and alternatives is constructed using the scale denoted in Table 2 as shown in Table 5. Also, fuzzy decision matrix with corresponding trapezoidal fuzzy numbers is expressed in Table 6.

Table 5. The rating of the alternatives

	C_1	C_2	C_3	C_4	C_5
A_1	G	AA	VG	VG	L
A_2	A	BA	BA	G	A
A_3	BA	P	G	BA	L
A_4	AA	BA	G	G	A
A_5	G	BA	BA	VG	AA

Table 6. Fuzzy decision matrix for the alternatives

	C_1	C_2	C_3	C_4	C_5
A_1	(0.6,0.7,0.8,0.9)	(0.5,0.6,0.7,0.8)	(0.8,0.9,1,1)	(0.8,0.9,1,1)	(0.1,0.2,0.3,0.4)
A_2	(0.4,0.5,0.5,0.6)	(0.2,0.3,0.4,0.5)	(0.2,0.3,0.4,0.5)	(0.6,0.7,0.8,0.9)	(0.4,0.5,0.5,0.6)
A_3	(0.2,0.3,0.4,0.5)	(0.1,0.2,0.3,0.4)	(0.6,0.7,0.8,0.9)	(0.2,0.3,0.4,0.5)	(0.1,0.2,0.3,0.4)
A_4	(0.5,0.6,0.7,0.8)	(0.2,0.3,0.4,0.5)	(0.6,0.7,0.8,0.9)	(0.6,0.7,0.8,0.9)	(0.4,0.5,0.5,0.6)
A_5	(0.6,0.7,0.8,0.9)	(0.2,0.3,0.4,0.5)	(0.2,0.3,0.4,0.5)	(0.8,0.9,1,1)	(0.5,0.6,0.7,0.8)

In the next step, separation measure from the fuzzy best value ($\tilde{S}_i$) and separation measure from the fuzzy worst value ($\tilde{R}_i$) are calculated using Eqs. (16)–(19) and the results are shown in Table 7.

Table 7. Separation measure from the best and the worst values

	$\tilde{S}_i$	$\tilde{R}_i$
A_1	(-0.32,-0.08,0.26,2.48)	(0.007,0.029,0.15,1.34)
A_2	(-0.029,0.33,0.88,4.15)	(0.035,0.18,0.45,2.23)
A_3	(0.019,0.41,1.02,4.61)	(0.024,0.18,0.45,2.23)
A_4	(-0.20,0.10,0.66,3.58)	(-0.007,0.07,0.30,1.78)
A_5	(-0.24,0.029,0.54,3.17)	(0.035,0.07,0.23,1.39)

Then, fuzzy values S^*, S^-, R^* and R^- are computed by using Eq. (20) and the obtained values are shown in Table 8.

Table 8. The best and worst values of $\tilde{S}_i$ and $\tilde{R}_i$

S^*	(-0.32,-0.082,0.26,2.48)
S^-	(0.019,0.41,1.02,4.61)
R^*	(-0.007,0.029,0.15,1.34)
R^-	(0.035,0.18,0.45,2.23)

After that, using Eq. (25), $\tilde{Q}_i$ values are calculated with assumption of weight of the strategy of the maximum group utility (v) being 0.5 in the calculations, and then, using the graded mean integration method(22), fuzzy values are defuzzified and the results have shown in Table 9.

Table 9. Calculation of $\tilde{Q}_i$ and Q_i

	$\tilde{Q}_i$	Q_i
A_1	(-0.58,-0.28,3.20,-1.07)	0.7
A_2	(-0.53,0.07,10.35,-1.75)	3.09
A_3	(-0.54,0.10,10.84,-1.84)	3.25
A_4	(-0.57,-0.15,7.07,-1.46)	1.97
A_5	(-0.55,-0.20,5.57,-1.23)	1.49

Finally, Q_i values are arranged in increasing order to obtain the ranking. The results of ranking the alternatives are denoted in Table 10.

Table 10. results of ranking the alternatives

	1	2	3	4	5
$Q(v = 0.2)$	A_1	A_5	A_4	A_2	A_3

The results show that the first contractor (A_1) has the least Q_i value. So, it's the best alternative, and the ranking of the alternatives in descending order are A_1, A_5, A_4, A_2, and A_3.

6. Conclusion

Contractor selection is a multi-criterion decision problem and resolving the problem of evaluation and although ranking the candidate contractors has become a key factor for firms and enterprises.Recently, Contractors play a major role in construction projects of buildings, roads, waterworks and other main projects under supervision of project's employers. Evaluation of the most eligible contractors is important for project performance and success in construction projects.The methods used for evaluating capable contractors in the construction industry are based on the principle of acceptance of the lowest bid price. But, as various researchers and practitioners indicate, the ultimate aim for contractor selection should be to identify the "best bidder", but not the "lowest bidder" [52].An application example in the construction industry were denoted the applicability of the proposed multi-criteria method for evaluating contractors. In the assessment procedure, criteria were considered such as experience, financial stability, past performances, quality standards and current projects.

This paper had expressed a methodology by combining fuzzy sets, AHP and VIKOR methods to rank the possible alternatives and to select the best contractor to effectively solve the contractor evaluation and selection problems under a fuzzy environment. By using this method for the selection of contractors, the uncertainty involved in the evaluation data can be described to use as a suitable and effective tool for contractor selection procedure. So, pair-wise comparison matrix for the importance weights and decision matrix for the alternatives are both have expressed using fuzzy sets. We also converted evaluations in linguistic variables to trapezoidal fuzzy numbers, so we could use them in calculations.

In this paper, fuzzy AHP methodology was used for obtaining weights of the selection criteria. Then, VIKOR methodology also was applied as a multi-criteria decision making technique to determine a compromise solution for a contractor selection problem with conflicting criteria to evaluate and rank candidate contractors.Finally, a numerical example was described to illustrate an application of the denoted method that demonstrates the applicability and effectiveness of the expressed model.

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