A practical Approach Based on Fuzzy Analytic Hierarchy Process for Contractor Selection: a Case Study of An Engineering and Development Company in Iran

Mitra Daneshmandi, and Siamak Hajiyackchali

Abstract**—** Methods for assessing competences of Contractors is very important because choice of Contractor is one of the most important decisions and as the selected Contractor is responsible for the coordination of a project, any failure may leads the probable problems to achieve project's three goals (time, cost, and quality). So many researches and procedures are being applied to solve the problem and select the Contractors based on technical and managerial capabilities.

In this study, a practical approach based on fuzzy analytic hierarchy process is presented for evaluating and selecting Contractors and facilitates defining criteria weights by aggregation of decision makers' judgments. In this approach, if the Contractor does not achieve the minimum technical-managerial score, will be excluded from competition and his offered price will not be checked. At the end of the research, in order to evaluate the validity of the proposed approach, the approach is implemented in an engineering and development company active in the field of oil and gas in Iran. The results of the study are in accordance with the experts' opinion.

Keywords**—**Analytic Hierarchy Process (AHP); Contractor Selection; Fuzzy theory.

I. Introduction

ONE of the most important tasks encountered by a Client who hopes for successful project outcomes is selecting a capable Contractor[1]. In project management environment, the Contractor selection is known as the time-cost-quality trade-off problem, in which the aim is to select a Contractor that performs the project with the highest quality and minimum cost and time [2].

Studies regarding the problems of Contractor selection have been carried out for many years. As a result of these studies, several researches are conducted and several methods have emerged. The Contractor selection problems are still ongoing issue and updated constantly [3].

The bidding price has been the most important criterion affecting the Contractor selection in time. However the Client shouldn't be carried away by attractant effect of the low prices and should behave cautiously. Otherwise the decisions that are made based on prices might cause greater losses in terms of other goals [3].

A wide variety of criteria have been proposed for Contractor selection [6][7][8][4][9]. Criteria for selection may vary between projects since the characteristics of them are distinct although there are some common characteristics of Contractor selection[10]. All the projects have a reasonable cost, require a reasonable quality, within a reasonable time and with reasonable security [11]. Due to this, the most common criteria considered during the selection Contractor are those related with the following aspects[12][13][14]:

1. Technical capacity and experience. The Contractor must demonstrate that it has the technical capacity and related experience to perform the activities of the specific project for which it is seeking the selection.

2. Management capability. The Contractor must demonstrate that it is capable of planning, organizing and controlling a project.

3. Financial stability. The Client must reach an informed opinion regarding the overall financial position and capability of Contractor.

In order to avoid arguments and protests from the potential bidders, bid assessment procedures have to be based on reliable and verifiable data and conducted in an objective way. In the case of qualitative criteria it is necessary to describe the scoring method, which usually involves constructing discrete scales with verbal explanations[11].

Contractor selection can be regarded as a multi-criteria problem. Many multi-criteria techniques are proposed and applied for this problem solution such as multi-criteria decision making (MCDM)[15] ,multi-attribute analysis (MAA) [16], multi-attribute utility theory (MAUT)[6], case-based reasoning (CBR)[17],cluster analysis (CA)[18].

Holt [19] examined two decades' published research and specific research tools used among the sample (in respect of 16 classifications) and forms of fuzzy theory and AHP were sixth and seventh favorite tools.

Several applications in the field of Contractor pre-qualification and Contractor selection [20][16][15][21] have utilized the Analytical Hierarchy Process (AHP) model. Nydick and Hill [22] describe the AHP as a methodology to rank alternative courses of action based on the decision maker's judgment concerning the importance of the criteria

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and the extent to which they are met by each alternative. Hatush and Skitmore [6] have initiated the use of systematic multi-criteria decision analysis techniques for Contractor selection and bid evaluation based on utility theory which permits different types of Contractor capabilities to be evaluated. Multi-criteria utility theory generally combines the main advantages of simple scoring techniques and optimization models.

A decision maker is asked to assess the "quality control policy" of a Contractor compared to the others; it is difficult for a decision maker to give an exact numerical value to express his opinion, so some Contractor selection approaches have been based on using linguistic assessments instead of numerical values. Fuzzy Set Theory [23] provides a useful tool to deal with decisions in which the phenomena are imprecise and vague, it enables to qualify imprecise information, to reason and make decisions based on vague and incomplete data[24]. Fuzzy sets were for the first time used to build a Contractor selection model by Nguyen[25].

A fuzzy neural network (FNN) model, amalgamating both the fuzzy set and artificial neural network theories, was developed by Lam [26]. Singh and Tiong [27] presented a model which allows taking into consideration different types of criteria and characterizing them as sub-criteria. Li [8] proposed a fuzzy framework to solve construction Contractor selection problems that takes full advantage of the experts' knowledge, experiences, and makes the decision maker feels comfortable to give judgment on selection issue.

II. Problem Definition and Proposed Approach

The process of evaluating and ranking Contractors is a costly and timely task for the organizations. In order to outsource, Organizations initially deals with a large number of Contractors that evaluating and ranking them impose great costs to the organization. Hence, organizations are trying to do this task using tools, models and approaches that are low-cost and fast. So in this article, we seek a quick, inexpensive, accurate and practical way to evaluate to rank and evaluate Contractors. An approach based on Fuzzy Analytic Hierarchy Process (FAHP) for evaluating and selecting the Contractors of in Iran is presented in the following:

A. The first step: selecting the evaluation criteria and sub-criteria

In this step, the criteria and sub-criteria affecting selection of qualified Contractor will be selected. These criteria are extracted with the help of experts. Then, in order to consider a comprehensive sets of sub-criteria, the sub-criteria discussed in the literature are used. But this source cannot include the whole evaluation factors. So, based on the experts' experience, some of the criteria will be determined by the experts of this organization. The goal in this step is providing a complete set of criteria and sub-criteria for Contractor selection process.

B. The second step: weighting the factors

Because there is a hierarchical relationship between criteria and sub-criteria and according to experts' opinion, the very little interdependence between the factors is negligible; the analytic hierarchy process method is used for weighting method. Also the fuzzy theory will be utilized in order to consider ambiguity and uncertainty in the model. Therefore, a fuzzy analytic hierarchy process is applied to evaluate the Contractors.

We use pairwise comparison matrices to determine the local weight of the sub-criteria. For this purpose, we use paired comparisons questionnaires and ask experts to determine the significance of the paired comparisons using Table 1 [28].

Using fuzzy numbers in this section, on the one hand enables experts use linguistic words for pairwise comparisons and on the other hand, the uncertainty and ambiguity can also be entered in the problem.

After completing the questionnaire and extracting pairwise comparison matrix, the local weight of each factor will be calculated using the method presented by Bozbura and Beskese[29] for defuzzifying and obtaining the weight of each factor. The Process presented by them is given below:

Assume $M_{g_i}^{j}$ represents the triangular fuzzy numbers located in the *i*th row and the *j*th column of the pairwise comparison matrix, and the following is true:

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} a_{ij}, \sum_{j=1}^{m} b_{ij}, \sum_{j=1}^{m} c_{ij}\right), i = 1,2,3,...,n$$

Where a, b and c illustrate lower, middle and upper bounds of triangular fuzzy numbers, respectively. Fuzzy synthetic extent is shown with S_i and is defined as follows

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

It should be operated as follows to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1}$:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right] = \left(\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} b_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}\right)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} b_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}}\right)$$

Then, the degree of possibility should be determined. For example, this possibility is defined for $M_2 \geq M_1$ as follows:

Degree of possibility is calculated via the following formula

.

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \mu_{M_2}(d) = \begin{cases} 1 & b_2 \geq b_1 \\ 0 & a_1 \geq c_2 \\ \dfrac{a_1 - c_2}{(b_2 - c_2) - (b_1 - a_1)} & Otherwise \end{cases}$$

Where d is the maximum height between μ_{M_1} and between μ_{M_2}. Figure 1 illustrates this concept.

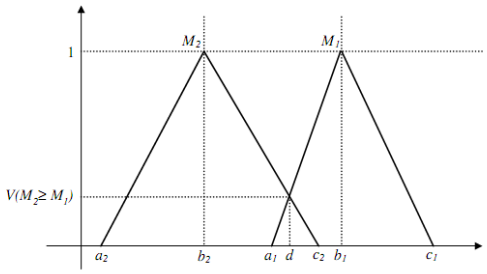

Fig. 1 The intersection between M1 and M2

In the next stage, the degree of possibility for convex fuzzy numbers is defined as follows:

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

$$V\left(M \geq M_1, M_2, ..., M_k\right) =$$

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

Thus, it is assumed that

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

Then, the un-normalized weight vector is defined as follows:

$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T$

Then, the obtained weight vector is normalized as follows:

$W = (d(A_1), d(A_2), ..., d(A_n))^T$

In this way, it is possible to calculate the local weight for each sub-criteria.

C. The third step: Evaluation of Contractor's sub-criteria performance

In this step, the sub-criteria performance for each Contractor is evaluated. For this purpose, we ask experts to use the linguistic words in table (2)[30] to score each of the Contractors for each sub-criterion. Triangular fuzzy numbers equivalent to linguistic words are also provided in table 2. Then, experts' average opinion for each sub-criterion is obtained, and finally, the final score of performance evaluation for each Contractor is calculated using the sum product of sub-criteria weights by their numerical values (values evaluated in this step).

At the end of this stage, technical-managerial score is calculated for each Contractor and the Contractor who obtains the minimum technical score will be evaluated financially in the next stages.

D. The fourth step: calculating the impact factor of Project

The impact factor is calculated based on three criteria of engineering, procurement and construction and it adapts different values in terms of the values of each of these three criteria.

E. The fifth step: opening the financial envelopes and financial evaluation of Contractors

In this step, the financial offers by Contractors that had been delivered in sealed envelopes at the beginning of the tender will be opened up for the financial assessment. Based on the bids, an acceptable range to reject or accept the offered price is determined. For this purpose, the weighted average of the prices provided by Contractors is calculated and the top and bottom limits are determined based on expert opinion. The Contractors whom proposed price is out of range will be removed.

F. The Sixth step: calculating the scaled financial proposal and selecting the qualified Contractor

In this step, using below equation, the Contractors' scaled prices is calculated based on two criteria of financial and technical-managerial. Contractor that has the lowest financial scaled price will be elected as a qualified Contractor.

$$Scaled\ Financial\ Proposal = \frac{100 \times price}{100 - impact\ factor \times (100 - technical\ score \times 100)}$$

TABLE 1
LINGUISTIC SCALE FOR DIFFICULTY AND IMPORTANCE

Linguistic scales for difficulty	Linguistic scales for importance	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	Just equal	(1, 1, 1)	(1, 1, 1)
Equally difficult(ED)	Equally importance(EI)	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more difficult(WMD)	Weakly more importance(WMI)	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more difficult(SMD)	Strongly more importance(SMI)	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more difficult(VSMD)	Very Strongly more importance(VSMI)	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more difficult(AMD)	Absolutely more importance(AMI)	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

TABLE II
LINGUISTIC VALUES AND MEAN OF FUZZY NUMBERS

Linguistic values for sub-criteria	Triangular fuzzy numbers	The mean of fuzzy numbers
Very weak	(0,0,0)	0
Weak	(0,0.167,0.333)	0.167
Weak-Mid	(0.167,0.333,0.5)	0.333
Mid	(0.333,0.5,0.667)	0.5
Mid-Strong	(0.5,0.667,0.833)	0.667
Strong	(0.667,0.833,1)	0.833
Very strong	(1,1,1)	1

III. Case Study

Iran is among the countries that have oil and gas fields shared with neighboring countries. In recent years due to the problems such as the 8-year war with Iraq, sanctions etc., the development of oil and gas fields has been faced with the slow growth. Therefore, in line with the policies of prioritizing the expanding and developing policies of shared fields, National Iranian Oil company have entrusted some field development plans to the certain engineering companies in Iran. In order to perform the mentioned projects, these companies need Contractors to outsource some activities related to expanding and development of fields. In this section, in order to demonstrate the efficiency and effectiveness of the proposed approach, the information on a company's engineering and development of oil fields is used to choose the best Contractor. The implementation procedure of the proposed approach is given below:

A. The first step: selecting the evaluation criteria and sub-criteria

In this step, the criteria and sub-criteria affecting assessment are extracted. For this purpose, some factors are derived from literature and the majority of them are derived from the documents and experts' opinion in the firm under study. Evaluation criteria are divided into two general groups of cost and technical-managerial criteria. Technical-managerial criteria are presented in Tables (3) to (10); Figure 2 is depicted to understand better its hierarchical structure.

Table III
The sub-criteria of technical- managerial

Sub-criteria	Abbreviation
Ensuring the power of Contractor organization by the project dimensions	C1
Ensuring the Contractor's financial power	C2
The way of supplying the product	C3
Ensuring the ability to conduct the duty by the Contractor	C4
Ensuring the complete understanding of duty by the Contractor	C5
Records and Documents (documents maturity)	C6

Table IV
The sub-criteria of ensuring the power of Contractor organization by the project dimensions

Sub-criteria	Abbreviation
The company organizational chart, key personnel with their resumes, education, confirmations, special experiences and international documents	A1
The company Organization Chart	A2
The ability to utilize the reputable domestic and foreign companies together with providing work experience and methods of communications	A3

Table V
The sub-criteria of ensuring the Contractor's financial power

Sub-criteria	Abbreviation
Turnover during the last 5 years	B1
Financial strength (balance sheet, tax, Payable insurance, bank credit)	B2

Table VI
The sub-criteria of the way of supplying the product

Sub-criteria	Abbreviation
Resources and organization of procurement	D1
Documentation of procurement procedures (inspection, warehousing, etc.)	D2
technical support and spare parts supply method	D3
Training and technology transfer	D4

Table VII
The sub-criteria of ensuring the ability to conduct the duty by the Contractor

Sub-criteria	Abbreviation
Similar experiences in the past 5 years contracts	E1
Contractor credit history (the list of successfully completed contracts with the employer's approval)	E2
Declaring competitive advantages over competitors	E3
The facilities, equipment, and applicable resources	E4

TABLE VIII
THE SUB-CRITERIA OF ENSURING THE COMPLETE UNDERSTANDING OF DUTY BY THE CONTRACTOR

Sub-criteria	Abbreviation
Full understanding of duty with validation to conduct it in The prescribed period	F1
Schedule	F2
Innovative proposals to reduce the time and cost	F3
Contractor's work capacity	F4
Anticipating the major challenges of work	F5
Arrangement and equipping the shop to the required number of work fronts	F6

TABLE IX
THE SUB-CRITERIA OF THE RECORDS AND DOCUMENTS (DOCUMENTS MATURITY)

Sub-criteria	Abbreviation
project Policy (organizing, planning, risk, quality, progress, events, and logistics)	G1
Valid and relevant certificates received by the Contractor	G2
The Contractor's ranking Documents in PBO	G3
List of All procedures and deployment systems of project management along with the last date modified	G4

TABLE X
THE SUB-CRITERIA OF THE COMPANY ORGANIZATIONAL CHART

Sub-criteria	Abbreviation
Organization and workflow chart of the Project Management Office (PMO)	K1
Organization and workflow chart of Logistics and product	K2
Organization and workflow chart Implementation and start-up	K3
Project organization chart and work flow of engineering unit	K4
Organization and workflow chart of QA/QC	K5
Organization and workflow chart of financial unit	K6
Organization and workflow chart of HSE	K7

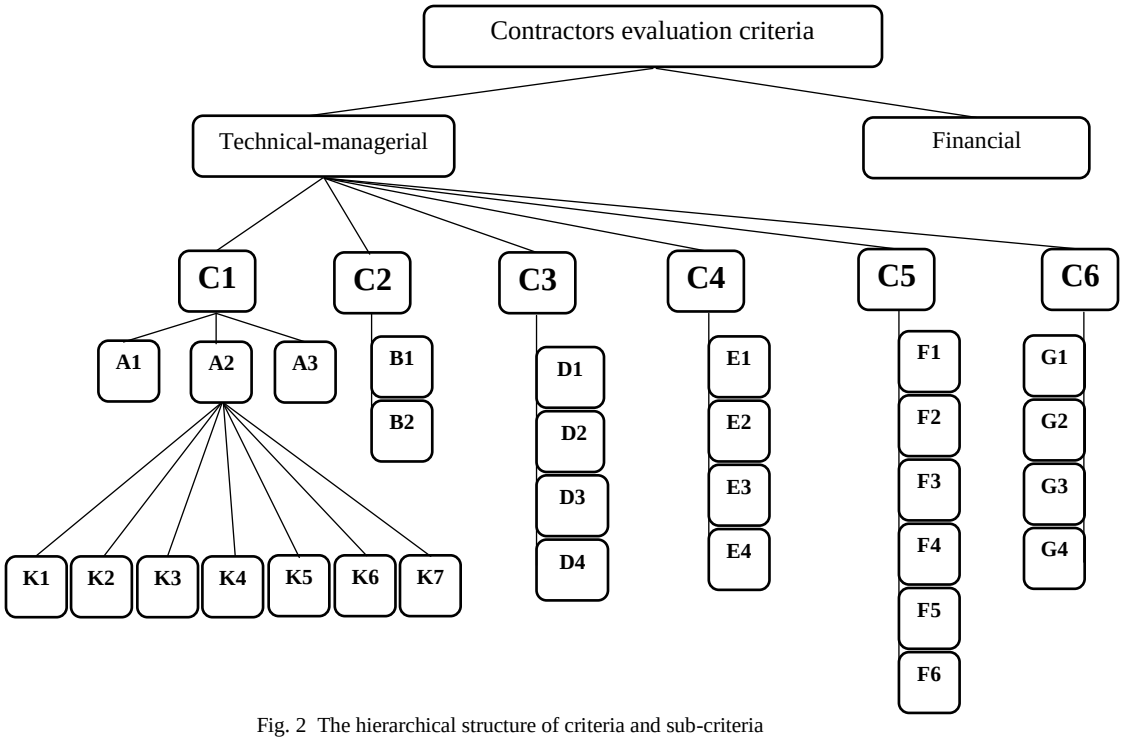

Fig. 2 The hierarchical structure of criteria and sub-criteria

B. The second step: weighting the factors

In this step, we addressed weighting the factors obtained from the previous step. For this purpose, experts will be asked to compare mutually each criteria and sub-criteria category, using the linguistic terms provided in table (1). The results of the comparisons are presented in Tables (11) to (18).

Now, using the method developed by Bozbura & Beskese [29], we calculate the weights of all criteria and sub-criteria. The results of calculating the criteria and sub-criteria are presented in the table (19).

To calculate the Global weight of the sub-criteria, the criteria local weight should be applied in sub-criteria global weight. The results of the calculations are presented in the table (20).

TABLE XI

PAIRWISE COMPARISON MATRIX BETWEEN SUB-CRITERIA OF TECHNICAL-MANAGERIAL

	C1	C2	C3	C4	C5	C6
C1	(1,1,1)	(1/2,1,3/2)	(3/2,2,5/2)	(2/3,1,2)	(1,3/2,2)	(2,5/2,3)
C2	(2/3,1,2)	(1,1,1)	(1,3/2,2)	(1/2,2/3,1)	(1/2,1,3/2)	(3/2,2,5/2)
C3	(2/5,1/2,2/3)	(1/2,2/3,1)	(1,1,1)	(2/5,1/2,2/3)	(2/3,1,2)	(1/2,1,3/2)
C4	(1/2,1,3/2)	(1,3/2,2)	(3/2,2,5/2)	(1,1,1)	(1,3/2,2)	(2,5/2,3)
C5	(1/2,2/3,1)	(2/3,1,2)	(1/2,1,3/2)	(1/2,2/3,1)	(1,1,1)	(1,3/2,2)
C6	(1/3,2/5,1/2)	(2/5,1/2,2/3)	(2/3,1,2)	(1/3,2/5,1/2)	(1/2,2/3,1)	(1,1,1)

TABLE XII

PAIRWISE COMPARISON MATRIX BETWEEN SUB-CRITERIA OF ENSURING THE POWER OF CONTRACTOR ORGANIZATION BY THE PROJECT DIMENSIONS

	A1	A2	A3
A1	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)
A2	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)
A3	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)

TABLE XIII

PAIRWISE COMPARISON MATRIX BETWEEN SUB-CRITERIA OF ENSURING THE CONTRACTOR'S FINANCIAL POWER

	B1	B2
B1	(1,1,1)	(1,3/2,2)
B2	(1/2,2/3,1)	(1,1,1)

TABLE XIV

PAIRWISE COMPARISON MATRIX BETWEEN SUB-CRITERIA OF THE WAY OF SUPPLYING THE PRODUCT

	D1	D2	D3	D4
D1	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)	(3/2,2,5/2)
D2	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)	(1,3/2,2)
D3	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)	(1/2,1,3/2)
D4	(2/5,1/2,2/3)	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)

TABLE XV

PAIRWISE COMPARISON MATRIX BETWEEN SUB-CRITERIA OF ENSURING THE ABILITY TO CONDUCT THE DUTY BY THE CONTRACTOR

	E1	E2	E3	E4
E1	(1,1,1)	(1/2,1,3/2)	(3/2,2,5/2)	(1,3/2,2)
E2	(2/3,1,2)	(1,1,1)	(1,3/2,2)	(1/2,1,3/2)
E3	(2/5,1/2,2/3)	(1/2,2/3,1)	(1,1,1)	(2/3,1,2)
E4	(1/2,2/3,1)	(2/3,1,2)	(1/2,1,3/2)	(1,1,1)

TABLE XVI

PAIRWISE COMPARISON MATRIX BETWEEN SUB-CRITERIA OF ENSURING THE COMPLETE UNDERSTANDING OF DUTY BY THE CONTRACTOR

	F1	F2	F3	F4	F5	F6
F1	(1,1,1)	(2,5/2,3)	(1,3/2,2)	(2,5/2,3)	(1/2,1,3/2)	(3/2,2,5/2)
F2	(1/3,2/5,1/2)	(1,1,1)	(1/2,2/3,1)	(2/3,1,2)	(2/5,1/2,2/3)	(2/3,1,2)
F3	(1/2,2/3,1)	(1,3/2,2)	(1,1,1)	(1,3/2,2)	(2/3,1,2)	(1/2,1,3/2)
F4	(1/3,2/5,1/2)	(1/2,1,3/2)	(1/2,2/3,1)	(1,1,1)	(2/5,1/2,2/3)	(2/3,1,2)
F5	(2/3,1,2)	(3/2,2,5/2)	(1/2,1,3/2)	(3/2,2,5/2)	(1,1,1)	(1,3/2,2)
F6	(2/5,1/2,2/3)	(1/2,1,3/2)	(2/3,1,2)	(1/2,1,3/2)	(1/2,2/3,1)	(1,1,1)

TABLE XVII

PAIRWISE COMPARISON MATRIX BETWEEN SUB-CRITERIA OF THE RECORDS AND DOCUMENTS (DOCUMENTS MATURITY)

	G1	G2	G3	G4
G1	(1,1,1)	(3/2,2,5/2)	(1,3/2,2)	(1/2,1,3/2)
G2	(2/5,1/2,2/3)	(1,1,1)	(2/3,1,2)	(1/2,2/3,1)
G3	(1/2,2/3,1)	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)
G4	(2/3,1,2)	(1,3/2,2)	(1/2,1,3/2)	(1,1,1)

TABLE XVIII

PAIRWISE COMPARISON MATRIX BETWEEN SUB-CRITERIA OF THE COMPANY ORGANIZATIONAL CHART

	K1	K2	K3	K4	K5	K6	K7
K1	(1,1,1)	(1,3/2,2)	(1,3/2,2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,3/2,2)	(3/2,2,5/2)
K2	(1/2,2/3,1)	(1,1,1)	(1,3/2,2)	(1/2,2/3,1)	(1,3/2,2)	(1,3/2,2)	(3/2,2,5/2)
K3	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1,3/2,2)	(3/2,2,5/2)
K4	(2/3,1,2)	(1,3/2,2)	(1,3/2,2)	(1,1,1)	(1/2,2/3,1)	(1,3/2,2)	(3/2,2,5/2)
K5	(2/3,1,2)	(1/2,2/3,1)	(1,3/2,2)	(1,3/2,2)	(1,1,1)	(1,3/2,2)	(1,3/2,2)
K6	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,1,3/2)
K7	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)

TABLE XIX
THE LOCAL WEIGHTS OF SUB-CRITERIA

Sub-criteria	Local weight	Sub-criteria	Local weight	Sub-criteria	Local weight
C1	0.2305	A1	0.36935	-	-
		A2	0.33066	K1	0.1761
				K2	0.1661
				K3	0.1370
				K4	0.1715
				K5	0.1643
				K6	0.1022
				K7	0.0828
		A3	0.29998	-	-
C2	0.1886	B1	0.68415	-	-
		B2	0.31585	-	-
C3	0.1110	D1	0.3153	-	-
		D2	0.2701	-	-
		D3	0.2257	-	-
		D4	0.1890	-	-
C4	0.2409	E1	0.3153	-	-
		E2	0.2701	-	-
		E3	0.1890	-	-
		E4	0.2257	-	-
C5	0.1530	F1	0.2695	-	-
		F2	0.1084	-	-
		F3	0.1756	-	-
		F4	0.0965	-	-
		F5	0.2241	-	-
		F6	0.1259	-	-
C6	0.0760	G1	0.3153	-	-
		G2	0.1890	-	-
		G3	0.2257	-	-
		G4	0.2701	-	-

TABLE XX
THE GLOBAL WEIGHTS OF SUB-CRITERIA

Sub-criteria	Global weights
A1	0.085135
K1	0.013422
K2	0.01266
K3	0.010442
K4	0.013071
K5	0.012522
K6	0.007789
K7	0.006311
A3	0.069145
B1	0.129031
B2	0.059569
D1	0.034998
D2	0.029981
D3	0.025053
D4	0.020979
E1	0.075956
E2	0.065067
E3	0.04553
E4	0.054371
F1	0.041234
F2	0.016585
F3	0.026867
F4	0.014765
F5	0.034287
F6	0.019263
G1	0.023963
G2	0.014364
G3	0.017153
G4	0.020528

C. The third step: Evaluation of Contractor's sub-criteria performance

In this step, the questionnaires are provided to the experts and they have been asked to complete the questionnaires using table (2); so that, the score of each Contractor can be calculated based on each sub-criteria. The average of four experts' opinion about scoring Contractors is presented in table (21).

To obtain the technical-managerial score of each Contractor, we should calculate summation of the multiplication of the sub-criteria's global weight and evaluated average. Table 22 shows the results of these calculations.

Based on a directive of the company under study, Contractors who do not achieve the minimum acceptable score (0.6 of 1) in the technical-managerial criteria, will be excluded. So Contractor 4 was excluded among the present Contractors.

TABLE XXI
THE AVERAGE OF EXPERT'S OPINION

Sub-criteria	Contractor 1	Contractor 2	Contractor 3	Contractor 4
A1	0.5	0.3335	0.45825	0.167
K1	0.6665	0.83325	0.5	0.5
K2	0.833	0.74975	0.5	0.5
K3	0.833	0.833	0.58325	0.3335
K4	0.6665	0.62475	0.4165	0.5
K5	0.833	0.833	0.5415	0.375
K6	0.833	0.833	0.49975	0.5
K7	0.6665	0.833	0.58325	0.5
A3	0.5	0.833	0.6665	0.29175
B1	0.9165	0.6665	0.833	0.4165
B2	0.833	0.583	0.74975	0.54175
D1	0.75	0.62475	0.625	0.5
D2	0.5835	0.5	0.5	0.3335
D3	0.3335	0.3335	0.3335	0.3335
D4	0.3335	0.29175	0.3335	0.29175
E1	0.833	0.6665	0.833	0.50025
E2	0.833	0.6665	0.667	0.33325
E3	0.9165	0.625	0.4165	0.333
E4	0.833	0.4165	0.625	0.45825
F1	0.9165	0.75	0.833	0.5
F2	0.9165	0.9165	0.833	0.54175
F3	0.74975	0.54175	0.49975	0.37475
F4	0.6665	0.6665	0.5	0.333
F5	0.9165	0.6665	0.7915	0.5
F6	0.9165	0.83325	0.6665	0.62475
G1	0.9165	0.7915	0.6665	0.4165
G2	0.4165	0.75	0.45825	0.25025
G3	0.74975	0.833	0.45825	0.375
G4	0.5	0.74975	0.25	0.167

TABLE XXII
THE FINAL SCORE OF CONTRACTORS FOR TECHNICAL-MANAGERIAL CRITERION

Sub-criteria	Contractor 1	Contractor 2	Contractor 3	Contractor 4
Final score	0.749754	0.631703	0.6325	0.39414

D. The fourth step: calculating the impact factor of Project

In this step, the three categories of Engineering (E), Procurement (P) and Construction (C) are used to determine the technical impact factor. For this purpose, using the pairwise comparisons tables, we calculated the weight of each criterion and using Table 2, the E, P and C nature of the intended project has been determined and then, the sum product of the criteria weights by their assessed values, the technical scores will be calculated.

Then, the weights of E, P and C criteria will be calculated using the pairwise comparison table (23) and Bozbura & Beskese method (2007).

Now, using the expert opinion based on linguistic terms of Table 2, the E, P and C nature of the project will be checked and its results is presented in the table (24).

The impact factor of sum product of criteria weight by their evaluated values is calculated as follows:

$$Impact\ Factor = 0.131 \times 0.0835 + 0.537 \times 0.7085 + 0.332 \times 0.3747 = 0.5158$$

E. The fifth step: calculating the scaled financial proposal and selecting the qualified Contractor

At this point, the financial envelopes of three Contractors is opened, according to which, any of the Contractors have announced their bids for the project. The prices are provided in the table 25.

Using three proposed price, the average price is obtained and its upper and lower bounds will be considered (the top and bottom limits are determined based on expert opinion). This process is done in order that if a Contractor announces a price outside the range (i.e. the price is too low for the proposed project) will not be participated in the tender. So:

$$Average = \frac{98776792 + 78362441 + 111431192}{3} = 96190141$$

$$Lower\ bound : Average - \%15 \times Average = 85961124$$

$$Upper\ bound : Average + \%25 \times Average = 126413418$$

$$Acceptable\ Range : [85961124, 126413418]$$

The Financial Proposal of the Contractor 1 was outside the accepted range and the company was excluded from the tender

F. The Sixth step: calculating the scaled financial proposal and selecting the qualified Contractor

In this step, the balanced (scaled) prices are calculated using the following formula and whichever that has the lower balanced price Contractor is the winner of the tender.

$$Scaled\ price = \frac{100 \times price}{100 - impact\ factor \times (100 - technical\ score \times 100)}$$

Accordingly, the balanced price of each of remained Contractors is calculated each which is provided in the table (26).

So the Contractor 2 with lower balanced financial proposal as the best Contractor is selected as the winner of tender.

TABLE XXIII
WEIGHT OF ENGINEERING, PROCUREMENT AND CONSTRUCTION

	E	P	C	Weights
E	(1,1,1)	(2/7,1/3,2/5)	(2/5,1/2,2/3)	0.131
P	(5/2,3,7/2)	(1,1,1)	(1,3/2,2)	0.537
C	(3/2,2,5/2)	(1/2,2/3,1)	(1,1,1)	0.332

TABLE XXIV
EVALUATED SCORE OF ENGINEERING, PROCUREMENT AND CONSTRUCTION

Criteria	Expert 1	Expert 2	Expert 3	Expert 4	Average
E	0.167	0	0	0.167	0.0835
P	0.667	0.667	0.667	0.833	0.7085
C	0.5	0.333	0.333	0.333	0.3747

TABLE XXV
FINANCIAL PROPOSAL OF EACH CONTRACTOR

Contractor	Financial proposal (Euro)
Contractor 1	78362441
Contractor 2	98776792
Contractor 3	111431192

TABLE XXVI
SCALED (BALANCED) FINANCIAL PROPOSAL OF EACH CONTRACTOR

Contractor	Financial proposal (Euro)
Contractor 2	121941778
Contractor 3	137494091

IV. CONCLUSION

Contractor selection problem is a strategic issue, and many organizations are looking for a functional approach to assess Contractors and choose the most appropriate one. The importance of this issue is growing with increasing the scale of the projects, so that, choosing a suitable, committed and capable Contractor in macro level is as one of the concerns of many project-driven organizations. In this paper, we follow a functional approach according to the need for a development and engineering Company active to choose the right Contractor for outsourcing sub-projects. To this end, weights of the criteria and sub-criteria are calculated using analytic hierarchy process and the technical-managerial score of any Contractor will be achieved. If a Contractor does not acquire the minimum required score, the organization Contractors will be excluded from the list. After evaluating the Contractors' technical-managerial ability, they will be financially assessed based on the proposed price. This evaluation is conducted based on a price range which is achieved from the Contractors' proposed price; and if the proposed price of each of the Contractors is not in the range, it will be excluded from the list of Contractors. Because the Contractors are unaware of the competitors' bid and they may offer an unreasonable price to obtain project, this approach avoids this problem. Finally, financial proposal will be balanced and the Contractor who has proposed the lowest balanced price is selected as the qualified Contractor.

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