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Optimal Selection Contractors Using Crisp and Fuzzy Multi-Attribute Decision Making (Case Study: Kermanshah Gas Company)

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Abstract

The appropriate selection of contractors is one of the fundamental challenges encountered by the organizations which their main executive activity takes place in the framework of contractual agreements. So selecting an inefficient contractor leads to significant damages to quality, expense and duration of executing projects. The present paper presents a comprehensive model in Kermanshah Gas Company which is able to select an optimal contractor to execute project considering the effective quantitative and qualitative factors in the evaluation of contractors.

Firstly, a decision making group was formed and the most effective criteria (including work experience, financial situation, etc.) for selecting contractor using questionnaire were identified. Then, taking advantage of the opinion of experts which include five members of the technical committee, the weight of criteria was determined in a fuzzy and crisp way; which based on fuzzy weight and crisp weight, work experience, and machinery and facilities accounted for the maximum weight, respectively. In fuzzy method, work experience and based on the crisp weight of machinery and facilities, they accounted for the maximum weight.

Then four contractors participating in tender were ranked using ELECTRE, TOPSIS and FTOPSIS methods, which Nil AbMostahkamGharb Company ranked first at TOPSIS and FTOPSISmethod, and GharbKousha Architectures Co. ranked first at ELECTRE method.

In the end, after performing Friedman test for detecting concordance using ranks mean technique, the final ranking of contract companies was obtained.

Keywords: Contractors Evaluation and Ranking; Fuzzy Multi-Attribute Decision Making Techniques; Kermanshah Gas Company; Linguistic Variables.

1- Introduction

Decision making is evaluating existing solutions and selecting the best option which includes problem identification and problem solution. In the area of management, decision making plays significant roles, so Herbert Simon regard the decision making same as management. Decision making is conducted based on different criteria, some qualitative and sometimes even at odds with each other. In this situation, the necessity of applying decision making will be clear, and multi-attribute decision making (MADM) is considered as the best procedure in this regard. The MADM method choice decision should wait until the analyst and the decision-makers understand the problem, the feasible alternatives, different outcomes, conflicts between the criteria and level of the data uncertainty (mergias et al,2007). In MADM, some options (choices) are investigated based on several criteria and the optimal option in MADM model is the mental option A, and it provides the best value of each attribute. In other words, A is composed of the most preferred value or utility of each decision making attribute. Construction project outcome may be measured in terms of time, cost and quality achieved (Halt et al,1995). Arguably, the construction owner decision most impacting these superlative value criteria, is that of selecting the appropriate, i.e. best, contractor (Halt et al,1995;Rusell&Skibniewski, 1988; Odusote, 1990).Considering the fact that contracting powers and contractors are among the main agents for providing commodities and services, they play crucial roles in the fulfillment of societies and organizations' goals. Decision making to select the optimal contractor is a sensitive and crucial task of managers and experts in this area, because wrong selection of inefficient contractors which have no reasonable scientific base may give rise to huge spiritual, material and sometimes irretrievable losses. Contractor assessment at the prequalification stage is usually based on a number of criteria. As in the case of most Multi-Attribute Decision Making (MADM)
Problems, The criteria may be related to contradictory aims, so the decision is a compromise. Moreover, such decisions require that decision makers reach consensus (Jaskowski et al,2010). The MADM method, criteria and their significance, chosen at the discretion of the ordering party, have to be determined at the stage of preparing tender terms and specifications. Selection of capable contractors is critical for project performance and overall success in construction projects. An inappropriate contractor increases the risk of delays, cost overruns, substandard work, disputes, or even bankruptcy (Hatush & Skitmore, 1997; Skorupka,2005). Selecting a capable contractor is one of the most important tasks a construction client has to face to achieve a satisfactory project outcome (Fong & Choi,2000; Turkis, 2008).Numerous researchers have identified sets of criteria common to most projects and proposed methodologies for contractor selection or prequalification. Hatush and skitmore present the results of a Delphic study investigating the perceived relationship between 20 contractor selection criteria (CSC) currently in use and the predominant project success factors (Hatush and skitmore, 1997). Yasamis et al introduced a contractor quality performance evaluation model that can be used in a contractor prequalification or selection system. The model was based on a list of contractor quality performance indicators derived from the contractors' records on previously completed projects and their overall performance at corporate level (Yasamis et al, 2002). Minchin and Smith proposed a model, called the Quality-Based Performance Rating system, for contractor selection. This model receives input from traditional subjective sources and integrates it with objective data input from the results of tests on a project' s materials and workmanship quality, then uses both to produce a score for each project (Minchin and Smith , 2005).Edita Plebankiewicz proposes a model for each employer in order to determine the efficiency of contractors. Using fuzzy theory and to achieve employer's goals, he considers different criteria to evaluate contractors. At different stages of each project, for selecting an efficient contractor, he uses a mathematical model through which employers can evaluate contractor of each project with a focus on a part of plan. The goals of contractors include: cost, time and quality (Plebankiewicz, 2011). Jaskowski, Biruk and Bucon introduced FAHP and AHP and also proposed a method for evaluating contractors' selection which it not only included pair-wise comparisons matrix and determination of weight but also it was a new

application in prioritization problems. Contractor selection criteria include equipment and manpower, financial strength, past experiences, work experience and management capabilities. To determine the weight of criteria, experts opinion was used (Jascowski et al., 2010). Singh and Robert considered the most significant criteria for the selection of contractors as financial strength to maintain liquidity, sufficient technical capability to satisfy contract requirement, facilities to guarantee quality and ability to fulfill all safety requirements and health (Singh and Robert, 2005).
In the recent years, delay or disagreement on the execution of projects due to the inefficiency of project executive contractors has led to significant losses. Based on the present statistics, a considerable part of such problems is due to the incorrect selection of contractors. They have been selected, in few past years, based on the least cost, and this has caused a dozens of problems when execution of projects. To solve such problems, a special filter is required to prevent inefficient contractors from entering tender (Hatush & Skitmor, 1998).
At the time being, there is not an effectual method dependent upon modern management principles and contractors are not selected based on suitable scientific techniques and procedures. Therefore, in a great deal of projects, many problems are raised such as excessive costs, prolonging the time of execution and a output reduced quality. The present study mainly attempts to select the optimal contractor using Multi-Attribute Decision Making Techniques (MADM) with a crisp and Fuzzy approach in Kermanshah Gas Company.
Using scientific resources and instructions provided by Kermanshah Gas Company, the current paper investigate effective criteria on the selection of contractors in Gas Company, and by benefiting from Multi Attribute Decision Making Criteria, the contractor selection optima model is designed. The model designed by the present study is able to identify the most significant and precise criteria in the selection of Kermanshah Gas Company's contractors.
This could be achieved by determining weight (significance). In addition, the designed model is capable of selecting and ranking the best contractors among a group of volunteer contractors based on their professional and educational situation and also determined effective criteria.

2- Literature Reopinion

2-1 Multi Attribute Decision Making Techniques

Multi Attribute Decision Making as a method of decision making is applied to prioritize and to select the most optimal option among the existing one and based on decision making criteria. MADM Models are applied to select the best option among m existing options. Although MADM methods could be seen technically in diverse forms, such methods also have their own specific characteristics such as the existence of options, multi-form criteria, conflict between criteria, incommensurable measurement units, decision criteria weight and decision criteria.

Suppose that a decision maker is to select or rank n option $x_j = (j = 1,2,.....,n)$ based on m attribute $f_j = (i = 1,2,.....,m)$. In general, there are two types of criteria: attributed based on interest and the ones based on cost. Therefore, the set of criteria (F) can be divided into two sub-sets of F^2, F^1 which F^1indicates criteria with an interest nature and F^2 indicates criteria with a cost nature. So a MADM model could be explained as follows:

$$i \in F^1\} \mid \max\{ f_i(x_j)$$

$$i \in F^2\} \; | \; \min\{ f_i(x_j)$$

s.t: x Є X

Criteria in a MADM maybe fuzzy and it could be better to use fuzzy calculations for final decision making. As it was mentioned earlier, MADM models are used to select the most optimal options among possible ones.

MADM methods generally involve two stages as follows:

1- The consensus of opinions on criteria and options
2- The sequence of options based on collective opinions

The crisp FTOPSIS, ELECTRE and TOPSIS methods used in the present paper are described in the following.

2-2Methods

2-2-1The Fuzzy TOPSIS Method

In the method of the classic similarity to classic ideal option, accurate and crisp values are applied to determine criteria and options weight. In most cases, human thinking is accompanied with indeterminacy and this influences decision making. Therefore, it is better to use fuzzy methods which the method of the similarity to fuzzy ideal option is one of such methods. In this case, the elements of decision making matrix or criteria weight or both of them are evaluated by using linguistic variables presented by fuzzy umbers and thereby the problems with technique for order performance by similarity to idea solution have been overcome. The use of fuzzy set theory (Zadeh, 1965) allows the decision-makers to in incorporate unquantifiable information, incomplete information, non-obtainable information and partially ignorant facts into decision model. This study uses triangular fuzzy number for fuzzy TOPSIS. The reason for using a triangular fuzzy number is that it is intuitively easy for decision-makers to use and calculate. In addition, modeling using a triangular fuzzy numbers has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise (Chang &Yeh, 2002; Chang et al,2007; Kahraman et al,2004; Zimmerman, 1996). In the following, some basic important definitions of fuzzy sets are given (Chen et al, 2006; Wang & Chang, 2007; Zimmerman,1996).

Definition1. A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{A}}(x)$which associates with each element x in X a real number in the interval$[0,1]$. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of x in $\tilde{A}$.

Definition2. A linguistic variable is a variable values of which are linguistic terms (Chen, 2000; Zadeh, 1975). The concept of linguistic variable is very useful in dealing with situations which are too complex or too ill-defined to be reasonably described in conventional quantitative expressions.

Fuzzy TOPSIS method steps

Chen and Hwang have described stages of fuzzy TOPSIS method in the multi-criteria decision making with n criterion and m option as follows:

Phase 1: decision matrix formation

Considering the number of criteria, options and the evaluation of all options for different criteria, decision matrix is formed as follows:

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

When fuzzy numbers are used, $\tilde{x}_{ij=(}a_{ij}, b_{ij}, c_{ij})$ is the function of the option i(i=1,2,…,m) in relation to the criterion j(j=1,2,…,n). if decision maker committee have k member and fuzzy ranking k is OMIN of decision maker $\tilde{x}_{ijk=(a_{ijk},b_{ijk},c_{ijk})}$ (triangular fuzzy number) for (j=1,2,…,n) and (i=1,2,…,m), considering integrated fuzzy ranking criteria $\tilde{x}_{ij=(}a_{ij}, b_{ij}, c_{ij})$, the options could be obtained as follows:

$$a_{ij} = \min_k\{a_{ijk}\} \quad (۱)$$

$$b_{ij} = \frac{\sum_{k=1}^{k} b_{ijk}}{k} \quad (۲)$$

$$c_{ij} = \max_k\{c_{ijk}\} \quad (۳)$$

Stage 2: determining the matrix of criteria weight

Then, different criteria significance coefficient in decision making is defined as follows:

Which if triangular fuzzy numbers is used, each component w_j (the weight of each criterion) is defined as $\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$. If decision making committee have K member and the K[th] significance coefficient of the decision maker $\widetilde{w}_{jk} = (w_{jk1}, w_{jk2}, w_{jk3})$ (triangular fuzzy number) for j=1, 2,… ,n, the integrated fuzzy ranking $\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$could be obtained as follows:

$$w_{j1} = \min_k\{w_{jk1}\} \quad (۴)$$

$$w_{j2} = \frac{\sum_{k=1}^{k} w_{jk2}}{k} \quad (۵)$$

$$w_{j3} = \max_k\{c_{jk3}\} \quad (۶)$$

Stage 3: the normalization of fuzzy decision matrix

When every x_{ij} is fuzzy, every r_{ij} is undoubtedly fuzzy. To normalize, linear scale change for converting different criteria scale into applicable criterion is used. If fuzzy number is triangular, it will be calculated in non-scale decision arrangements for criteria with negative and positive dimensions as follows:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \quad (۷)$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \quad (۸)$$

Which in these equations:

$$c_j^* = \max_i c_{ij} \quad (9)$$

$$a_j^- = \min_i a_{ij} \quad (10)$$

Stage 4: determining weighted fuzzy decision matrix

Given the weight of different criteria, weighted fuzzy decision matrix is obtained through multiplying significance coefficient related to each criterion in fuzzy normalized matrix as follows:

$$\tilde{v}_{ij} = \tilde{r}_{ij} . \tilde{w}_j \quad (۱۱)$$

If fuzzy numbers are triangular, for criteria with a positive and negative dimension, we have:

$$\tilde{v}_{ij} = \tilde{r}_{ij} . \tilde{w}_j = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) . \ (w_{j1}, w_{j2}, w_{j3}) = \left(\frac{a_{ij}}{c_j^*} w_{j1}, \frac{b_{ij}}{c_j^*} w_{j2}, \frac{c_{ij}}{c_j^*} w_{j3}\right) \quad (12)$$

$$\tilde{v}_{ij} = \tilde{r}_{ij} . \tilde{w}_j = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) . (w_{j1}, w_{j2}, w_{j3}) = \left(\frac{a_j^-}{c_{ij}} w_{j1}, \frac{a_j^-}{b_{ij}} w_{j2}, \frac{a_j^-}{a_{ij}} w_{j3}\right) \quad (۱۳)$$

Stage 5: finding ideal fuzzy solution (FPIS,A^*) and anti-ideal fuzzy solution (FNIS,A^-)

Ideal fuzzy solution (FPIS,A^*) and anti-ideal fuzzy solution (FNIS,A^-) are solved as follows:

$$A =^* \{\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*\} \quad (۱۴)$$

$$A^- = \{\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-\} \quad (۱۵)$$

which$\tilde{v}_i^*$ is the best value of i among all options and $\tilde{v}_i^-$ is the worst value of I among all options. The values are obtained through the following equations:

$$\tilde{v}_j^* = \max_i \{\tilde{v}_{ij3}\} \quad i=1,2,\dots,m \ ,j=1,2,\dots,n \quad (16)$$

$$\tilde{v}_j^- = \min_i \{\tilde{v}_{ij1}\} \quad i=1,2,\dots,m \ ,j=1,2,\dots n \quad (17)$$

The options which are placed in A^*&A^-, show very high and very low options, respectively. In this study, $A^* = (1,1,1)$ is considered as positive ideal reply and $A^- = (0,0,0)$ as negative ideal reply.

Stage 6: calculating distance between fuzzy ideal solution and fuzzy anti-ideal solution

The distance of each option from fuzzy ideal solution and fuzzy anti-ideal solution could be obtained as follows:

$$S_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*), i=1,2,\ldots,m \qquad (۱۸)$$

$$S_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-), i=1,2,\ldots,m \qquad (۱۹)$$

d(.,.) is the distance between two fuzzy numbers, which if (a_1, b_1, c_1) $and(a_2, b_2, c_2)$ are two triangular fuzzy numbers, the distance between two numbers are:

$$d_v(\tilde{M}_1, \tilde{M}_2) = \sqrt{1/3[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]} \qquad (۲۰)$$

It could be added that $d(\tilde{v}_{ij}, \tilde{v}_j^-)$and $d(\tilde{v}_{ij}, \tilde{v}_j^*)$are crisp numbers.

Stage 7: similarity criteria calculations

Similarity attribute is obtained by the following equation:

$$CC_i = \frac{S_i^-}{S_i^* + S_i^-} \quad i = 1,2,\ldots,m \qquad (۲۱)$$

Stage 8: ranking the options

In this stage, considering the amount of the similarity attribute, the options are ranked, so that the options with similarity attribute are prioritized.

2-2-2The TOPSIS Method

TOPSIS (technique for order performance by similarity to idea solution) was first developed by Hwang and Yoon (1981). According to this technique, the best alternative would be the one that is nearest to the positive- ideal solution and farthest from the negative- ideal solution (Ertugrul & Karakasglu, 2007).

the positive- ideal solution is a solution that maximizes the benefit criteria and minimizes the cost criteria , whereas the negative- ideal solution maximizes the cost criteria and minimizes the benefit criteria (Wang &Elhag , 2006). In short, the positive- ideal solution is composed of all best values attainable from the criteria, whereas the negative- ideal solution consist of all worst values attainable from the criteria (Dagdeviren et al, 2008 ;Wang, 2007). The TOPSIS method consists of the following steps:

Step 1: Calculate the normalized decision matrix (n_{ij}). The normalized value $n_{ij}$is calculated as:

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} \qquad (22)$$

Step 2: constructing weighted normalized matrix by assuming vector W as an input to algorithm. So:

weighted normalized matrix $=V = N_D . W_{n\times n} = \begin{pmatrix} V_{11} & \cdots & V_{1n} \\ \vdots & \ddots & \vdots \\ V_{m1} & \cdots & V_{mn} \end{pmatrix}$

So that N_D is a matrix that scores of its attribute has been "normalized" and compared and $W_{n\times n}$ is a diametrical matrix which only the elements of its main diameter is non-zero.

Step 3: specifying positive-ideal solution and negative-ideal solution.

Positive- ideal solution and negative- ideal solution are defined as follows.

$$A^+ = \{(\max_i V_{ij} \,|j\epsilon J), (\min_i V_{ij} \,|j\epsilon \acute{J})|i = 1,2, \dots, m\} = \{V_1^+, V_2^+, \dots, V_j^+, \dots V_n^+\} \qquad (23)$$

$$A^- = \{(\min_i V_{ij} \,|j\epsilon J), (\max_i V_{ij} \,|j\epsilon \acute{J})|i = 1,2, \dots, m\} = \{V_1^-, V_2^-, \dots, V_j^-, \dots V_n^-\} \qquad (24)$$

So that,

$J = \{j = 1,2, \dots, m|\text{js related to benefit}\}$

$\acute{J} = \{j = 1,2, \dots, m|js\ related\ to\ cost\}$

Step 4: calculating separation size (distance)

The distance between the option Ith and the ideal using Euclidean Method is as follows:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^+)^2} \quad i=1, 2,\dots,m \qquad (25)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^-)^2} \quad j = 1,2,\dots,n \qquad (26)$$

Step 5: calculating relative closeness of A_i to the ideal solution. Such relative closeness is defined as follows:

$$CL_i^* = \frac{d_i^-}{d_i^- + d_i^*} \qquad (۲۷)$$

Step 6: ranking the options. Based on decreasing order CL_i^*, the options taken from assumed problem could be ranked.

2-2-3 ELECTRE Method

This model was proposed at late 1980s and it is regarded as a one of the best techniques of MADM. The model is based on "non-ranked equations", i.e. it does not lead to the ranking of the options, but it may delete some options. The algorithm for solving this decision making model is as follows:

Step 1: in this stage, the values of the problem decision making matrix are normalized using norm. This matrix is called N.

$$N = [n_{ij}] \quad , \quad n_{ij} = \frac{a_{ij}}{\left[\sum_{i=1}^{m} a_{ij}^2\right]^{\frac{1}{2}}} \qquad (۲۸)$$

Step2: in this stage, using matrix W (the weights of the criteria) and following equation, "weighted normalized matrix" could be obtained as follows:

$$V = N \times W_{n\times n} \qquad (29)$$

V is weighted normalized matrix

$\mathbf{W_{n\times n}}$=the diametrical matrix of the weights obtained for the criteria

Step 3: in this step, all the options are evaluated, compared to all the criteria and a set of "coordinate and un-coordinate matrices" are formed. The coordinate set of the options 1 and K which is shown by $S_{k,l}$ includes all the criteria in which A_k has a more utility thanA_l.

If relevant attribute has a positive aspect, we have:

$$S_{k,l} = \{j|V_{kj} \geq V_{lj}\} \quad , \ j = 1, \dots \dots , m \qquad (۳۰)$$

If the attribute has a negative aspect, we have:

$$S_{k,l} = \{j|V_{kj} \leq V_{lj}\} \quad , \ j = 1, \dots \dots , m \qquad (۳۱)$$

discordance set $D_{k,l}$also includes the criteria in which $A_k$has a lesser utility than A_l, i.e.

$$\mathrm{D_{k,l}} = \{\mathrm{j}|\mathrm{V_{kj}} < \mathrm{V_{lj}}\} \quad , \ \mathrm{j} = 1, \dots \dots , \mathrm{m} \qquad (۳۲)$$

This formula is for negative criteria, and for positive ones we have:

$$\mathrm{D_{k,l}} = \{\mathrm{j}|\mathrm{V_{kj}}>\mathrm{V_{lj}}\} \quad , \ \mathrm{j} = 1, \dots \dots , \mathrm{m} \qquad (33)$$

Step 4: in this step, the concordance matrix is obtained using the above data. This matrix is a square matrix m×m which its diameter has not an element. Other elements of such element is obtained by the overall weight of the criteria related to the concordance set; i.e.

$$\mathrm{I_{kl}} = \sum \mathrm{W_j} \quad , \ \mathrm{j} \in \mathrm{A_{k,l}} \qquad (۳۴)$$

Step 5: in this step, "discordance matrix" is calculated. The matrix is shown by NI and like concordance matrix is a m×m matrix. The main diameter of such matrix has no element and other elements of this matrix are obtained by the weighted normalized matrix. The elements are obtained using the following equation:

$$NI_{kl} = \frac{MAX|V_{kj} - V_{lj}| \ , \ \ j \in D_{k,l}}{MAX|V_{kj} - V_{lj}| \ , j \in all\ of\ atribute} \qquad (۳۵)$$

Step 6: in this step, "effective concordance matrix" is calculated which is specified by H. To create this matrix, a threshold limit first must be defined and if each element of the matrix I is greater than or equal to it, that component in matrix h becomes one, otherwise it becomes zero. A general criterion for specifying such limit is average matrix I values (i.e.$\bar{I}$):

$$\bar{I} = \sum_{l=1}^{m} \sum_{k=1}^{m} I_{kl}/m(m-1) \qquad (۳۶)$$

Now we have:

$H_{kl} = 1 \qquad \leftarrow I_{kl} \geq \bar{I} \qquad$ If

$H_{kl} = 0 \qquad \leftarrow I_{kl} < \bar{I}$If

This matrix shows the superiority of one option over another option.

Step 7: "effective concordance matrix" is calculated in this step, as well and this matrix is shown with G. The threshold limit for this matrix is calculated as follows:

$$\overline{NI} = \sum_{l=1}^{m} \sum_{k=1}^{m} NI_{kl}/m(m-1) \qquad (۳۵)$$

The elements of the matrix also are obtained as follows:

$G_{kl} = 0 \qquad \leftarrow NI_{kl} \geq \overline{NI} \qquad If$

$G_{kl} = 1 \qquad \leftarrow NI_{kl} < \overline{NI} \qquad If$

Step 8: in this step, "overall effective matrix" (G) is acquired by integrating effective concordance matrix (H) and effective non-coordinate matrix (F). The matrix is calculated as follows:

$$F_{kl} = H_{kl} \times G_{kl} \qquad (۳۷)$$

This matrix shows the superiority of different strategies in comparison to each other; i.e. if $F_{kl} =$, then A_k is superior to A_l. Therefore, A_k could be a superior option in the above method, if:

For at least one and $F_{lk} = 1$

For all ones and $F_{kj} = 0$

It is possible to delete each column of H with at least "element one", and then made a decision based on other lines.

3-the proposed model

The model is composed of six stages. The overall opinion of the designed model to select the optima contractor is presented as follows:

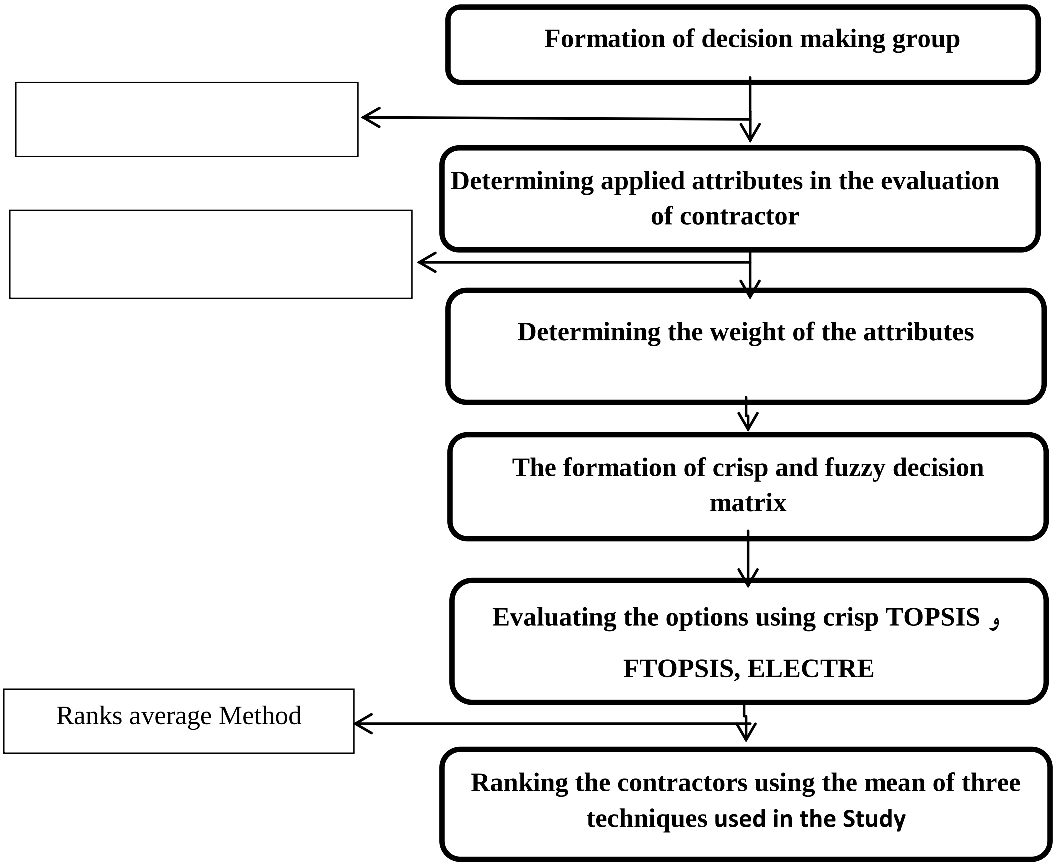

Figure 1: the study conceptual model

Next, we describe the stages of the designed model along with a numerical example.

Stage 1: the formation of decision making group

The first stage to select a qualified contractor is the formation of decision making group. Considering the procedure to select contractor in Kermanshah Gas Company, decision making group is composed of five members of technical committee with positions such as managing consultant, chief technical inspector, estimation expert, planning supervisor and financial affairs supervisor. The group is entitled to investigate the experiences of the contractors participating in tender.

Stage 2: determining applied criteria in evaluation of contractors

In this stage, in order to determine contractor selection criteria, document and papers on the procedures to select contractors are studied and then 8 attributes were selected and in the form of a questionnaire were administered to gas company experts and they were asked to consider a score of 1-10 based on the significance of each attribute. After administering experts' opinions and calculating given scores, some criteria as applied criteria were selected including financial strength, financial stability, bidding, work experience, machinery and equipment, expertise and reputation for quality and good reputation; among them, bid has a negative dimension and other ones has a positive one.

Stage 3: determining the weight of criteria
To evaluate the options, the weight of the criteria must be calculated. As the criteria are performed in a fuzzy and crisp environment, the criteria weight in each environment is separately determined.

a) Determining the criteria fuzzy weight

In order to calculate attribute fuzzy weight, linguistic variables are used. The experts express their ideas on the criteria in the form of linguistic variables. Triangular fuzzy scale to show the opinions is presented.

Table 1: linguistic variables for evaluating the significance of the criteria

Fuzzy Numbers	Significance
(۰,۰,۰,۱)	Very Low(VL)
(۰,۰,۱,۰,۳)	Low(L)
(۰,۱,۰,۳,۰,۵)	Mean-Low(ML)
(۰,۳,۰,۵,۰,۷)	Mean (M)
(۰,۵,۰,۷,۰,۹)	Mean-High(MH)
(۰,۷,۰,۹,۱)	High (H)
(۰,۹,۱,۱)	Very High (VH)

Source: (Tiryaki and Ahlatcioglu, 2005)

Experts' opinion in the form of linguistic variables is as follows.

Table 2: the significance of the criteria from experts' opinion

(	M	M	M	ML	MH
(	MH	MH	MH	L	M

	ML	ML	MH	H	VH
	VH	VH	VH	MH	VH
	H	H	H	ML	MH
	ML	ML	M	ML	M
	L	L	L	L	MH

After presenting the opinions, the mathematical mean is used to integrate experts' opinions. Then, fuzzy weight matrix is formed as follows:

Table 3: the criteria' fuzzy weight matrix

Criteria	Triangular Fuzzy Weight
	(۰,۳,۰,۵,۰,۷)
	(۰,۳۶,۰,۵۴,۰,۷۴)
	(۰,۴۶,۰,۶۴,۰,۷۸)
	(۰,۸۲,۰,۹۴,۰,۹۸)
	(۰,۵۴,۰,۷۴,۰,۸۸)
	(۰,۱۸,۰,۳۸,۰,۵۸)
	(۰,۱,۰,۲۲,۰,۴۲)

b- Determining crisp weight

In order to determine crisp weights, Shannon entropy technique is used. In this technique, the weights are determined based on initial decision matrix. Such matrix includes information on one of the tenders held in Gas Company. The information on the four proposed companies is as follows:

Table 4: the initial decision matrix

Manpower	Machinery	Popularity	Work Experience	Bidding	Financial Stability	Financial Power	Company
۱	۴۰۰۰۰۰۰۰۰	H	H	۹۱۵۲۲۱۵۲۶	M	۱۲۰۰۰۰۰۰۰۰	KoushaMemaranGharb
۵	۱۲۰۰۰۰۰۰۰۰	VH	VH	۸۳۳۳۱۸۸۳۵	M	۱۲۰۰۰۰۰۰۰۰	Nil AbMostahkamGharb
۲	۸۰۰۰۰۰۰۰	VH	VH	۷۷۷۸۲۸۰۰۰	MF	۱۰۰۰۰۰۰۰۰۰	SaMANGostarBardia
۲	۱۲۰۰۰۰۰۰۰۰	H	H	۱۰۳۷۷۰۰۷۶۰	M	۱۰۰۰۰۰۰۰۰۰	ToosanBehin Industries

After the experts assigned scores to 4 proposed company, the integrated matrix is obtained through mathematical mean calculation as follows:

Table 5: Experts' opinion integrated matrix

	۶,۸	۴,۶	۵,۸	۸,۲	۷,۴	۶,۲	۵,۴
	۶,۲	۵	۱۰	۹	۹	۱۰	۷
	۶,۴	۵	۸,۲	۴,۸	۷	۴,۲	۵,۴
	۶,۶	۵	۴,۴	۴,۸	۷	۴,۶	۵,۴

Then, the normalized matrix (P_{ij}) and the weight of the criteriais calculated as follows:

Table 6: Crisp normalized matrix (P_{ij})

	۰,۲۶۱۵۴	۰,۲۳۴۶۹	۰,۲۰۴۲۳	۰,۳۰۵۹۷	۰,۲۴۳۴۲	۰,۲۴۸۰۰	۰,۲۳۲۷۶
	۰,۲۳۸۴۶	۰,۲۵۵۱۰	۰,۳۵۲۱۱	۰,۳۳۵۸۲	۰,۲۹۶۰۵	۰,۴۰۰۰۰	۰,۳۰۱۷۲
	۰,۲۴۶۱۵	۰,۲۵۵۱۰	۰,۲۸۸۷۳	۰,۱۷۹۱۰	۰,۲۳۰۲۶	۰,۱۶۸۰۰	۰,۲۳۲۷۶
	۰,۲۵۳۸۵	۰,۲۵۵۱۰	۰,۱۵۴۹۳	۰,۱۷۹۱۰	۰,۲۳۰۲۶	۰,۱۸۴۰۰	۰,۲۳۲۷۶

Table 7: the calculation of the criteria' weights

	۰,۹۹۹۰۹	۰,۹۹۹۰۹	۰,۹۶۵۸۱	۰,۹۶۹۶۲	۰,۹۹۵۴۱	۰,۹۵۴۲۲	۰,۹۹۴۵۹
	۰,۰۰۰۹۱	۰,۰۰۰۹۴	۰,۰۳۴۱۹	۰,۰۳۰۳۸	۰,۰۰۴۵۹	۰,۰۴۵۷۸	۰,۰۰۵۴۱
	۰,۰۰۷۴۴	۰,۰۰۷۶۸	۰,۲۷۹۷۹	۰,۲۴۸۵۸	۰,۰۳۷۵۲	۰,۳۷۴۶۷	۰,۰۴۴۳۱

Step4: the formation of crisp and fuzzy matrix

A) Fuzzy decision matrix

In order to form fuzzy matrix, the experts were asked to express their opinion on the proposed companies in the form of linguistic variables. The used triangular fuzzy scale to rank the options is as follows:

Table 8: linguistic variables for ranking the options

Fuzzy Numbers	Significance
(۰,۰,۱)	Very Poor (VP
(۰,۱,۳)	Poor (P)
(۱,۳,۵)	Mean Poor (MP)
(۳,۵,۷)	Fair(F)
(۵,۷,۹)	Mean-Good (MG)
(۷,۹,۱۰)	Good (G)
(۹,۱۰,۱۰)	Very Good (VG)

Source: (Tiryaki and Ahlatcioglu, 2005)

The experts' opinions on the condition of companies are presented as follows:

Table 9: the experts' opinions matrix on the condition of the companies

		MG	F	F	G	G	F	G
		F	F	MG	G	G	F	G
		F	F	G	MG	F	F	G

		F	F	MP	MG	F	F	G
I		MG	F	MG	VG	G	MG	MG
		G	F	G	VG	G	MG	MG
		G	F	VG	F	G	F	MG
		MG	F	F	F	G	F	MG
I		G	F	MG	VG	G	G	F
		G	F	MG	G	G	G	F
		MG	F	G	F	G	F	F
		MG	F	F	F	G	F	F
I		MG	F	MG	VG	G	MG	G
		G	F	G	VG	G	MG	G
		G	F	VG	G	F	G	G
		MG	F	F	G	F	F	MG
I		MG	F	MG	VG	G	G	F
		MG	F	G	VG	G	G	F
		MG	F	VG	F	G	F	F
		MG	F	F	F	G	F	F

To integrate the opinions, the mathematical mean was used. The obtained fuzzy matrix is as follows:

Table 10: The integrated fuzzy decision matrix

A	(۵,۴,۷,۴,۹,۲)	(۳,۵,۷)	(۴,۶,۶,۶,۸,۶)	(۸,۶,۹,۸,۱۰)	(۷,۹,۱۰)	(۵,۴,۷,۴,۹)	(۵,۷,۸,۶)
A	(۵,۸,۷,۸,۹,۲)	(۳,۵,۷)	(۶,۲,۸,۲,۹,۶)	(۸,۲,۹,۶,۱۰)	(۷,۹,۱۰)	(۵,۴,۷,۴,۹)	(۵,۷,۸,۶)
A	(۵,۴,۷,۴,۹)	(۳,۵,۷)	(۸,۲,۹,۶,۱۰)	(۴,۲,۶,۲,۸)	(۵,۴,۷,۴,۸,۸)	(۳,۸,۵,۸,۷,۶)	(۵,۷,۸,۶)
A	(۴,۶,۶,۶,۸,۶)	(۳,۵,۷)	(۲,۶,۴,۶,۶,۶)	(۴,۲,۶,۲,۸)	(۵,۴,۷,۴,۸,۸)	(۳,۵,۷)	(۴,۶,۶,۶,۸,۴)

B) Crisp decision matrix

To form crisp decision matrix, the experts were asked to present their opinion based on a distance scale of 1-10. The experts' opinions integrated matrix is formed as follows:

Table 11: the integrated crisp decision matrix

	۶,۸	۴,۶	۵,۸	۸,۲	۷,۴	۶,۲	۵,۴
	۶,۲	۵	۱۰	۹	۹	۱۰	۷

	۶,۴	۵	۸,۲	۴,۸	۷	۴,۲	۵,۴
	۶,۶	۵	۴,۴	۴,۸	۷	۴,۶	۵,۴

Step 5: the evaluation of contraction companies using fuzzy TOPSIS, TOPSIS and ELECTRE
In this stage, after doing calculations and evaluating the contractors using three methods of fuzzy TOPSIS, crisp TOPSIS and ELECTRE, the obtained ranks is presented as follows:

Table 12: the ranking using here methods

Company	The rank based on FTOPSIS	The rank based on TOPSIS	The rank based on ELECTRE
KoushaMe'maranGharb	۲	۲	۱
Nil AbMostahkamGharb	۱	۱	۲
SamanGostarBardia	۳	۴	۳
ToosanBehin Industries	۴	۳	۳

As it could be seen from Table 12, Nil AbMostahkamGharb Company and KoushaMe'maranGharb Company, ranked the first at the ranking, based on TOPSIS-FTOPSIS and ELECTRE, respectively.
Step 6: ranking contractors using the mean of three techniques
Since, in this paper, three methods were applied to rank contractors, the obtained ranks are naturally different. In this situation, combination method is used to obtain the final rank. In this study, mean ranks method among different combination methods.
Before integrating the ranking obtained by three methods, the degree of concordance between the ranks obtained from three methods is determined by Kendal's coefficient of concordance. Kendal has introduced a criterion called coefficient of concordance which it is used for measuring general concordance, when there are more than two variables. The coefficient of concordance has a close relationship with Friedman test statistics (Kendal , 1939).

If we show Kendall's Coefficient of Concordance as w, there is the following relation between Friedman test statistics and Kendal's coefficient of concordance:

$$w = \frac{T}{b(k-1)} \qquad (38)$$

Therefore, w is a simple changed form of Friedman statistics, and by calculating T for w, it is possible to perform each hypothetical test in which w is calculated as test statistics. If the statistics degree of t-test rejects H0, the statistics w also rejects it. Therefore, it is possible to use same degree of Friedman test statistics for Kendal concordance test.
The degrees calculated by SPSS which the result of Friedman test is reported are described.
The following table shows Friedman test statistics along with P-value or same sig calculated by SPSS.

Table13: Friedman Test Results

Conclusion	**The Significance Level**	**Friedman test statistics**	**The Correlation between the Methods Rank**
There is a significant .relationship	۰,۷۷۹	۰,۵	ELECTRE،FTOPSIS،TOPSIS

Based on the results at the above table, the degree of test statistics is small and p-value is more than 0.05. This shows that, at the level $\alpha = 0.05$, assuming zero which is the concordance of the ranks is accepted by three methods and, in turn, we can integrate the ranks assigned to the companies by three methods.

Table 14: the final ranking of contracting companies based on three techniques

Final Ranks	The Mean of the Ranks	Rank Based on ELECTRE	Rank Based on TOPSIS	Rank Based on FTOPSIS	Company
۲	۱,۶۶	۱	۲	۲	KoushaMe'maranGharb
۱	۱,۳۳	۲	۱	۱	Nil AbMostahkamGharb
۳	۳,۳۳	۳	۴	۳	SamanGostarBardia
۳	۳,۳۳	۳	۳	۴	TosanSan'atBehin Industries

Based on the results from the above table, final contractors ranking is as follows:

$$A_2 > A_1 > A_3 = A_4$$

which it is seen that Nil Ab Mostahkam Gharb Company has the first rank and is introduced as the optimal contractor.

4-Conclusion

Tendering based on minimum price has some disadvantages which overshadow its advantages. As decision making parameter is bidding, some problems concerning time, quality, immunity, etc. may arise. Therefore, a multi criteria model was proposed in which along with cost of implementation, other qualitative and quantitative criteria during the execution of project are considered as well.

In this model, it is assumed that contractors perform project as best as it can and obtains maximum scores in terms of total proposed criteria. Considering the above and the results from the present paper, even though bidding is significant, it has achieved second rank among the applied criteria to evaluate and rank contractors. The present study showed that contactors are selected in Kermanshah Gas Company based on some qualifications and documents such as taking privilege of contracting authority rank from Iran Vice-Presidency of Planning and Strategic Supervision.

Although different criteria like ones applied to the present paper are used for ranking, the final selection of contractors is performed based on bidding. Since, to select contractors, it is possible to design decision matrix in which a couple of options are investigated based on some criteria, so it could be said that the present model could be used for selecting contractors in Gas Company. The difference between the proposed model and other models is that the contractors are ranked in both crisp and fuzzy environment, and the results from two methods are integrated and final ranking is specified.

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