Iranian Journal of Management Studies (IJMS)
Vol. 7, No. 1, January 2014
pp. 151-173

Contractor selection in MCDM context using fuzzy AHP

Rahmatollah Gholipour[1], Gholamreza Jandaghi[2], Reza Rajaei*[3]

1. Associate Professor, Faculty of Management, University of Tehran, Iran
2. Professor, Faculty of Management Farabi Campus, University of Tehran, Iran
3. PhD Candidate of Financial Management, Faculty of Management, Farabi Campus, University of Tehran, Iran

(Received: 30 December 2012; Revised: 20 June 2013; Accepted: 30 June 2013)

Abstract

Contractor selection is one of the most important problem in supply chain and its strongly effect on firm`s performance. Because a significant amount of a university`s budget assigns to construction contracts, contractor selection is an important problem for the financial status of universities. Since Contractor selection is a multi-criteria decision making problem (MCDM), lots of methods proposed to face this problem. Selection is a broad comparison of contractors using a common set of criteria and measures. Analytic hierarchy process (AHP) and other traditional methods widely used for contractor and vendor selection by researches regarding to lots linguistic variables and both qualitative and quantitative criteria and to tackle ambiguous nature of contractor selection problem, although there is some Insufficiency about them. In this article we use FAHP that is a fuzzy extension of AHP to handle the fuzziness of the data involved in deciding the preferences of different decision variables. The linguistic level of comparisons produced by experts for each comparison is tapped in the form triangular fuzzy numbers to construct fuzzy pairwise comparison matrices. We priorities Tehran university`s construction contractor about each criteria and determine the best one about all of them.

Keywords:

analytic hierarchy process, contractor selection, fuzzy set theory, multi-criteria decision making problem. .

---

* Corresponding Author, Tel: +982122117089 Email: r.rajaei@ut.ac.ir

Introduction

In recent years supplier selection problem has received considerable attention in the supply chain management literature. There are many companies that tend to increase their financial performance through cutting their costs by chosing a suitable supplier. Since a significant part of the company's budget assign to contractor contracts, choosing the right supplier is very important. The contemporary supply management is to maintain long term partnership with suppliers, and use fewer but reliable suppliers. Therefore, choosing the right suppliers involves much more than scanning a series of price list, and choices will depend on a wide range of factors which involve both quantitative and qualitative. (Ho *et al*., 2010) Because of many criteria and different suppliers, how to choose a suitable and right supplier is important for many corporations. A suitable supplier may become and develop into a cooperative and long-term partnership in SCM, which can help the growth of a company and can be crucial to the success of the business (Chen & Chao, 2012).

In each industry such as construction, there are a lot of contractor companies which claim that they supply their services with the lower price, better quality and more suitable to the firm`s needs than their competitors. Companies try to find a contractor that brings the most beneficiary in comparison with others and this beneficiary can be in each criteria such as cost, quality, flexibility and so on. Simultaneously taking all of these factors into account is difficult for decision makers and managers, so they prefer to focus on just one or two more important factors and ignore other factors even though they are significant in determine the most suitable contractor (Lee, 2009).

Most of supplier selection proposed models are according to simple decision making supposes. It doesn’t seem most of this method pay attention to the unstructured and complicated nature of current contract and venture decisions (Boer *et al*., 1998). The nature of supplier selection decision making problems is generally complicated and unstructured and there are many quantitative and qualitative criteria that must be considered to identify the appropriate supplier. Supplier selection and evaluation is especially an MCDM problem consists of multi-criteria factors and the factors can be both qualitative and quantitative. Since supplier selection problem process requires a formal, systematic and rational choosing model, There`re lots of proposed models about supplier selection and evaluation (Huang *et al*., 2006).

MCDM approaches extensively proposed for supplier selection such as the analytic network process (ANP), fuzzy set theory, analytic hierarchy process (AHP), data envelopment analysis (DEA), mathematical programming, case-based reasoning (CBR), genetic algorithm (GA) and simple multi-attribute rating technique (SMART) (Ho *et al*., 2010). Finding the best way to evaluate and select supplier is difficult and companies use different ways facing this problem. Then the most important issue in supplier selection is to develop a method to choose the right supplier and it's essential to use a systematical and effective procedure or method to select the most appropriate supplier (Chen & Chao, 2012; Chen *et al*., 2006). Some innovative approaches, based on artificial intelligence techniques such as Fuzzy Logic match very well with decision-making situations where supplier's evaluation is also perceptive, decision-makers express heterogeneous judgments, many decision rules are implied and unstructured, precise and accurate data are not available (Dulmin *et al*., 2003).

In this study we aim to prioritize contractor selection criteria and rank the construction contractors according to decision aims with take all of the essential criteria into account by utilizing the structure of criteria in the fuzzy analytic hierarchy process (FAHP). The main questions of this study are as follows:

1. What is the rank of construction contractors in our decision model, according to all contractor criteria?
2. What is the rank of construction contractors in our decision model, according to each contractor criterion?

The rest of the paper is arranged as follows. Firstly, the recent rating methods in supplier selection will be briefly discussed. Secondly, the essential criteria for supplier selection will be reviewed and we will portray the decision hierarchy of this paper. The proposed method uses the FAHP to rank contractors. Therefore, thirdly, the fuzzy set theory and fuzzy AHP will be briefly described. Then, the proposed rating method using FAHP is presented. Finally, we will rank construction contractors using FAHP process and we will demonstrate the contractor rating according to both each criterion and decision model as a whole.

Background

There are lots of keywords associated with the supplier selection. The term "supplier selection" and "vendor selection" are interchangeably used in the literature. These two terms have a same meaning about the process of selection. The term "contractor selection" and "tender selection" refer to similar processes to supplier selection. The term "contractor selection" is mostly associated with the purchasing of services offered by a firm in urban and engineering and construction industry in particular. (Snomez, 2006). Research on supplier selection can be traced back to the early 1960s and different solution methodologies have been proposed to deal with it, ranging from linear programming to nonlinear programming. Treating supplier selection as an optimization problem requires the formulation of an objective function. (Huang *et al*., 2007).

Braglia and Petroni (2000) applied DEA to measure the efficiencies of alternative suppliers. Forker and Mendez (2001) applied DEA to measure the comparative efficiencies of suppliers. Liu *et al*. (2000) proposed a simplified DEA model to evaluate the overall performances of suppliers with respect to three input and two output criteria. Narasimhan *et al*. (2001) applied DEA model to evaluate alternative suppliers for a multinational corporation in the telecommunications industry. Talluri and Baker (2002) used a three-phase approach for the logistics distribution network design. Talluri and Sarkis (2002) applied DEA to measure the performance of suppliers. Talluri and Narasimhan (2004) applied DEA for effective supplier sourcing. Garfamy (2006) applied DEA to measure the overall performances of suppliers based on total cost of ownership concept. Ross *et al*. (2006) used DEA to evaluate the supplier performance with respect to both buyer and supplier performance attributes. Saen (2006) developed a DEA model to evaluate technology suppliers with respect to three factors, in which there was a qualitative factor – amount of know-how transfer. Seydel (2006) used DEA to tackle the supplier selection problem. Talluri *et al*. (2006) presented a so-called chance-constrained DEA approach to evaluate the performance of suppliers in the presence of stochastic performance measures. Saen (2007) presented a so-called imprecise DEA to evaluate the performance of suppliers in the presence of both quantitative and qualitative data. Wu *et al*. (2007) presented a so-called augmented imprecise DEA for supplier selection. Talluri and Narasimhan (2005) developed a linear programming model to evaluate and select potential suppliers with respect to the strengths of existing suppliers and exclude underperforming suppliers from a telecommunications company’s supply base. Ng (2008) developed a weighted linear programming model for the supplier selection problem. Hong *et al*. (2005) presented a mixed-integer linear programming model for the supplier selection problem. Narasimhan *et* *al*. (2006) constructed a multi-objective programming model to select the optimal suppliers and determine the optimal order quantity possible ways of generating the weightings. Wadhwa and Ravindran (2007) modeled the supplier selection problem as a multi-objective programming problem.

In recent decade there were some researches about a contractor or supplier evaluation and selection that use AHP, fuzzy set theory and integration of these two methods to deal with supplier selection problems. Akarte *et al*. (2001) developed a web-based AHP system to evaluate the casting suppliers with respect to 18 criteria. Muralidharan *et al*. (2002) proposed a five-step AHP-based model to aid decision makers in routing and selecting suppliers with respect to nine evaluating criteria. Chan (2003) developed an interactive selection model with AHP to facilitate decision makers in selecting suppliers. Chain and Chan (2004) applied AHP to evaluate and select suppliers. Liu and Hai (2005) applied AHP to evaluate and select suppliers. Chan *et al*. (2007) developed an AHP-based decision making approach to solve the supplier selection problem. Hou and Su (2007) developed an AHP-based decision support system for the supplier selection problem in a mass customization environment. Chen *et al*. (2006) presented a hierarchy model based on fuzzy sets theory to deal with the supplier selection problem. Sarkar and Mohapatra (2006) suggested that performance and capability were two major measures in the supplier evaluation and selection problem. Florez-Lopez (2007) picked up 14 most important evaluating factors from 84 potential added-value attributes, which were based on the questionnaire response from US purchasing managers. Xia and Wu (2007) incorporated AHP into the multi-objective mixed integer programming model for supplier selection. Kahraman *et al*. (2003) applied a fuzzy AHP to select the best supplier in a Turkish white good manufacturing company. Chan and Kumar (2007) also used a fuzzy AHP for supplier selection. Chain and Chan (2010) proposed an AHP based model to solve the supplier evaluation and selection problem taking the example of fashion industry. Kumar and Roy (2011) proposed a rule based model with the application of AHP to aid the decision makers in vendor evaluation and selection taking the power transmission industry. Chang *et al*. (2011) proposed fuzzy decision making trial and evaluation laboratory (DEMATEL) method to effectively find evaluation factors for supplier selection. Jiang and Chan (2011) proposed a methodology with the application of fuzzy set theory (FST), based on twenty criteria to deal with supplier evaluation and selection problem. This paper tried to go beyond the previous literature and considers all the significant criteria, which have been ignored in the supplier selection problem. There are a bit articles about contractor selection, so to deal with contractor selection problems (like construction contractor selection as it investigated in this paper) that we often deal with some companies which their supply is a combination of their products and services, the context of selection is different and supplier selection model must fit to such context properly.

Contractor selection criteria

C_1: Technical: To provide a consistently high quality product or service, promote successful development efforts, and ensure future improvements, a firm needs competent technical support from its suppliers.

C_2: Capability and skill: The potential capacity to produce a good or service. Some factors that should be considered are internal manufacturing capacity, constraining processes, direct labor availability and key components/materials availability.

C_3: Financial: The firm should require its suppliers to have good financial position. Financial strength can be a good Indicator of the supplier's long-term stability. A solid financial position also helps ensure that performance standards can be maintained and that products and services will continue to be available.

C_4: Managerial: Maintaining a good supplier relationship requires management stability. The firm should have confidence in its supplier's management's ability to run the company. It is also important that the supplier's management be committed to managing its supply base. The supplier's level of quality, service, and cost are directly affected by its supplier's ability to meet its needs.

C_5: Facilities and support resource: The supplier's resources need to be adequate to support product or service development. Criteria need to consider the supplier's facilities, information systems, and provisions for education and training.

C_6: Performance history: The historical experiments of working with a special supplier and the amount of satisfaction or dissatisfaction.

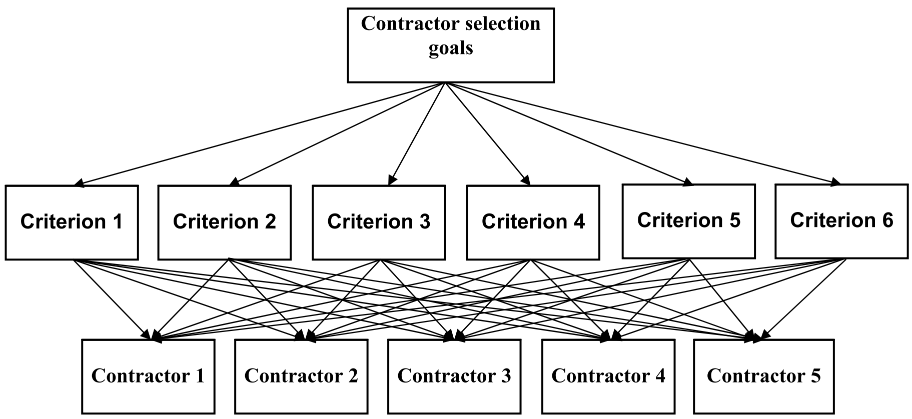

Figure 1. Hierarchy for Contractor selection

Contractor selection decision making hierarchy tree is portrayed in figure 1. The contractors have been choosen among construction companies which sent their proposal price to technical office, Tehran university to participate in establishing Tehran university dormitory building trend that was held in 2010. The contractors are Bonyan Saze, Charbarg, Abad Tadbir, Tabanshahr and Omran Vaheb in order to contractor numbers.

Fuzzy set theory and fuzzy AHP

The analytic hierarchy process (AHP) is widely used for tackling multi-attribute decision-making problems in real situations but this method is often criticized for using of a discrete scale of one to nine and to its inability to adequately handle the inherent uncertainty and imprecision associated with decision maker`s perception. However, in many practical cases the human preference model is uncertain and decision makers might be reluctant or unable to assign exact numerical values to the comparison judgments (chan *et al*., 2007).

Since some of the evaluation criteria involve a high degree of subjective judgment and individual preferences, it is very difficult for the decision maker to express their preferences in exact numerical values and to provide exact pairwise comparison judgments so AHP, in spite of its popularity and simplicity in concept, is not sufficient to take into account the uncertainty associated with the mapping of one's perception to a number. The linguistic assessment of human feelings and judgments are vague and it is not reasonable to represent it in terms of precise numbers. It feels more confident to give interval judgments than fixed value judgments. To improve the AHP method, triangular fuzzy numbers are used to decide the priority of one decision variable over another and this is fuzzy extended of AHP (FEAHP) approach to represent decision makers' comparison judgments to decide the final priority of different decision criteria.

The fuzzy set theory has the advantage of mathematically represent uncertainty and vagueness and provide formalized tools for dealing with the imprecision intrinsic to many problems. Like other artificial intelligence method it has some advantages within uncertain, imprecise and vague contexts than AHP and other MCDM method, in resembles human judgments. This method uses the triangular fuzzy numbers as a pairwise comparison scale for deriving the priorities of different selection criteria and attributes. The weight vectors with respect to each element under a certain criterion is developed using the principle of the comparison of fuzzy numbers. It's efficiently handled the fuzziness of the data involved in the supplier selection decision and can take into account quantitative and qualitative data in the multi-attribute decision making problems. In this approach triangular fuzzy numbers are used in the preferences of one criterion over another. Triangular fuzzy numbers also used for determining each supplier capacity about each criterion then by using the extent analysis method, the synthetic extent value of the pairwise comparison is calculated, the weight vectors are decided and normalized, thus the normalized weight vectors will be determined. As a result, based on the different weights of criteria the final priority weights of the alternative global suppliers are decided. Finally the weight of each supplier about each criterion will be determined and the best contractor will be chosen according to its capacity of each criteria and the weight of that criteria on contractor selection. (Chan *et al.*, 2007)

A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one. Two triangular fuzzy number M_1 (m_1^-, m_1, m_1^+) and M_2 (m_2^-, m_2, m_2^+) shown in Fig. 2 are compared. When $m_1^- \geq m_2^-$, $m_1 \geq m_2$, $m_1^+ \geq m_2^+$, we define the degree of possibility $V(M_1 \geq M_2) = 1$. Otherwise, we can calculate the ordinate of the highest intersection point (Chang, 1996 mentioned by Lee, 2009):

Table 1. Importance (or preference) of one criterion over another

Linguistic scale	triangular fuzzy numbers
Absolute	(7/2, 4, 9/2)
Very strong	(5/2, 3, 7/2)
Strong	(3/2, 2, 5/2)
Fairly strong	(2/3, 1, 3/2)
Equal	(1, 1, 1)
Fairly weak	(2/3, 1, 3/2)
Weak	(2/5, 1/2, 2/3)
Very weak	(2/7, 1/3, 2/5)
zero	(2/9, 1/4, 2/7)

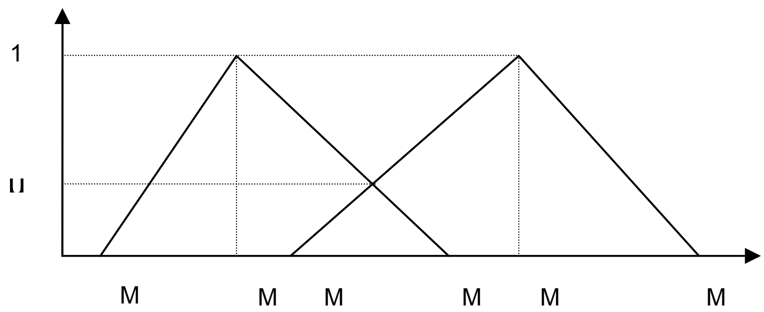

Figure 2. Two triangular fuzzy numbers M1 and M2

$\mu(d)/\mu(m_1) = (m_1^- - d)/ (m_1^- - m_1)$ and (1)

$\mu(d)/\mu(m_2) = (m_2^+ - d)/ (m_2^+ - m_2)$ (2)

then $\mu(d) = (m_1^- - m_2^+)/ ((m_1^- - m_1) – (m_2^+ - m_2)) \leq 1$ (3)

The value of fuzzy synthetic extent with respect to the criterion form goals is defined as:

$$Fi = \sum_{j=1}^{m} M_{g_i}^{j} \times \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} \quad (4)$$

Where $M_{g_i}^{j} = \left[M_{ij}^{-}, M_{ij}, M_{ij}^{+} \right]$ (5)

$$\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} M_{ij}^{-} , \sum_{j=1}^{m} M_{ij} , \sum_{j=1}^{m} M_{ij}^{+} \right) \qquad (6)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} = \left(1 \Big/ \sum_{j=1}^{m} M_{ij}^{+} ,\ 1 \Big/ \sum_{j=1}^{m} M_{ij} ,\ 1 \Big/ \sum_{j=1}^{m} M_{ij}^{-} , \right) \qquad (7)$$

A convex fuzzy number can be defined by:

$V (F\geq F_1, F_2, \ldots, F_K) = \min V(F\geq F_i)$ $i= 1, 2, \ldots, K$ (8)

$D (F_i) = \min V (F_i \geq F_k) = w_i^{'}$, $K = 1, 2, \ldots, n , K \neq i$ (9)

Based on the above procedure, we can calculate the weights, $w_i^{'}$, of criteria.

$W' = (w_1^{'}, w_2^{'}, \ldots, w_n^{'})^T = (d(F_1), d(F_2),\ldots, d(F_n))^T$ (10)

After normalization, the priority weights are as follows:

$W = (w_1, w_2, \ldots, w_n)^T$ (11)

5. Methodology

Based on Lee (2009) and Chan & Kumar (2007), a systematic fuzzy AHP model for supplier selection is proposed in this section. The steps are summarized as follows:

Step1. Identify all important criteria in contractor selection that mentioned in supplier selection literature.

Step2. Ask experts to identify the most important criteria that involve in contractor selection.

Step3. Design a questionnaires base on criteria that exploited in step 2 to pairwise compare elements.

Step4. Ask experts to fill out the nine scale questionnaires by choosing the most appropriate linguistic comparison variable. In this step, the experts compare two criteria respect to their capability in supporting contractor selection goals.

Step5. Transform expert's responds into nine scale numbers and calculating the final comparative value of each comparison by geometric mean.

Step6. Transform final numerical comparison into triangular fuzzy numbers according to table 1

Step7. Calculate criteria relative important weights in supplier selection according to 4_{th} to 11_{th} formulas that mentioned in part 4.

Step8. Ask experts to fill out the nine scale questionnaires by choosing the most appropriate linguistic comparison variable to compare two contractor respects to their capability in support each criterion.

Step9. Repeat step 5 to 7 to calculate contractor relative important weight in support each criterion.

Step10. Calculate the final contracted weight by synthesizing priorities of each contractor under each criterion and by multiplying the calculated weights of criteria attained in step 7 to the calculated weight of each contractor in supporting each criterion.

Table 2. The Fuzzy evaluation of criteria with respect to the overall objective

Objects	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6	Weights
Criterion 1	(1, 1, 1)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(2/3, 1, 3/2)	(7/2, 4, 9/2)	(3/2, 2, 5/2)	$W_1 = 0.301$
Criterion 2	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(5/2, 3, 7/2)	(3/2, 2, 5/2)	$W_2 = 0.237$
Criterion 3	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(2/3, 1, 3/2)	$W_3 = 0.137$
Criterion 4	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(7/2, 4, 9/2)	(5/2, 3, 7/2)	$W_4 = 0.301$
Criterion 5	(2/9, 1/4, 2/7)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(2/9, 1/4, 2/7)	(1, 1, 1)	(2/3, 1, 3/2)	$W_5 = 0.019$
Criterion 6	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/7, 1/3, 2/5)	(2/3, 1, 3/2)	(1, 1, 1)	$W_6 = 0.003$

Based on the collected opinions of the experts and the proposed model, the performance results of the suppliers can be generated as follows:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j} = (1,1,1) + \left(\frac{2}{3},1,\frac{3}{2}\right) + \ldots + (1,1,1) = (35.95, 45.17, 57.04)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{57.04},\frac{1}{45.17},\frac{1}{35.95}\right) = (0.018, 0.022, 0.028)$$

$$\sum_{j=1}^{m} M_{g_1}^{j} = (1,1,1) + \left(\frac{2}{3},1,\frac{3}{2}\right) + \left(\frac{3}{2},2,\frac{5}{2}\right) + \left(\frac{2}{3},1,\frac{3}{2}\right) + \left(\frac{7}{2},4,\frac{9}{2}\right) + \left(\frac{3}{2},2,\frac{5}{2}\right) = (8.83, 11, 13.5)$$

$$\sum_{j=1}^{m} M_{g_2}^{j} = (7, 9, 11.5)$$

$$\sum_{j=1}^{m} M_{g_3}^{j} = (4.9, 6.5, 8.67)$$

$$\sum_{j=1}^{m} M_{g_4}^{j} = (9, 11, 13.5)$$

$$\sum_{i=1}^{m} M_{g_5}^{j} = (2.8, 3.33, 4.14) \sum_{i=1}^{m} M_{g_6}^{j} = (3.42, 4.33, 5.73)$$

The fuzzy synthetic degree values of criterion can be calculated as follows:

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

F_1= (8.83×0.018, 11.00×0.022, 13.50×0.028) = (0.15, 0.24, 0.38)

Following a similar calculation, the fuzzy synthetic degree values of other four contractor selection criteria are obtained as shown below:

F_2= (0.12, 0.20, 0.32)

F_3= (0.09, 0.14, 0.24)

F_4= (0.16, 0.24, 0.38)

F_5= (0.05, 0.07, 0.12)

F_6= (0.06, 0.10, 0.16)

$V(F_1 \geq F_2)$ =1, $V(F_1 \geq F_3)$=1, $V(F_1 \geq F_4)$=1, $V(F_1 \geq F_5)$=1, $V(F_1 \geq F_6)$=1

$V(F_2 \geq F_1)$= 0.79, $V(F_2 \geq F_3)$=1, $V(F_2 \geq F_4)$=0.79, $V(F_2 \geq F_5)$ =1, $V(F_2 \geq F_6)$=1

$V(F_3 \geq F_1)$=0.46, $V(F_3 \geq F_2)$=0.68, $V(F_3 \geq F_4)$=0.46, $V(F_3 \geq F_5)$=1, $V(F_3 \geq F_6)$ =1

$V(F_4 \geq F_1)$ =1, $V(F_4 \geq F_2)$=1, $V(F_4 \geq F_3)$=1, $V(F_4 \geq F_5)$=1, $V(F_4 \geq F_6)$=1

$V(F_5 \geq F_1)$ =0.31, $V(F_5 \geq F_2)$=0.06, $V(F_5 \geq F_3)$=0.29, $V(F_5 \geq F_4)$=0.34,

$V(F_5 \geq F_6)=0.71$

$V(F_6 \geq F_1)=0.03$, $V(F_6 \geq F_2)=0.26$, $V(F_6 \geq F_3)=0.61$, $V(F_6 \geq F_4)=0.01$, $V(F_6 \geq F_5)=1$

The weights are calculated as follows:

$d(F_1) = \min V(F_1 \geq F_2, F_3, F_4, F_5, F_6) = \min(1, 1, 1, 1, 1) = 1$

$d(F_2) = \min V(F_2 \geq F_1, F_3, F_4, F_5, F_6) = \min(0.79, 1, 0.79, 1, 1) = 0.79$

$d(F_3) = \min V(F_3 \geq F_1, F_2, F_4, F_5, F_6) = \min(0.46, 0.68, 0.46, 1, 1) = 0.46$

$d(F_4) = \min V(F_4 \geq F_1, F_2, F_3, F_5, F_6) = \min(1, 1, 1, 1, 1) = 1$

$d(F_5) = \min V(F_5 \geq F_1, F_2, F_3, F_4, F_5) = \min(0.31, 0.06, 0.29, 0.34, 0.71) = 0.06$

$d(F_6) = \min V(F_6 \geq F_1, F_2, F_3, F_4, F_5) = \min(0.03, 0.26, 0.61, 0.01, 1) = 0.01$

$W' = (d(F_1), d(F_2), \ldots, d(F_n))^T = (1, 0.79, 0.46, 1, 0.06, 0.01)^T$

After normalization, the normalized weight of contraction selection criteria is:

$W = (0.301, 0.237, 0.137, 0.301, 0.019, 0.003)$

Similar procedures are carried out to calculate relative importance weight of contractors with respect to each selection criterion. These weights are shown in the right columns of follow tables (table 3-8).

Table 3. The Fuzzy evaluation of criteria with respect to 1th criterion

Criterion 1	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Weights
Supplier 1	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/9, 1/4, 2/7)	(1, 1, 1)	0.031
Supplier 2	(3/2, 2, 5/2)	(1, 1, 1)	(3/2, 2, 5/2)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	0.215
Supplier 3	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	(2/7, 1/3, 2/5)	(2/3, 1, 3/2)	0.115
Supplier 4	(7/2, 4, 9/2)	(2/3, 1, 3/2)	(5/2, 3, 7/2)	(1, 1, 1)	(7/2, 4, 9/2)	0.608
Supplier 5	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/9, 1/4, 2/7)	(1, 1, 1)	0.031

Table 4. The Fuzzy evaluation of criteria with respect to 2th criterion

Criterion 2	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Weights
Supplier 1	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/9, 1/4, 2/7)	(2/3, 1, 3/2)	0.081
Supplier 2	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	0.100
Supplier 3	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(2/7, 1/3, 2/5)	(2/3, 1, 3/2)	0.067
Supplier 4	(7/2, 4, 9/2)	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(1, 1, 1)	(3/2, 2, 5/2)	0.652
Supplier 5	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(1, 1, 1)	0.100

Table 5. The Fuzzy evaluation of criteria with respect to 3th criterion

Criterion 3	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Weights
Supplier 1	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/9, 1/4, 2/7)	(2/3, 1, 3/2)	0.130
Supplier 2	(2/3, 1, 3/2)	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	0.175
Supplier 3	(2/3, 1, 3/2)	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	0.175
Supplier 4	(7/2, 4, 9/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	0.332
Supplier 5	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	0.189

Table 6. The Fuzzy evaluation of criteria with respect to 4th criterion

Criterion 4	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Weights
Supplier 1	(1, 1, 1)	(2/7, 1/3, 2/5)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	0.091
Supplier 2	(5/2, 3, 7/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	0.344
Supplier 3	(3/2, 2, 5/2)	(2/3, 1, 3/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	0.249
Supplier 4	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(1, 1, 1)	0.181
Supplier 5	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(1, 1, 1)	(1, 1, 1)	0.135

Table 7. The Fuzzy evaluation of criteria with respect to 5th criterion

Criterion 5	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Weights
Supplier 1	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/7, 1/3, 2/5)	(1, 1, 1)	0.083
Supplier 2	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	0.285
Supplier 3	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	0.076
Supplier 4	(5/2, 3, 7/2)	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(1, 1, 1)	(5/2, 3, 7/2)	0.473
Supplier 5	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	(2/9, 1/4, 2/7)	(1, 1, 1)	0.083

Table 8. The Fuzzy evaluation of criteria with respect to 6th criterion

Criterion 6	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	Weights
Supplier 1	(1, 1, 1)	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/5, 1/2, 2/3)	(2/3, 1, 3/2)	0.030
Supplier 2	(2/3, 1, 3/2)	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/7, 1/3, 2/5)	(2/3, 1, 3/2)	0.077
Supplier 3	(2/3, 1, 3/2)	(3/2, 2, 5/2)	(1, 1, 1)	(2/3, 1, 3/2)	(5/2, 3, 7/2)	0.316
Supplier 4	(3/2, 2, 5/2)	(5/2, 3, 7/2)	(2/3, 1, 3/2)	(1, 1, 1)	(7/2, 4, 9/2)	0.499
Supplier 5	(2/3, 1, 3/2)	(2/3, 1, 3/2)	(2/7, 1/3, 2/5)	(2/9, 1/4, 2/7)	(1, 1, 1)	0.078

Table 9. shows a summarized of suppliers with respect to each criterion.

Contractor selection goals	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6
Supplier 1	0.031	0.081	0.130	0.091	0.083	0.030
Supplier 2	0.215	0.100	0.175	0.344	0.285	0.077
Supplier 3	0.115	0.067	0.175	0.249	0.076	0.316
Supplier 4	0.608	0.652	0.332	0.181	0.473	0.499
Supplier 5	0.031	0.100	0.189	0.135	0.083	0.078

And the final contractor weight by synthesizing priorities of each contractor under each criterion by defining W_j as criteria weights and w'_j as contractor weights about each criterion can be calculated as follow:

$$W_t = \sum_{j=1}^{m} (W_j \times W_j^{'}) \tag{12}$$

W_1= ((0.031*0.301)+(0.081*0.237)+…+(0.030*0.003) = 0.076
Respectively other contractor's weight calculated as follows:
$W_2 = 0.222$
$W_3 = 0.152$
$W_4 = 0.449$
$W_5 = 0.102$
The final results portrayed in following charts:

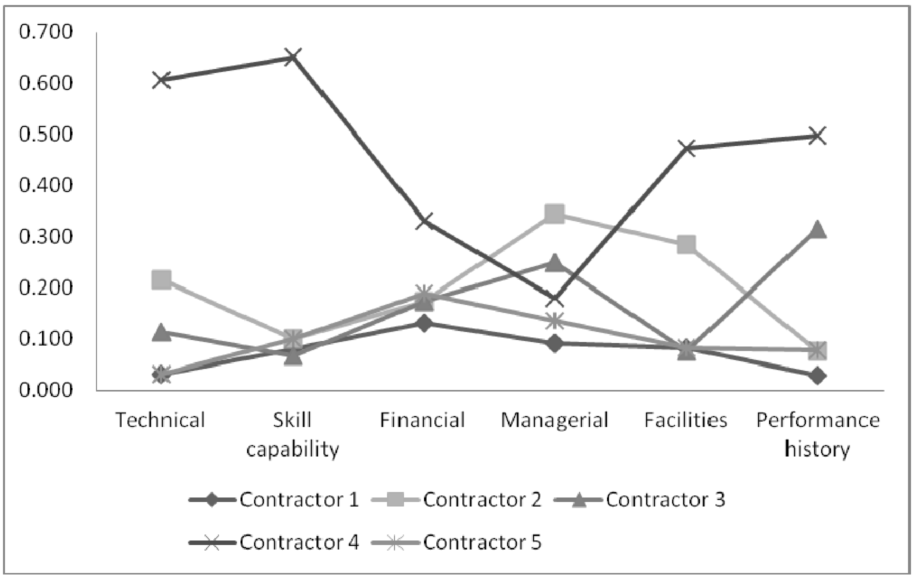

Figure 3. Line chart of contractors weight with respect to each criteria

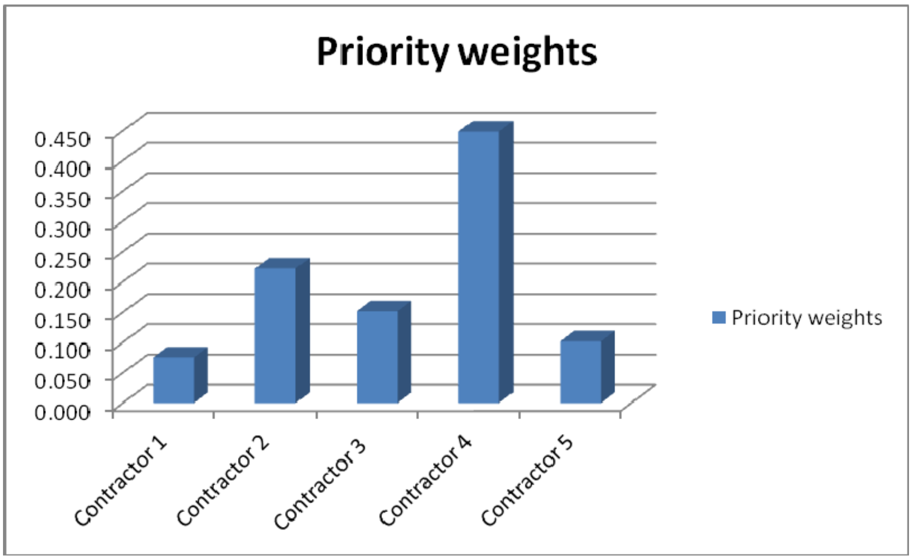

Figure 4. Final priority of each contractor

As mentioned before, the normalized weights of contraction selection criteria calculated as:

W = (technical=0.301, Capability=0.237, Financial=0.137, Managerial=0.301, Facilities=0.019, Performance history=0.003)

So it can be received through article's finding, the priority of 5 construction contractor is as follows:

1- Tabanshahr, 2- Charbarg, 3- Abad Tadbir, and 4,5- Omran Vaheb, Bonyan Saze about technical criterion.

1- Tabanshahr, 2,3- Charbarg, Omran Vaheb, 4-, Bonyan Saze and 5- Abad Tadbir about skill capability criterion.

1- Tabanshahr, 2- Omran Vaheb, 3,4- Abad Tadbir, Charbarg and 5- Bonyan Saze about financial criterion.

1- Charbarg, 2- Abad Tadbir, 3- Tabanshahr, 4- Omran Vaheb and 5- Bonyan Saze about managerial criterion.

1- Tabanshahr, 2- Charbarg and 3,4,5- Abad Tadbir, Bonyan Saze, Omran Vaheb about facilities criterion.

1- Tabanshahr, 2- Abad Tadbir, 3,4- Charbarg, Omran Vaheb and 5- Bonyan Saze about performance history criterion.

And as the result of all FAHP system the priority of 5 construction contractor is as follows:

1- Tabanshahr, 2- Charbarg, 3- Abad Tadbir, and 4- Omran Vaheb and 5- Bonyan Saze.

Conclusion and future work

In this paper a fuzzy AHP approach has been presented to select the best construction contractor for Tehran university technical office. The main criteria have been chosen respect to construction context and experience of the experts in the respective fields. Each chosen factor affecting the performance of the contractor has been analyzed and discussed. Fuzzy set theory is incorporated into the model to overcome the uncertainty and ambiguity in human decision-making process.

As it can be found in paper results, managerial criterion that almost do not attract sufficient attention in the contractor selection decision making, in common with technical criterion has the first place in affecting contractor performance. Despite, there is wide attention to the financial criterion and even in some cases it is the only selection factor, it does not have a significant effect on supporting the goals of selection. Considering this paper results, pay attention to just one or two important factors in contractor selection and ignore other factors is not logically acceptable and so this research provides a comprehensive model that considers all affecting factors in contractor selection. The model can accept a wide range of factors and dynamic nature of model help decision makers to add or omit any factors according to decision making context.

This research work can be extended to many important industries that contractor and supplier selection are very important to them, and in some industries that choosing the right supplier can make competitive advantages for firms.

References

Akarte, M.M., Surendra, N.V., Ravi, B., Rangaraj, N., 2001. Web based casting supplier evaluation using analytical hierarchy process. Journal of the Operational Research Society 52 (5), 511–522.

Boer,L.,vanderWegen,L.,Telgen,J.,1998. Outranking methods in support of supplier selection. European Journal of Purchasing & Supply Management4, 109–118.

Braglia, M., Petroni, A., 2000. A quality assurance-oriented methodology for handling trade-offs in supplier selection. International Journal of Physical Distribution and Logistics Management 30 (2), 96–111.

Chan, F.T.S., 2003. Interactive selection model for supplier selection process: An analytical hierarchy process approach. International Journal Production Research 41 (15), 3549–3579.

Chan, F.T.S., Chan, H.K., 2004. Development of the supplier selection model – A case study in the advanced technology industry. Proceedings of the Institution of Mechanical Engineers Part B – Journal of Engineering Manufacture 218 (12), 1807–1824.

Chan, F.T.S., Chan, H.K., Ip, R.W.L., Lau, H.C.W., 2007. A decision support system for supplier selection in the airline industry. Proceedings of the Institution of Mechanical Engineers Part B – Journal of Engineering Manufacture 221 (4), 741–758.

Chang B., Chang C., & Wu C. 2011. Fuzzy DEMATEL method for developing supplier selection criteria. Expert Systems with Applications, 38, 1850–1858

Chen, C.T., Lin, C.T., Huang, S.F., 2006. A fuzzy approach for supplier evaluation and selection in supply chain management. International Journal of Production Economics 102 (2), 289–301.

Chen, Y.M., Huang, P.N., 2007. Bi-negotiation integrated AHP in suppliers selection. Benchmarking: An International Journal 14 (5), 575–593.

Dulmin, R., Mininno, V., 2003. Supplier selection using a multi-criteria decision aid method, Journal of Purchasing and Supply Management, Vol.9, No.4, pp. 177-187.

Florez-Lopez, R., 2007. Strategic supplier selection in the added-value perspective: A CI approach. Information Sciences 177 (5), 1169–1179.

Forker, L.B., Mendez, D., 2001. An analytical method for benchmarking best peer suppliers. International Journal of Operations and Production Management 21 (1–2), 195–209.

Garfamy, R.M., 2006. A data development analysis approach based on total cost of ownership for supplier selection. Journal of Enterprise Information Management 19 (6), 662–678.

Ho, W., Xu, X., Dey, P.K., 2010. Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. European Journal of Operational Research 202 16–24

Hong, G.H., Park, S.C., Jang, D.S., Rho, H.M., 2005. An effective supplier selection method for constructing a competitive supply-relationship. Expert Systems with Applications 28 (4), 629–639.

Hou, J., Su, D., 2007. EJB–MVC oriented supplier selection system for mass customization. Journal of Manufacturing Technology Management 18 (1), 54–71.

Huang, S.H., Keska, H., 2007. Comprehensive and configurable metrics for supplier selection. International Journal of Production Economics 105 (2), 510–523.

Hung, S.-W. 2006. Competitive strategies for Taiwan's thin film transistor-liquid crystal display (TFT-LCD) industry. Technology in Society, 28, 349–361.

Jiang W., & Chan F.T.S. 2011. A new fuzzy dempster MCDM method and its application in supplier selection. Expert Systems with Applications, 38(8), 9854-9861.

Kahraman, C., Cebeci, U., Ulukan, Z., 2003. Multi-criteria supplier selection using fuzzy AHP. Logistics Information Management 16 (6), 382–394.

Kumar J., & Roy N. 2011. Analytic hierarchy process (AHP) for a power transmission industry to vendor selection decisions. International Journal of Computer Applications. 12 (11), 26-30.

Lee, A.H.I. 2009. A fuzzy supplier selection model with the consideration of benefits, opportunities, costs and risks. Expert Systems with Applications 36, 2879–2893

Liu, J., Ding, F.Y., Lall, V., 2000. Using data development analysis to compare a suppliers for supplier selection and performance improvement. Supply Chain Management: An International Journal 5 (3), 143–150.

Liu, F.H.F., Hai, H.L., 2005. The voting analytic hierarchy process method for selecting supplier. International Journal of Production Economics 97 (3), 308–317.

Muralidharan, C., Anantharaman, N., Deshmukh, S.G., 2002. A multi-criteria group decision-making model for supplier rating. Journal of Supply Chain Management 38 (4), 22–33.

Narasimhan, R., Talluri, S., Mendez, D., 2001. Supplier evaluation and rationalization via data envelopment analysis: An empirical examination. Journal of Supply Chain Management 37 (3), 28–37.

Narasimhan, R., Talluri, S., Mahapatra, S.K., 2006. A Multiproduct, multicriteria model for supplier selection with product life-cycle considerations. Decision Sciences 37 (4), 577–603.

Ng, W.L., 2008. An efficient and simple model for multiple criteria supplier selection problem. European Journal of Operational Research 186 (3), 1059–1067.

Ross, A., Buffa, F.P., Dr◌ge, C., Carrington, D., 2006. Supplier evaluation in a dyadic relationship: An action research approach. Journal of Business Logistics 27 (2), 75–102.

Saen, R.F., 2006. A decision model for selecting technology suppliers in the presence of nondiscretionary factors. Applied Mathematics and Computation 181 (2), 1609–1615.

Saen, R.F., 2007. Supplier selection in the presence of both cardinal and ordinal data. European Journal of Operational Research 183 (2), 741–747.

Seydel, J., 2006. Data development analysis for decision support. Industrial Management and Data Systems 106 (1), 81–95.

Snomez M., 2006. A review and critique of supplier selection process and practices. Business School Occasional Papers Series Paper,

Talluri, S., Baker, R.C., 2002. A multi-phase mathematical programming approach for effective supply chain design. European Journal of Operational Research 141 (3), 544–558.

Talluri, S., Narasimhan, R., 2004. A methodology for strategic sourcing. European Journal of Operational Research 154 (1), 236–250.

Talluri, S., Sarkis, J., 2002. A model for performance monitoring of suppliers. International Journal of Production Research 40 (16), 4257–4269.

Talluri, S., Narasimhan, R., Nair, A., 2006. Vendor performance with supply risk: A chance-constrained DEA approach. International Journal of Production Economics 100 (2), 212–222.

Wadhwa, V., Ravindran, A.R., 2007. Vendor selection in outsourcing. Computers and Operations Research 34 (12), 3725–3737.

Wu, T., Shunk, D., Blackhurst, J., Appalla, R., 2007. AIDEA: A methodology for supplier evaluation and selection in a supplier-based manufacturing environment. International Journal of Manufacturing Technology and Management 11 (2), 174–192.

Xia, W., Wu, Z., 2007. Supplier selection with multiple criteria in volume discount environments. OMEGA – International Journal of Management Science 35 (5), 494–504.