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Group decision making process for contractor selection based on SWOT in fuzzy environment

L. Izadi,
Industrial Engineering Department
University of Payame Noor
Hamedan, Iran
izadi_ie@yahoo.com

G. Mohammadi
Industrial Engineering Department
University of Shahid Bahonar
Kerman, Iran
ghorbanalim@yahoo.co.uk

Abstract – **Currently competitive world outsourcing is one of the important strategies used by modern enterprises. Contractor selection is characterized as a multi-criteria decision-making problem that comprises tangible and intangible factors. Previous contractor selection techniques do not consider strategic perspective. This paper applied quantified SWOT in the context of contractor selection under a fuzzy environment, for the first time. In proposed strategic method, a semi-AHP with two hierarchies is established, main criteria for contractor selection are studied in first hierarchy, SWOT factors and their sub-factors are investigated in second. In some levels of hierarchies Pairwise comparison is used. By using fuzzy logic and triangular fuzzy numbers, human vagueness in decision making is considered.**

Proposed method is a quantified strategic method which captures imprecise human thought. Moreover it is interesting for managers for its applied aspect SWOT analysis and is applicable for every enterprise with some changes.

Key words- Contractor selection, Fuzzy logic, Semi-AHP, Quantified SWOT (Strengths, Weaknesses, Opportunities and Threats), Triangular fuzzy numbers.

I. INTRODUCTION

During the recent swift progress of network technology and economic globalization, modern industry has been trending towards the increasingly precise division of labor. Consequently, individual enterprises focus on developing their core capabilities and outsource non-core affairs to other partners with different professional capabilities to upgrade their competitive advantage by applying these external and special sources and technology knowledge [7]. Companies try to reduce costs and manage risks. It is important to know that one of the major portions of the firms' expenses is related to logistics activities which mostly are more than 50% of all companies' costs [1], [14]. The overall objective of contractor selection process is to reduce project risk, maximize overall value to the project owner, and build the close and long term relationships between members of the project. Contractor selection constitutes a critical decision for project owners. The selection process should embrace investigation of contractors' potential to deliver a service of acceptable standard, on time, and within budget [24]. Today's growing numbers of contractor selection methodologies reflect the increasing for improving procurement process and performance [28].

When researchers and practitioners have realized that lowest-price is not the promising approach to attain the overall lowest project cost upon project completion, multi-criteria selection becomes more popular [8], [10].

In the previous research, several authors considered the contractor selection problem. But most of them considered contractor selection in construction industry and other fields are disregarded, whereas many other companies such as energy generation and distribution companies face to this problem. More ever, most of previous investigations didn't pay attention to strategic perspective. SWOT (Strengths, Weaknesses, Opportunities and Threats) is a useful technique which is commonly known in strategic management area. SWOT analyzes the external opportunities and threats as well as the internal strengths and weaknesses. Besides, it is one of the most famous tools for strategy formulation. The goal of the analysis of external opportunities and threats is to evaluate whether a company can capture opportunities and avoid threats when facing an uncontrollable external environment such as change in the rule of [5], [14].

In this paper, we use quantified SWOT analysis as a decision tool to formulate strategic plans for contractor selection. To our knowledge, no one has applied SWOT analysis in contractor selection. In this paper, we used the concept of fuzzy set theory and linguistic values to overcome uncertainty and qualitative factors. Then, two hierarchies MCDM model based on fuzzy sets theory and SWOT analysis are proposed to deal with the contractor selection problems. Pairwise comparison used in model, make the obtained weights of criteria are more precise. Fuzzy logic has been integrated with SWOT analysis to deal with vagueness and imprecision of human thought. The model applied in electric distribution company also it's applicable to use in other companies. The proposed decision model is comprehensive and competitive for contractor selection due to its dynamic nature and strategic oriented.

The organization of this paper is as follows: Section 2 discusses the literature review about contractor selection and SWOT. Fuzzy AHP and EAM are presented in Section 3. In Section 4, methodology is illustrated. Case study is presented in Section 5. Finally, conclusions are presented in Section 6.

II. LITERATURE REVIEW

A. Contractor selection

Bozbura, Beskese & Kahraman (2007) developed a quantitative model for selecting construction contractors which utilizes the multi-attribute analysis (MAA) technique [3]. Sonmez, Yang & Holt (2001) applied the evidential reasoning (ER) approach (which is capable of processing both quantitative and qualitative measures) as a means of solving the contractor selection problem (CSP) [23]. Hatush & Skitmore (1998) proposed a systematic multi-criteria decision analysis technique that is described for contractor selection and bid evaluation based on utility theory and which permits different types of contractor capabilities to be evaluated [15]. Chau, Sing & Leung (2003) tested how different managers choose maintenance contractors. This in turn led them to focus on the identification of the major selection attributes, and the trade-off weightings among attributes during the selection process [6].

El-Sawalhi, Eaton & Rustom (2007) suggested a state-of-the-art model for contractor's pre-qualification by using a hybrid model, combining the merits of Analytical Hierarchy Process (AHP), Neural Network (NN) and Genetic Algorithm (GA) in one consolidated model [13].

Juan (2009) proposed a systematic decision support approach to solve housing refurbishment contractor selection problem by using case-based reasoning (CBR) and data envelopment analysis (DEA) [18]. Darvish, Yasaei & Saeedi (2009) showed how the graph theory and matrix methods may be served as a decision analysis tool for contractor selection [10].

Doloi, Iyer & Sawhney (2011) established a hierarchical structural model to understand pre-emptive qualification criteria and their links to contractors' performance on a project, By employing the structural equation modeling technique [11].

Jaskowski, Biruk & Bucon (2010) suggested the application of an extended fuzzy AHP method to the process of group decision making in contractor selection problem [17]. Watt, Kayis & Willey (2010) used an experimental design approach to quantify the importance of nine common criteria used in an actual evaluation and selection of a contractor/supplier [26].

Ng & Tang (2010) established a set of Critical Success Factors (CSFs) for construction sub-contractors which are labor-intensive in nature [22].

B. Quantified SWOT

SWOT (Strengths, Weaknesses, Opportunities and Threats) is one of the most well-known techniques for conducting a strategic study [14]. SWOT analysis is a commonly used tool for analyzing internal and external environments in order to attain a systematic approach and support for a decision situation (e.g. [19], [27]). Kurttila, Pesonen, Kangas & Kajanus (2000) presented a hybrid method for improving the usability of SWOT analysis [20]. AHP's connection to SWOT yields analytically determined priorities for the factors included in SWOT analysis and makes them commensurable. Reference [30] using Analytic Network Process (ANP), demonstrated a process for quantitative SWOT analysis that can be performed when there is dependence among strategic factors.

Chang & Huang (2006) presented a Quantified SWOT analytical method which provides more detailed and quantified data for SWOT analysis. The Quantified SWOT analytical method adopts the concept of Multiple-Attribute Decision Making (MADM), which uses a multi-layer scheme to simplify complicated problems, and thus is able to perform SWOT analysis on several enterprises simultaneously [5].

III. FUZZY AHP AND EAM

Fuzzy set theory was introduced by Zadeh in 1965 to solve problems involving the absence of sharply defined criteria [31]. Because fuzziness and vagueness are common characteristics in many decision-making problems, good decision-making models should be able to tolerate vagueness or ambiguity [29]. Thus, if the uncertainty (fuzziness) of human decision-making is not taken into account, the results from the models can be misleading. Fuzzy theory has been applied in a variety of fields since its introduction. Many fuzzy AHP methods are proposed to solve various types of problems [21]. The main theme of these methods, is using the concepts of fuzzy set theory and hierarchical structure analysis to present systematic approaches in selecting or justifying alternatives [3].

Zhu et al. proves the basic theory of the triangular fuzzy number and improves the formulation of comparing the triangular fuzzy number's size. Reference [4] introduced an approach for handling fuzzy AHP, using triangular fuzzy number for pairwise comparison scale of fuzzy AHP, and the use of Extent Analysis Method (EAM) for the synthetic extent value of the pairwise comparison.

Reference [25] claimed that the extent analysis method cannot estimate the true weights from a fuzzy comparison matrix and has led to quite a number of misapplications in the literature. They revised the normalize formula in Chang's EAM method. In this paper we used of revised version briefly discussed here.

1. sum up each row of the fuzzy comparison matrix $\tilde{A} = (\tilde{a}_{ij})_{n\times n}$, $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ by fuzzy arithmetic operations:

$$RS_i = \sum_{j=1}^{n} \tilde{a}_{ij} = \left(\sum_{j=1}^{n} l_{ij}, \sum_{j=1}^{n} m_{ij}, \sum_{j=1}^{n} u_{ij} \right), \quad i = 1,\ldots,n. \qquad (1)$$

2. normalize the above row sums by

$$\tilde{S}_i = \frac{RS_i}{\sum_{j=1}^{n} RS_j} = \left(\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{j=1}^{n} l_{ij} + \sum_{k=1, k\neq i}^{n} \sum_{j=1}^{n} u_{kj}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{k=1}^{n} \sum_{j=1}^{n} m_{kj}}, \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{j=1}^{n} u_{ij} + \sum_{k=1, k\neq i}^{n} \sum_{j=1}^{n}} \right), \quad i = 1,\ldots,n. \qquad (2)$$

3. compute the degree of possibility of $\tilde{S}_i \geq \tilde{S}_j$ by the following equation:

$$V(\tilde{S}_i \geq \tilde{S}_j) = \begin{cases} 1, & if m_i \geq m_j, \\ \frac{u_i - l_j}{(u_i - m_i) + (m_j - l_j)} & if l_j \leq u_i, \\ 0, & others \end{cases}$$

$$i, j = 1,\ldots,n;\ j \neq i \qquad (3)$$

Where $\tilde{S}_i = (l_i, m_i, u_i)$ and $\tilde{S}_j = (l_j, m_j, u_j)$.

4. calculate the degree of possibility of $\tilde{S}_i$ over all the other $(n-1)$ fuzzy numbers by

$$V(\tilde{S}_i \geq \tilde{S}_j \mid j = 1,\ldots,n; j \neq i) = \min_{j\in\{1,\ldots,n\}, j\neq i} V(\tilde{S}_i \geq \tilde{S}_j), \quad i = 1,\ldots,n. \qquad (4)$$

5. define the priority vector $W = (w_1,\ldots,w_n)^T$ of the fuzzy comparison matrix $\tilde{A}$ as

$$w_i = \frac{V(\tilde{S}_i \geq \tilde{S}_j \mid j = 1,\ldots,n; j \neq i)}{\sum_{j=1}^{n} V(\tilde{S}_k \geq \tilde{S}_j \mid j = 1,\ldots,n; j \neq k)}, \ i = 1,\ldots,n. \qquad (5)$$

III. METHODOLOGY

Based on [21] and [5] a systematic fuzzy model for contractor selection is proposed in this section. When the number of candidates and criteria grows, the pairwise comparison process becomes cumbersome, and the risk of generating inconsistencies grows. In addition, AHP, like as many systems which work based on pairwise comparisons, can produce ''rank reversal'' results [12]. Then we do not use pair wise comparison between criteria in each level of MCDM hierarchies. In some levels, that it is necessary, pair wise comparison is used and in others linguistic variables is used. The steps are summarized as below:

Step 1. Form the committee of experts: in the first step it's necessary to form a committee of experts in contractor selection in the company and define the problem and model.

Step 2. Model a criteria hierarchy: Form the hierarchy with the selection the best contractor as goal in first level, main company's criteria for contractor selection in second level and SWOT in third level (Fig . 1).The goal of the control hierarchy is to calculate the relative importance of the S,W,O and T factors.

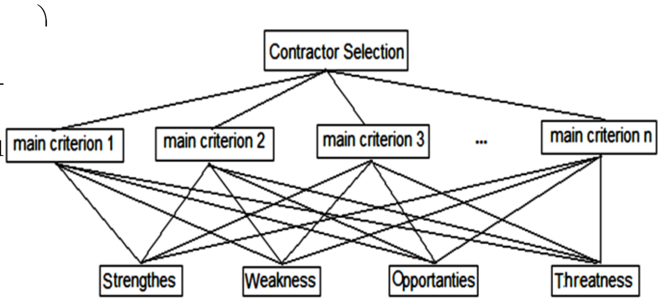

Fig. 1 Main criteria hierarchy

Step 3. Determine the priorities of SWOT in problem: Formulate the questionnaire and give to experts to fill them. This step is very important and time consumer. Determination the importance relative to main criteria is done through pairwise comparison between them. Alternatives in pairwise comparison questions are consist of "equal important (E), rather important (R), important (I), very important (V) and absolutely important (A) ". These linguistic variables are quantified as fuzzy numbers shown in Fig. 2.

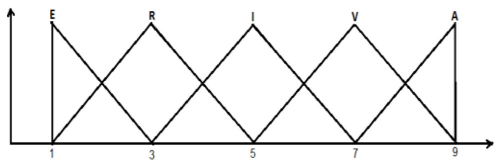

Fig. 2 Linguistic scale for pairwise comparison

Fuzzy relations and membership function in this section are as TABLE I:

TABLE I: Characteristic function of the fuzzy numbers

Fuzzy number	Membership function
$\tilde{x}$	(x-2, x, x+2)
$\frac{1}{\tilde{1}}$	$(3^{-1}, 1^{-1}, 1^{-1})$
$\frac{1}{\tilde{x}}$	$((x+2)^{-1}, x^{-1}, (x-2)^{-1})$
$\frac{1}{\tilde{9}}$	$(\tilde{9}, \tilde{9}, 7^{-1})$

Different linguistic variables that is used is scale of Amin and Razmi (2009) " Very low (VL), low (L), medium low (ML), medium (M), medium high (MH), high (H), very high (VH)" is the linguistic set used to express opinions on the group of attributes, that shown in Fig. 3 [2].

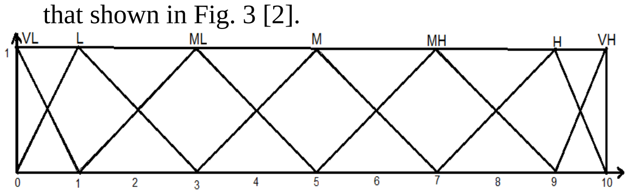

Fig. 3 Linguistic scale [2]

Step 4. Calculate crisp relative weights for main criteria: Calculate crisp relative importance weights for main criteria for attaining the goal. From each expert's questionnaires answers, establish fuzzy importance weights for main criteria.

A triangular fuzzy number is obtained by combining the expert's options.

And (l_t, m_t, u_t) is the importance weight form expert t. By adopting the extent analysis method (EAM) introduced in **S**ection 3, calculate crisp relative importance weights for main criteria.

Step 5. Calculate crisp relative weights for SWOT merits: For calculating crisp relative importance for SWOT factors with respect to goal, firstly calculate importance for each of SWOT factors with respect to main criteria by combination fuzzy importance weight provided from questionnaire. Then multiply these weights in weights of main criteria (in upper level) and sum fuzzy number obtained. Finally defuzz obtained number for each of SWOT factors by centroid method by (6).

The simple and popular method, centroid method is adopted to defuzzify triangular fuzzy numbers [9], It should be mentioned that the above methodology is simple and easy to use [14].

A defuzzified triangular fuzzy number $\tilde{D} = (n^-, n, n^+)$, is calculated by (6).

Defuzzified number =1/3 $(n^- + n + n^+)$ (6)

Step 6. Model a SWOT hierarchy: model a hierarchy with contractor selection as goal in first level, SWOT merits are in second level; in third level form sub hierarchy for each merit and lowest level contains the alternatives (contractors) that are under evaluation. SWOT hierarchy is sown in Fig. 4.

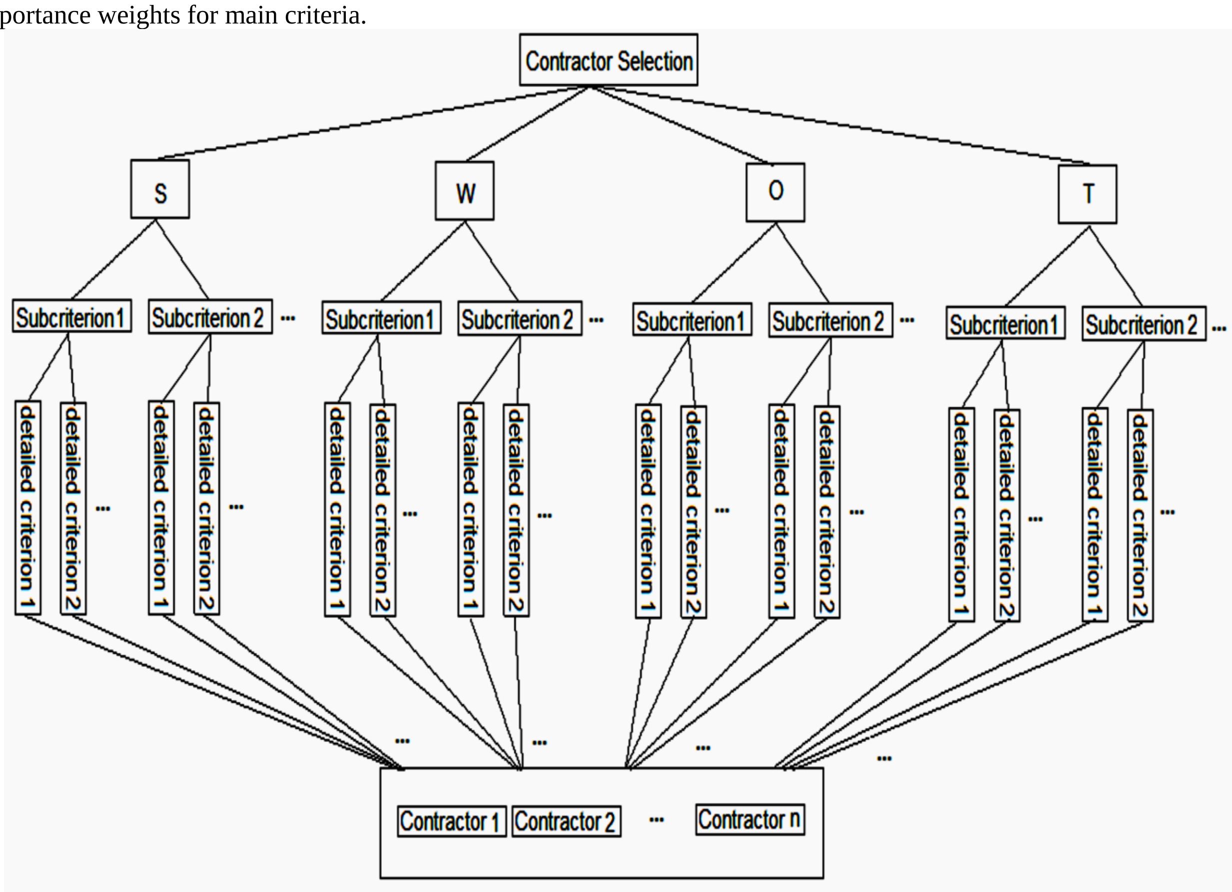

Fig. 4. SWOT hierarchy

Step 7. Publish an advertisement: The members of committee decide publish an advertisement in newspaper to identify the tier suppliers who are interested to contribute in the project. The team announce requirements such as financial ability, ...

Step 8. Model a questionnaire and determine scores of contractors: formulate a questionnaire to pair wise compare elements in level 3, 4 with respect to same upper level elements. Using the linguistic variables that shown in Fig. 2, and to consider preferences and scores of contractors with respect to detailed criterion, using the linguistic scale shown in Fig. 3.

Step 9. Calculate crisp relative importance weight sub-criterion and detailed criterion: Crisp importance relative for SWOT with respect to goal (contractor - selection) is obtained already.

Crisp relative weights sub-criterion and detailed criterion with respect to same upper level is calculated by using similar procedure in step 4.

Step 10. Calculate crisp score relative contractors: This step is performed by using similar procedure in step 5.

Step 11. Calculate the coordinated values for each contractor by (7) and (8), and compare the results. Then, demonstrate these values on the four-quadrant: firstly, the benchmarking value is subtracted from total weighted scores. The final value will be the coordinated value of the compared contractor in the SWOT matrix.

$$IC_j = I_j - IB \qquad j = 1,2,\ldots,n \tag{7}$$

$$EC_j = E_j - EB \qquad j = 1,2,\ldots,n \tag{8}$$

where IC_j is the internal (contained S,W) coordinated value of the j th contractor, I_j is the internal total weighted value of the j th contractor, IB is the benchmarking value of the internal assessment, EC_j is the external (contained O,T) coordinated value of the j th contractor, E_j is the external total weighted value of the j th contractor, and EB is the benchmarking value of the external assessment.

The contractor possesses strengths and opportunities when the coordinated value is larger than the benchmarking value. On the other hand, the contractor is comparatively weak and faces threats when the coordinated value is smaller than the benchmarking value.

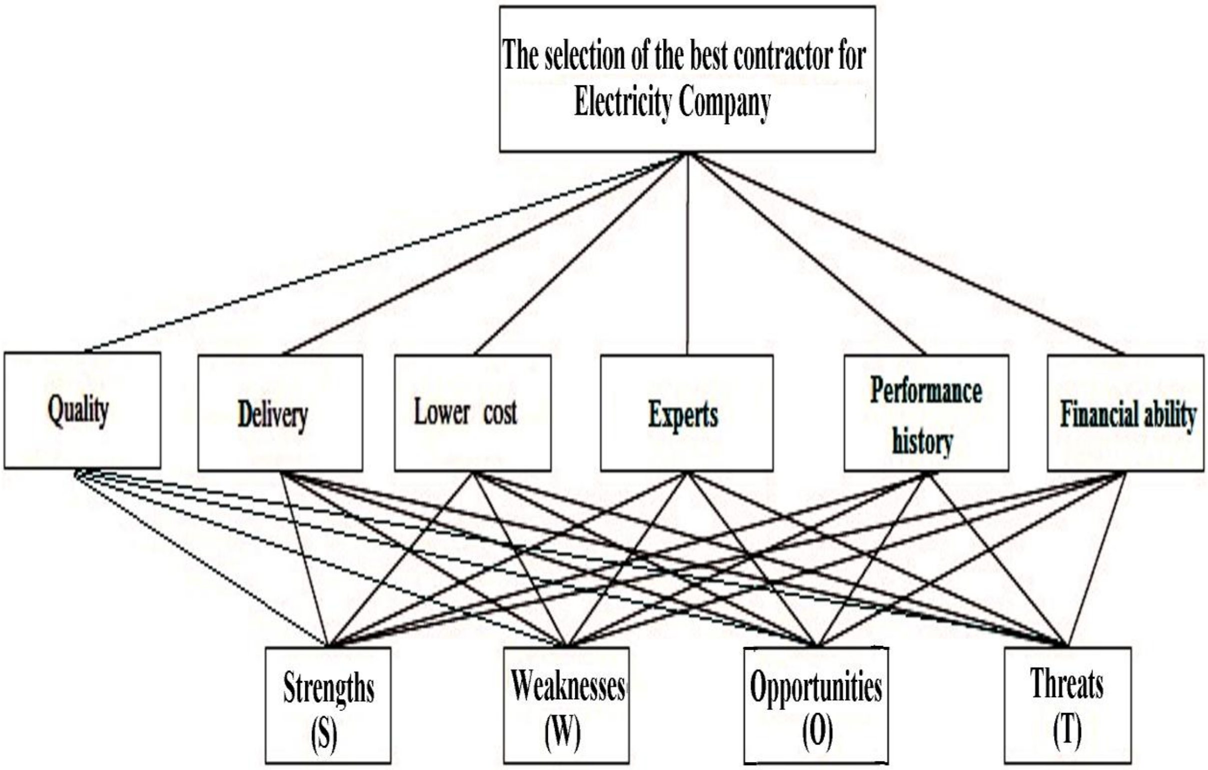

Fig. 5. Main hierarchy for Electricity Company

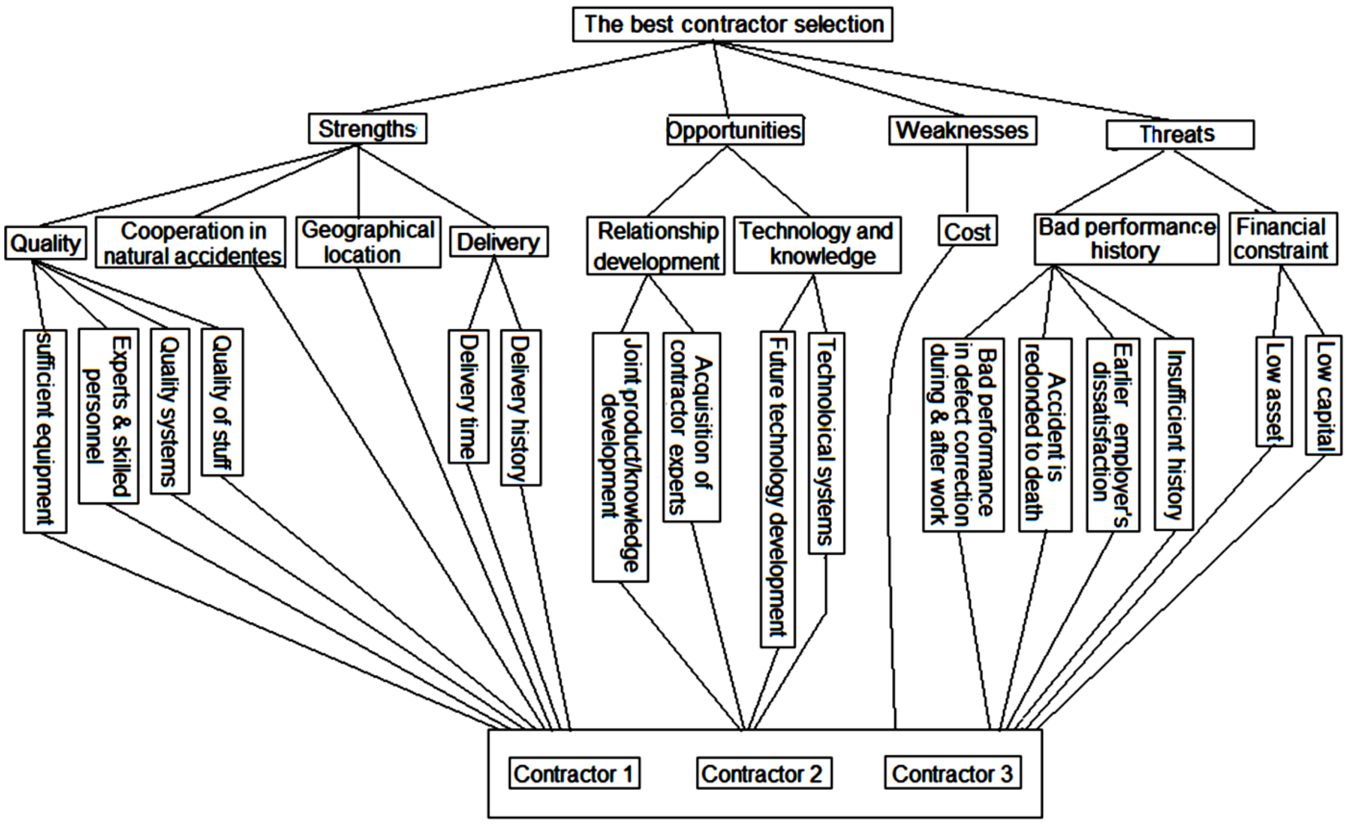

Fig. 6. SWOT hierarchy for Electricity Company

IV. CASE STUDY

A case study is presented in this section to demonstrate the practicality of proposed model. The model examined in Electricity Company of South Kerman. A committee including three experts from engineering and commercial departments in Electricity Company is formed. The research scope is in transition lines constructors in Iran.

With review of literature, consultation with experts and consideration of documents, main criteria hierarchy (Fig. 5) and SWOT hierarchy (Fig. 6) is organized. An advertisement is published in newspaper to identify the contractors who are interested to contribute in the project and requirement is announced.

The questionnaires are prepared and targeted on experts to fill. Fuzzy importance relative for main criteria is established based on the pairwise comparison results. For example, the pairwise comparison results between quality and sufficient delivery are (3,5,7), (1,3,5) , (5,7,9). The experts opinions are as below:

$$n^{-} = (3 \times 1 \times 5)^{\frac{1}{3}} = 2.466$$

$$n = (5 \times 3 \times 7)^{\frac{1}{3}} = 4.718$$

$$n^{+} = (7 \times 5 \times 9)^{\frac{1}{3}} = 6.805$$

Crisp weights relative main criteria in contractor are calculated by EAM. Then S, W, O, T rating are obtained, results are shown in TABLE II.

The crisp values for decision matrix and weight of internal and external criteria are computed as shown in TABLE III, IV.

Score of every detailed criteria is provided by decision makers. Average of decision makers' opinions is the score of detailed criteria which is a triangular fuzzy number, these fuzzy numbers are defuzzed by (6) and crisp score for each contractor is obtained.

With multiplying score of detailed criteria (internal and external) in their weights for each contractor and sum the results, internal total weighted values and external total weighted values for each contractor is obtained, as shown in TABLES V, VI.

TABLE II
SWOT rating

	Quality (0.298)	Lower cost (0.134)	Sufficient delivery (0.244)	Financial ability (0.119)	Cooperation history (0.04)	Performance history (0.096)	Experts (0.069)	Final priority	Normalized weights
Strengths	0.276	0.22	0.271	0.213	0.291	0.282	0.405	0.269	0.512
Weaknesses	0.287	0.247	0.249	0.265	0.186	0.269	0.161	0.256	0.488
Opportunities	0.16	0.253	0.271	0.189	0.291	0.193	0.303	0.221	0.466
Threats	0.276	0.28	0.208	0.333	0.231	0.265	0.131	0.253	0.534

TABLE III
Relative priorities of internal criteria (S,W), Sub-criteria, Detailed criteria

Factors	Sub-criteria	Local weights	Detailed criteria	Local weights	Normalized weights
Strengths (0.512)	Quality	0.368	Quality of stuff	0.616	0.116
			Quality systems	0	0
			Experts& skilled personnel	0.232	0.044
			Sufficient equipment	0.152	0.029
	Delivery	0.275	Delivery time	0.5	0.07
			Delivery history	0.5	0.07
	Geographical location	0.09			0.046
	Cooperation in natural accidents	0.267			0.137
Weaknesses (0.488)	Cost				0.488
				Sum	1

TABLE IV
Relative priorities of external criteria (O,T), Sub-criteria, Detailed criteria

Factors	Sub-criteria	Local weights	Detailed criteria	Local weights	Normalized weights
Opportunities (0.466)	Relationship development	0.752	Joint product/knowledge development	0.823	0.288
			Acquisition of contractor's experts	0.177	0.062
	Technology and knowledge	0.248	Technological systems	0.855	0.099
			Future technology development	0.145	0.017
Threats (0.534)	Financial constraint	0.587	Low capital	0.734	0.23
			Low asset	0.266	0.083
	Bad performance history	0.414	Earlier employer's dissatisfaction	0.312	0.069
			Accident is redounded to death	0.365	0.081
			Insufficient history	0.169	0.037
			Bad performance in defect correction during& after work	0.154	0.034
				Sum	1

TABLE V

scores and Internal total weighted values for each contractor

Internal detailed criteria	weight	Scores Contractor 1	Contractor 2	Contractor 3
Quality of stuff	**0.116**	**3.17**	**4**	**6**
Quality systems	**0**	**1.22**	**4.33**	**3.78**
Experts& skilled personnel	**0.044**	**5**	**6.33**	**7.44**
Sufficient equipment	**0.029**	**7.78**	**7.56**	**6.89**
Delivery time	**0.07**	**6.33**	**6.33**	**8.44**
Delivery history	**0.07**	**6.89**	**8.67**	**6.89**
Geographical location	**0.046**	**8.44**	**5**	**4.44**
Cooperation in natural accidents	**0.137**	**6.89**	**3.11**	**5**
Cost	**0.488**	**6.89**	**4.33**	**5**
Internal total weighted values		**6.433**	**4.781**	**5.626**

(7) and (8), as shown in table 7. The benchmarking value is subtracted from total weighted scores. The final value will

n the SWOT matrix. Fig. 7 shows the position of contractors in the competition and helps the manager of company to evaluate contractor.

TABLE VI

scores and external total weighted values for each contractor

External detailed criteria	weight	Scores Contractor 1	Contractor 2	Contractor 3
Joint product/knowledge development	**0.288**	**5.56**	**5**	**7.56**
Acquisition of contractor's experts	**0.062**	**5.56**	**5.67**	**7.56**
Technological systems	**0.099**	**5**	**5.67**	**5.67**
Future technology development	**0.017**	**5.67**	**6.33**	**7.56**
Low capital	**0.23**	**4.33**	**3.11**	**3.78**
Low asset	**0.083**	**5**	**3.67**	**3.78**
Earlier employer's dissatisfaction	**0.069**	**4.33**	**3**	**3.11**
Accident is redounded to death	**0.081**	**4.44**	**1**	**0.67**
Insufficient history	**0.037**	**2.78**	**3**	**2.44**
Bad performance in defect correction during& after work	**0.034**	**1.89**	**3.11**	**2.44**
External total weighted values		4.774	3.985	4.961

TABALE VII

Coordinated values for each contractors in SWOT matrix

	Contractor 1	Contractor 2	Contractor 3	Benchmarking value (average)
Internal total weighted value	**6.433**	**4.781**	**5.626**	**5.613**
Internal coordinated value (x-axis)	**0.82**	**-0.832**	**0.013**	
External total weighted value	**4.774**	**3.985**	**4.961**	**4.573**
External coordinated value (y-axis)	**0.201**	**-0.588**	**0.388**	

As it can be seen in Fig. 7, contractor 1,3 are located in the first quadrant. It means that these two suppliers have external opportunities for development and potentially have internal competing strength to get the opportunities. Therefore, it can be concluded that they are in the best position for facing competition. Contractor 2 (in the third quadrant) has low competitive strength and facing threats from other competitors.

Fig. 7 SWOT analysis

VI. CONCLUSION

During the recent swift progress of network technology and economic globalization, modern industry has been trending towards the increasingly precise division of labor. Consequently, individual enterprises focus on developing their core capabilities and outsource non-core affairs to other partners with different professional capabilities. Companies try to reduce costs and manage risks. It is important to know that one of the major portions of the firms' expenses is related to logistics activities which mostly are more than 50% of all companies' costs. The overall objective of contractor selection process is to reduce project risk, maximize overall value to the project owner, and build the close and long term relationships between members of the project.

The aim of this paper is to propose a model based on quantified SWOT in fuzzy environment to solve contractor selection problem. In proposed strategic method, a semi-AHP with two hierarchies is established, main criteria for contractor selection are studied in first hierarchy and strengths, weaknesses, opportunities, threats (SWOT) and their sub-factors are investigated in second. Pairwise comparison is used in some levels of hierarchies. Weights of attributes and score matrix obtained from decision makers' opinion, which are in linguistic variable form. With aggregation decision makers' opinion, fuzzy decision matrix is obtained. From the score matrix, attribute weight information and using Quantified analytical method we establish a model to select the best contractor. A case study is presented to demonstrate the practicality of proposed model. The model examined in Electric Company of South Kerman. Results is shown in section 5. Proposed method is a quantified strategic method and deal with imprecisely human thought also. Moreover it's interesting for managers for its applied SWOT analysis. This model is applicable for every enterprise with some changes

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