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Vendor Selection:

An Enhanced Hybrid Fuzzy MCDM Model

Behnam Vahdani[a], Akbar Alem-Tabriz[b], Mostafa Zandieh[b,*]

[a]*Department of Industrial and Mechanical Engineering, Qazvin Azad University, Qazvin, Iran*

[b]*Department of Industrial Management, Management and Accounting Faculty, Shahid Beheshti University, G.C., Tehran, Iran*

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Abstract

The objective of this article is to develop an empirically based framework for formulating and selecting a vendor in supply chain. This study applies the fuzzy set theory to evaluate the vendor selection decision. Applying Analytic Hierarchy Process (AHP) in obtaining criteria weights and applied Technique for Order Performance by Similarity to Idea Solution (TOPSIS) for obtaining final ranking of vendors. The usefulness of this model is explained through an empirical study for vendor selection.

Keywords: vendor's selection; Fuzzy multi criteria decision making (FMCDM); Technique for Order Performance by Similarity to Idea Solution (TOPSIS); Analytic hierarchy process (AHP)

1. Introduction

Vendor (supplier) selection or evaluation is a common problem for acquiring the necessary materials to support the outputs of organizations. The problem is to find and to evaluate periodically the best or most suitable vendor(s) for the organizations based on various vendors' capabilities. This usually happens when the purchase is complex, high-dollar value, and perhaps critical (Dobler and Burt [13]). Also, a process of formal supplier evaluation and ranking is necessary. The process for supplier selection is indeed a problem-solving process, which covers the works of problem definition, formulation of criteria, qualification, and choice (Shih et al. [36]). However, most articles deal with qualification and choice phases to which operations research related techniques are adapted (Boer et al., [2]; Dulmin and Mininno [16]). Selecting an appropriate supplier is often a non-trivial task, in which multiple criteria need to be carefully examined. However, many decision makers or experts select suppliers based on their experience and intuition. These approaches are obviously subjective and their weakness has been addressed in several previous studies (Hwang and Yoon [20]; Kontio [24]).

Alternatively, multiple criteria decision making or multiple attributes decision making (MCDM/MADM) is the approach dealing with the ranking and selection of one or more suppliers from a pool of providers. The MCDM provides an effective framework for supplier comparison based on the evaluation of multiple conflict criteria. In order to manage the difficulty of determining the performance of a supplier on one criterion or the importance of some criterion with a high degree of precision, the analytic hierarchy process (AHP) is now widely used by both researchers and practitioners (Ghodsypour and O'Brien [18]; Min [27]). Ghodsypour and O'Brien ([18] argue that AHP is more accurate than other scoring methods for supplier selection. (Mehmet Sevkli et al [26]) applied a hybrid method of supplier selection to a well-known Turkish company operating in the appliance industry. Theoretically, the methodology is valuable when the decision making framework has a unidirectional hierarchical relationship among decision

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[*] Corresponding author. Tel. and Fax: (009821) 29902382 ; E-mail address: m_zandieh@sbu.ac.ir

levels. (Chan et al. [6]) discussed the fuzzy based Analytic Hierarchy Process (fuzzy-AHP) to efficiently tackle both quantitative and qualitative decision factors involved in selection of global supplier in current business scenario. However, (Carney and Wallnau [5]) point out that the evaluation criteria for alternatives are not always independent of each other, but often interact with one another. An invalid result can be drawn in such a complex environment. Several influence factors are often not taken into account in the decision making process, such as incomplete information, additional qualitative criteria and imprecision preferences. According to the vast literature on supplier selection (Boer et al., [2]; Choi and Hartley [8]; Weber et al. [43]), we conclude that some properties are worth considering when solving the decision making problem for supplier selection. First, the criteria may consider quantitative as well as qualitative dimensions (Choi and Hartley [8]; Dowlatshahi [14]; Verma and Pullman [39]; Weber et al. [43,45]). In general, these objectives among these criteria are conflicted. A strategic approach towards supplier selection may further emphasize the need to consider multiple criteria (Donaldson [15]; Ellram [17]; Swift [38]). Second, several decision makers are very often involved in the decision process for supplier selection (Boer et al., [2]). Third, decision making is often influenced by uncertainty in practice. An increasing number of supplier decisions can be characterized as dynamic and unstructured. Situations are changing rapidly or are uncertain and decision variables are difficult or impossible to quantify (Cook [9]). Fourth, the types of decision models can be divided into compensatory and non-compensatory methods (Boer et al., [2]; Ghodsypour and O’Brien [18]; Roodhooft and Konings [32]). The compensatory decision models lead to an optimal solution for dealing with supplier selection problems. The non-compensatory methods are that use a score of an alternative on a particular criterion can be compensated by high scores on other criteria. From the literature it can be concluded that in supplier selection the classic concept of ‘‘optimality’’ may not always be the most appropriate model (Boer et al., [2]). Overally speaking, we can conclude that supplier selection may involve several and different types of criteria, combination of different decision models, group decision making and various forms of uncertainty. It is difficult to find the best way to evaluate and select supplier, and companies use a variety of different methods to deal with it. A survey of the methods has been presented in Hwang and Yoon [20]. The purpose of this article is to develop an empirically based framework for formulating and selecting a vendor. A hierarchical fuzzy multi criteria decision making method is proposed. We can roughly divide these quantitative approaches into six categories: multi attribute decision making (or a general view of linear weighting models), multi-objective optimization (or a general view of mathematical/linear programming models), statistics/probabilistic approaches, intelligent approaches, fuzzy multi-attribute decision making/fuzzy multi objective decision making and others. Six categories, each with their own related approaches and examples, are listed in Table 1. Additionally, the first category concentrates on selection activities, which adopt a limited and countable number of predetermined alternatives through multiple attributes or criteria. The alternatives associate with them the level of achievement of the attributes. Though it may still be in doubt whether they are quantifiable or not, those attributes will act as a platform upon which the final choice is to be made. Most approaches utilized, such as AHP, conjoint analysis, the linear weighting (or scoring) method and the outranking method can be classified into this category. The second category involves the design for the best or required alternative by taking into consideration the various interactions within the design constraints that best satisfy the decision maker by way of attaining some acceptable levels of a set of some quantifiable objectives. Its alternatives have been implicitly expressed in the feasible zone of a constraint set, so that the most satisfactory objectives can be obtained. Techniques such as the " ε - constraint method, data envelopment analysis (DEA), and goal programming contribute to this category. The third category focuses on the evaluation which relies on a large number of tests or surveys or deals with the stochastic uncertainty related to the supplier choice (Weber et al., [43]; Boer et al., [2]). The categorical method, cluster analysis and uncertainty analysis all fall into this category. The fourth category will explore some newly developed intelligent techniques, such as case-based reasoning, expert systems, genetic algorithms, and neural networks, to process the activities of supplier selection. It is hoped that the preferred suggestion can be made within this stage. The fifth category includes the utilized fuzzy methods for the evaluation of alternative with respect to criteria. In these methods, two different strategies are employed. One of the strategies is to consider the fuzzy numbers for weights of criteria and also for the evaluation of alternatives with respect to criteria. The second strategy is to make use of linguistic variables. Overall, the fuzzy AHP and fuzzy TOPSIS are among those acceptable methods which can care to name. Since problems in the supplier evaluation process are widely examined for various materials and services purposes, some specific techniques are proposed and grouped into the fifth category covering what has been left out in the previous four categories. In addition, since ranking and selection are the major concerns for our problem, this study will devote much effort on the first category, with a deliberate account of the process involved. In order to show the practicality and usefulness of this model, an example is offered to verify this method.

Table 1
Taxonomy of approaches of supplier evaluation

Category	Approach	Proposed by
MADM models	AHP	Nydick and Hill [30]
	Conjoint analysis	Mummalaneni et al [28]
	Linear weighting method	Dobler and Burt [13]
	Outranking method	de Boer et al. [11]
	Promethee/Gaia	Riccardo Dulmin, Valeria Mininno [33]
MODM models	" ε -constraint method	Weber and Current [44]
	DEA	Weber [42]
	Goal programming	Buffa and Jackson, [3]
Statistical/probabilistic approaches	Categorical method	Zenz [48]
	Cluster analysis	Hinkle et al [19]
	Uncertainty analysis	Soukoup, 1987
Intelligence approaches	Case-based reasoning	Cook [10]
	Expert system	Vokurka et al [40]
	Genetic algorithm	Ding et al [12]
	Neural network	Wei et al [46]
Fuzzy MCDM models	Fuzzy AHP	Chan et al. [6]
	Fuzzy association rule mining	Jain et al [21]
	Fuzzy hierarchical TOPSIS	Wang et al [41]
Others	Activity-based costing	Roodhooft and Konings [32]
	Interpretive structure modeling	Mandal and Deshmukh [25]
	positioning matrix	Chou et al, [7]
	unidirectional hierarchical relationship	Mehmet Sevkli et al [26]

2. The proposed model

The proposed model has been applied to a vendor selection process of a firm working in the field of rail transportation. Specifically, a set of three possible alternative vendors (V_1, V_2, V_3) of a complex customized subsystem has been considered in a highly innovative new product development, for which quality assurance and innovative capacity represented the client firm's main competitive priorities. The client–vendor relationship is governed by a contractual agreement calling for design and production starting from performance specifications, with planned delivery times. Capability and quality/efforts in co-design activities offered by the vendors in the development stages, evaluated by a project engineer with his specialist designers, are of significant importance. A rigorous vendor' selection was required for each item internally classified as critical for its impact in terms of safety, completion of conveyance, customer satisfaction, management costs.

Performance criteria

The first step in applying the proposed model was to determine the evaluation criteria (C_i):

- Mark-up (C_1). Contractual percentage of reduction in unitary overhead related to unitary direct manufacturing costs (percentage scale). Overall mark-up (with respect to direct costs) to give the selling price is the sum of two distinct components: unitary net margin and overhead both related to unitary direct manufacturing costs.
  Unitary net margin being fixed, the vendor has to reduce overhead in order to reduce the related mark-up component, to reduce overall mark-up and price.
- Processing time (C_2). The time needed to develop product structural designs.
- Prototyping time (C_3). Speed in constructing prototypes.
- Design revision time (C_4). Flexibility to accept and perform project revisions.
- Quality system (C_5). Presence or absence of quality certifications. On/Off variable.
- Co-design (C_6). Vendor's effort within the project team. Qualitative evaluation performed by the project team, which investigated vendors' contributions to the design/use of standard components (usually called carry over), the identification of new materials, the study of new process technologies, the definition of the design review and RAM parameters, the availability of rapid prototyping and so forth. In this case, a qualitative impact value was used, expressed on a qualitative scale (judgments on a series of ordered semantic values; each semantic value included in the set {very low, low, fair, high, very high} is associated to a numerical value that is used for the calculations).
- Technological levels (C_7). Vendors' technological level was assessed considering their availability of key technologies (crucial for the vendor, enabling him to compete with success in the sector, constitute its distinctive capability) and investments in emerging technologies (in a state of development, which are expected to change the base of competitiveness, O'Neal [31]. Also in this

case a semantic differential five-point Likert scale was used.

2.1. The process for evaluating and selecting vendors includes three steps:

2.1.1. Evaluating the weights for the hierarchical relevance system

The AHP weighting (Saaty [34, 35]) is determined by the evaluators who conduct pair wise comparisons, by which the comparative importance of two criteria is shown. Furthermore, the relative importance derived from these pair wise comparisons allows a certain degree of inconsistency within a domain. Saaty used the principal eigenvector of the pair wise comparison matrix derived from the scaling ratio to determine the comparative weight among the criteria. Suppose that it wish to compare a set of n criteria in pairs according to their relative importance (weights). The criteria are denoted by $C_1, C_2, \cdots C_n$ and their weights by $w_1, w_2, \cdots w_n$ if $w = (w_1, w_2, ..., w_n)^t$ .A matrix A with the following formulation may represent the pair wise comparisons:

$$(A - \lambda_{\max} I)w = 0 \qquad (1)$$

Eq. (1) indicates that *A* is the matrix of pair wise comparison values derived from intuitive judgment for the ranking order. In order to determine the priority eigenvector, it must find the eigenvector *w* with respective $\lambda_{\max}$ that satisfies $Aw = \lambda_{\max} w$.Observations are made from the intuitive ranking order judgment to pair wise comparisons to test the consistency of the intuitive judgment. This is because small changes in the matrix *A* elements imply a small change in λ_j, ($\sum_{j=1}^{n} \lambda_i = tr(A)$ = the sum of the diagonal elements-*n*. Therefore only one of λ_j, it call it $\lambda_{\max}$, equals *n*, and if λ_j=0, the $\lambda_j \neq I_{\max}$). The deviation in the latter from n is a measure of consistency, i.e., $CI = (\lambda_{\max} - n)/(n-1)$, with the consistency index (CI) as our indicator of ''closeness to consistency''. In general, if this number is less than 0.1, it may be satisfied with our judgment (Saaty, [34, 35]).

2.1.2. Getting the performance value

Each vendor will acquire a score from the evaluators based upon their own subjective knowledge. Because of personal limitations such as habitual domain or asymmetrical information, a fuzzy environment has been formed. Thus, applying the fuzzy theory in solving this problem becomes essential. Since Zadeh [47] introduced the fuzzy set theory and Bellman and Zadeh [1] described the decision-making method in fuzzy environments, the application of this theory has become more popular, and a number of studies have been published applying similar methods. The procedures are described as follows:

2.2. Fuzzy numbers and linguistic variables

In this section, some basic definitions of fuzzy sets, fuzzy numbers and linguistic variables are reviewed from (Buckley [4]; Kaufmann and Gupta [22]; Negi [29]). The basic definitions and notations below will be used throughout this paper until otherwise stated.

Definition 2.2.1. 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 $\tilde{A}$ (Kaufmann and Gupta [22]).

Definition 2.2.2. A fuzzy set $\tilde{A}$ in the universe of discourse X is convex if and only if

$$\mu_{\tilde{A}}(\lambda x_1 + (1-\lambda)x_2) \geq \min(\mu_{\tilde{A}}(x_1), \mu_{\tilde{A}}(x_2)) \qquad (2)$$

for all x_1, x_2 in X and all $\lambda \in [0,1]$, where min de the minimum operator (Klir and Yuan [23]).

Definition 2.2.3. A fuzzy number is a fuzzy subset in the universe of discourse X that is both convex and normal.

Definition 2.2.4. (Triangular fuzzy numbers). The triangular fuzzy numbers can be denoted as $\tilde{A} = (a_1, a_2, a_3)$, the membership function of the fuzzy number $\tilde{A}$ is defined as (see Fig. 1):

$$\mu_{\tilde{A}}(x) = \begin{cases} 0 & x < a_1, \\ (x-a_1)/(a_2-a_1) & a_1 \leq x \leq a_2, \\ (a_3-x)/(a_3-a_2) & a_2 \leq x \leq a_3, \\ 0 & x > a_3. \end{cases} \qquad (3)$$

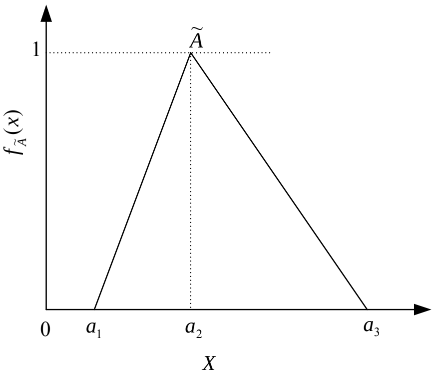

Fig. 1. A triangular fuzzy number $\tilde{A}$.

A non-fuzzy number r can be expressed as (r, r, r). The fuzzy sum $\oplus$ and fuzzy Subtraction Θ of any two triangular fuzzy numbers are also triangular fuzzy numbers; but the multiplication $\otimes$ of any two triangular fuzzy numbers is only an approximate triangular fuzzy number. Given any two positive triangular fuzzy numbers, $\tilde{A} = (a_1, a_2, a_3)$, $\tilde{B} = (b_1, b_2, b_3)$ and a positive real number r, some main operations of fuzzy numbers $\tilde{A}$ and $\tilde{B}$ can be expressed as follows:

$$\widetilde{A} \oplus \widetilde{B} = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \qquad (4)$$

$$\widetilde{A} \Theta \widetilde{B} = (a_1 - b_3, a_2 - b_2, a_3 - b_1) \qquad (5)$$

$$\widetilde{A} \otimes r = [a_1 r, a_2 r, a_3 r], \qquad (6)$$

$$\widetilde{A} \otimes \widetilde{B} \cong [a_1 b_1, a_2 b_2, a_3 b_3], \qquad (7)$$

Definition 2.2.5. A linguistic variable is a variable whose values are expressed in linguistic terms (Zimmermann [49]). The concept of a linguistic variable is very useful in dealing with situations, which are too complex or not well defined to be reasonably described in conventional quantitative expressions (Zimmermann [49]). Linguistic variables may take on effect-value such as ''very high (very good),'' ''high (good),'' ''fair,'' ''low (bad),'' and ''very low (very bad),'' (see Fig. 2). The use of linguistic variables is rather widespread at present, and the linguistic effect values for a vendor found in this study are primarily used to assess the linguistic ratings given by the evaluator. Furthermore, linguistic variables are used as a way to measure the performance value achievement for each criterion/objective.

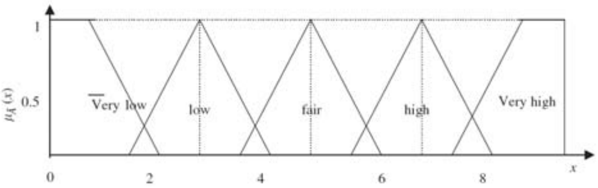

Fig. 2. The membership functions of the five levels of linguistic variables

2.2.6. Evaluating vendors

Bellman and Zadeh [1] were the first to probe the decision making problem in a fuzzy environment, for which they initiated fuzzy multiple-criteria decision-making (Fuzzy MCDM). Our study uses this method to evaluate various vendors and ranks them by their performance. The methods and procedures of the Fuzzy MCDM theory are as follows:

(1) Measuring criteria:

Using linguistic variable measurement to demonstrate the criteria performance (effect values) with expressions such as ''very high,'' ''high,'' ''fair,'' ''low,'' and ''very low,'' the evaluators were asked to make subjective judgments. Each linguistic variable can be indicated using a triangular fuzzy number (TFN). Alternatively, the evaluators could subjectively assign their own personal weights to the linguistic variables. Let E_{ij}^{k} indicate the fuzzy performance value of evaluator *k* toward strategy *i* under criteria *j*. Let the performance of the criteria be indicated by the set *S*; then,

$$E_{ij}^{k} = (LE_{ij}^{k}, ME_{ij}^{k}, UE_{ij}^{k}), j \in S \qquad (8)$$

Because the perception of each evaluator varies according to the evaluator's experience and knowledge, and the definitions of the linguistic variables vary as well, this study used the notion of average value to integrate the fuzzy judgment values of m evaluators, that is,

$$E_{ij} = (1/m) \otimes (E_{ij}^{1} \oplus E_{ij}^{2} \oplus \ldots E_{ij}^{m}) \qquad (9)$$

The sign $\otimes$ denotes fuzzy multiplication and the sign $\oplus$ denotes fuzzy addition. E_{ij} is the average fuzzy number for the judgment of the decision maker. It can be displayed using a triangular fuzzy number as follows:

$$E_{ij} = (LE_{ij}, ME_{ij}, UE_{ij}) \qquad (10)$$

The preceding end-point values

$$LE_{ij} = \left(\sum_{k=1}^{m} LE_{ij}^{k} \right) / m, \qquad (11)$$

$$ME_{ij} = \left(\sum_{k=1}^{m} ME_{ij}^{k} \right) / m, \qquad (12)$$

$$UE_{ij} = \left(\sum_{k=1}^{m} UE_{ij}^{k} \right) / m, \qquad (13)$$

Can be solved using the method introduced by (Buckley [4]).

(2) Fuzzy synthetic decision:

The weights of the different criteria as well as the fuzzy performance values (effect values) must be integrated using the fuzzy number operation located at the fuzzy performance value (effect values) of the integral evaluation. According to the weight w_j, derived by AHP, the weight vector and the fuzzy performance matrix *E* of each of the strategy can be obtained from the fuzzy performance value of each strategy under *n* criteria/objectives, that is,

$$w = (w_1, \ldots, w_j, \ldots w_n)^T,$$

$$E = (E_{ij},)$$

$$R = E \Leftrightarrow W,$$

Where the sign ''$\Leftrightarrow$'' indicates the fuzzy number operation. Because fuzzy multiplication is rather complex, it is usually denoted by the approximate fuzzy multiplication result and the approximate fuzzy number *R* of the fuzzy synthetic decision for each strategy. The expression then becomes

$$R_i = (LR_i, MR_i, UR_i), \qquad \forall i, \qquad (14)$$

where

$$LR_i = \sum_{k=1}^{m} LE_{ij} \otimes w_j , \qquad (15)$$

$$MR_i = \sum_{k=1}^{m} ME_{ij} \otimes w_j , \qquad (16)$$

$$UR_i = \sum_{k=1}^{m} UE_{ij} \otimes w_j , \qquad (17)$$

(3) Evaluation of the strategies (fuzzy number):

The fuzzy synthetic decision result reached using each vendor is a fuzzy number that can be employed during the comparison of strategies. In other words, the defuzzification procedure involves locating the Best Nonfuzzy Performance value (*BNP*). The *BNP* value for the fuzzy number R_i can be found using the following equation:

$$BNP_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i \quad \forall i. \qquad (18)$$

(4) Selecting the strategies (TOPSIS method):

MCDM is about selecting the best alternative among a set of alternatives. This is usually achieved by constructing a preference order for the alternatives based on their ‘‘performance’’ with respect to the criteria considered. This research adopted TOPSIS (Techniques of Preference by Similarity to the Ideal Solution) methods to evaluate the *BNP* value. Based upon the *BNP* value, it can select the best alternative. TOPSIS, developed by (Hwang and Yoon [20]), is very unique in the way it approaches a problem and is intuitively appealing and easy to understand. Its fundamental premise is that the best alternative, say *i*th, should have the shortest Euclidean distance $S_i^+ = \sqrt{\sum (r_{ij} - r_j^+)^2}$ from the ideal solution (r_j^+ , made up of the best value for each criterion regardless of the alternative), and the farthest distance $S_i^- = \sqrt{\sum (r_{ij} - r_j^-)^2}$ from the negative-ideal solution (r_j^- made up of the worst value for each criterion). The alternative with the highest relative closeness measure $\frac{S_i^-}{S_i^+ + S_i^-}$ is chosen as the best one.

3. Empirical study and discussions

3.1. Determination of criteria weights

The weights of criteria should be determined by top manager or the DM. The AHP is the most widely used approach to determining the weights of criteria. Suppose the pair wise comparison matrix for the seven assessment criteria provided by the DM is as follows:

$$A = \begin{bmatrix} 1 & 1 & 1 & 2 & 2 & 1 & 3 \\ 1 & 1 & 4 & 5 & 2 & 4 & 7 \\ 1 & 1/4 & 1 & 2 & 2 & 1 & 3 \\ 1/2 & 1/5 & 1/2 & 1 & 1 & 2 & 2 \\ 1/2 & 1/2 & 1/2 & 1 & 1 & 4 & 5 \\ 1 & 1/4 & 1 & 1/2 & 1/4 & 1 & 3 \\ 1/3 & 1/7 & 1/3 & 1/2 & 1/5 & 1/3 & 1 \end{bmatrix}$$

whose maximum eigen value is $\lambda_{\max}$ =7.6256and the corresponding normalized principal right eigenvector is $w = (0.1491, 0.3255, 0.1432, 0.0949, 0.1571, 0.0884, 0.0418)^T$ .The consistency index for the above paired comparison matrix is $CI = \frac{\lambda_{\max} - n}{n-1} = 0.1042$ and the corresponding consistency ratio is $CR = \frac{CI}{RI} = 0.0789$ .Due to the fact that CI < 0.1, the above pair wise comparison matrix is thought to have acceptable consistency and its normalized principal right eigenvector can be used as the weights of criteria.

3.2. Performance measure of vendors

From the criteria weights obtained from AHP, the performance of alternatives corresponding to each evaluation criterion evaluated by respondents is measured via linguistic variables which are expressed as triangular fuzzy numbers. The performance measures of each respondent are then calculated by Eqs. (8)–(17) to obtain the overall performance measure for each vendor. Table 2 lists the linguistic variables for the three vendors; Table 3. lists the fuzzy performance measure for the three vendors. Weighted fuzzy-decision matrix is constructed as in Table 4. After obtaining the performance measure in terms of fuzzy number, it defuzzify the fuzzy numbers into crisp numbers so as to conduct TOPSIS ranking procedure. It used Center-of-Area method (as Eq. (18)) to defuzzify the fuzzy numbers, which are as shown in Table 5.

Table 2
Ratings of the 3 vendors by decision-makers under various criteria

vendors evaluation criteria	V_1	V_2	V_3
Mark-up	F	L	H
Processing time	F	F	H
Prototyping time	L	L	F
Design revision time	H	H	H
Quality system	F	L	H
Co-design	F	F	F
Technological levels	F	L	H

Table 3
Fuzzy performance measures of vendors

vendors evaluation criteria	V_1	V_2	V_3
Mark-up	(4,5,6)	(2,3,4)	(6,7,8)
Processing time	(4,5,6)	(4,5,6)	(6,7,8)
Prototyping time	(2,3,4)	(2,3,4)	(4,5,6)
Design revision time	(6,7,8)	(6,7,8)	(6,7,8)
Quality system	(4,5,6)	(2,3,4)	(6,7,8)
Co-design	(4,5,6)	(4,5,6)	(4,5,6)
Technological levels	(4,5,6)	(2,3,4)	(6,7,8)

Table 4
Weighted fuzzy decision matrix

vendors evaluation criteria	V_1	V_2	V_3
Mark-up	(0.5964,0.7455,0.8946)	(0.2982,0.4473,0.5964)	(0.8946,1.0437,1.1928)
Processing time	(1.302,1.6275,1.953)	(1.302,1.6275,1.953)	(1.953,2.2785,2.604)
Prototyping time	(0.2864,0.4296,0.5728)	(0.2864,0.4296,0.5728)	(0.5728,0.716,0.8592)
Design revision time	(0.5694,0.6643,0.7592)	(0.5694,0.6643,0.7592)	(0.5694,0.6643,0.7592)
Quality system	(0.6284,0.7855,0.9426)	(0.3142,0.4713,0.6284)	(0.9426,1.0997,1.2568)
Co-design	(0.3536,0.442,0.5304)	(0.3536,0.442,0.5304)	(0.3536,0.442,0.5304)
Technological levels	(0.1672,0.209,0.2508)	(0.0836,0.1254,0.1672)	(0.2508,0.2926,0.3344)

Table 5
Overall performance measures of vendors

vendors evaluation criteria	V_1	V_2	V_3
Mark-up	0.7455	0.4473	1.0437
Processing time	1.6275	1.6275	2.2785
Prototyping time	0.4296	0.4296	0.716
Design revision time	0.6643	0.6643	0.6643
Quality system	0.7855	0.4713	1.0997
Co-design	0.442	0.442	0.442
Technological levels	0.209	0.1254	0.2926

3.3. Final ranking

In this paper, it use AHP method in obtaining criteria weight, and apply TFN to assess the linguistic ratings given by the evaluators. By using TOPSIS, aggregate the weight of evaluate criteria and the matrix of performance to evaluate the three vendors, the vendors evaluation results can be seen in Table 6.

Table 6
Final ranking of airlines

Rank	Vendor	Similarity to ideal solution
1	V_1	0.6548
2	V_3	0.5536
3	V_2	0.4463

4. Conclusions

Many practitioners and researchers have presented the advantages of supply chain management. In order to increase the competitive advantage, many companies consider that a well designed and implemented supply chain system is an important tool. Under this condition, building on the closeness and long-term relationships between buyers and vendors is critical success factor to establish the supply chain system. Therefore, vendor selection problem becomes the most important issue to implement a successful supply chain system. Therefore, in this paper, it establishes the procedures for assessment of vendors based on criteria. The evaluation procedures consist of the following steps: (1) identify the evaluation criteria for vendor selection; (2) assess the average importance of each criterion by Analytic Hierarchical Process over all the respondents. (3) Represent the performance assessment of vendor for each criterion by fuzzy numbers, which explicitly attempts to accurately capture the real preference of assessors. Individual assessment then is aggregated as an overall assessment for each vendor under each criterion. (4) Use TOPSIS as the main device in ranking the vendor. On other hand, it uses the fuzzy approach on vague objects such as the satisfaction of vendor. This method is effectual in establishing an analytic preview of the vendors available for a particular application in terms of its efficiency before the decision maker. Hence, the FMCDM approach was proved to be a powerful technique for a rapid and comparative assessment of the vendors.

References

[1] B.E. Bellman, L.A. Zadeh, Decision-making in a fuzzy environment, Management Science, vol. 17, 4, 141–164, 1970.

[2] L. Boer, D. Luitzen, L. Eva, M. Pierangela, A review of methods supporting supplier selection, European Journal of Purchasing & Supply Management, vol. 7, 75- 89, 2001.

[3] F.P. Buffa, W.M. Jackson, A goal programming model for purchasing planning, Journal of Purchasing and Materials Management, vol. 19, 3, 27–34, 1983.

[4] J.J. Buckley, Fuzzy hierarchical analysis, Fuzzy Sets and Systems, vol. 17, 233-247, 1985.

[5] D.J. Carney, K.C. Wallnau, A basis for evaluation of commercial software, Information and Software Technology, vol. 40, 851–860, 1998.

[6] F.T.S. Chan, N. Kumar, M.K. Tiwari, H.C.W. Lau, K.L. Choy, Global supplier selection: a fuzzy- AHP approach. International Journal of Production Research, First published on 16 February 2007.

[7] S.Y. Chou, C.Y. Shen, Y.H. Chang, Vendor selection in a modified re-buy situation using a strategy aligned fuzzy approach. International Journal of Production Research, vol. 45, 14, 3113 – 3133, 2007.

[8] T.Y. Choi, J.L. Hartley, An exploration of supplier selection practices across the supply chain. Journal of Operations Management, vol. 14, 333–343, 1996.

[9] R.L. Cook, Expert systems in purchasing applications and development. International Journal of Purchasing and Management, vol. 18, 20–27, 1992.

[10] R.L. Cook, Case-based reasoning systems in purchasing: applications and development, International Journal of Purchasing and Materials Management, vol. 33, 1, 32–39, 1997.

[11] L. De Boer, L. Van der Wegen, J., Telgen, Outranking methods in support of supplier selection. European Journal of Purchasing & Supply Management, vol. 4, 109–118, 1998.

[12] H. Ding, L., Benyoucef, X., Xie, A simulation-optimization approach using genetic search for supplier selection, in: Proceeding of the 2003 Winter Simulation Conference, 7–10 December, New Orleans, LA, USA, vol. 2, pp. 1260–1267, 2003.

[13] D.W. Dobler, D.N. Burt, Purchasing and Supply Management, 6th edition, McGraw-Hill, NY, 1996.

[14] S. Dowlatshahi, Design–buyer–supplier interface: Theory versus practice. International Journal of Production Economics, vol. 63, 111–130, 2000.

[15] B. Donaldson, Supplier selection criteria on the service dimension. European Journal of Purchasing and Supply Management, vol. 1, 209–217, 1994.

[16] R. Dulmin, V. Mininno, Supplier selection using a multi-criteria decision aided method, Journal of Purchasing and Supply Management, vol. 9, 177–187, 2003.

[17] L.M. Ellram, The supplier selection decision in strategic partnerships. International Journal of Purchasing and Management, vol. 18, 8–14, 1992.

[18] S.H. Ghodsypour, C. O'Brien, A decision support system for supplier selection using an integrated analysis hierarchy process and linear programming, International Journal of Production Economics, vol. 56–57, 199–212, 1998.

[19] C.L. Hinkle, P.J. P.E., Green, Green, Vendor evaluation using cluster analysis, Journal of Purchasing, vol. 5, 3, 49–58, 1969.

[20] C.L. Hwang, K. Yoon, Multiple Attribute Decision Making, Springer-Verlag, Berlin, 1981.

[21] V. Jain, S. Wadhwa, S.G. Deshmukh, Supplier selection using fuzzy association rules mining approach. International Journal of Production Research, vol. 45, 6 , 1323 – 1353, 2007.

[22] A. Kaufmann, M.M. Gupta, Introduction to Fuzzy Arithmetic: Theory and Applications. Van Nostrand Reinhold, New York, 1991.

[23] G.J. Klir, B. Yuan, Fuzzy Sets and Fuzzy Logic: Theory and Applications. Prentice-Hall Inc., USA, 1995.

[24] J. Kontio, A case study in applying a systematic method for COTS selection, in: Proceedings of the 18th International Conference on Software Engineering, 25–30 March 1996, 201–209, 1995.

[25] A. Mandal, S.G. Deshmukh, Vendor selection using interpretive structural modeling (ISM), International Journal of Operations and Production Management, vol. 14, 6, 52–59, 1994.

[26] S. Mehmet, S.C. Lenny Koh, Selim Zaim, Mehmet Demirbag, Ekrem Tatoglu, An application of data envelopment analytic hierarchy process for supplier selection: a case study of BEKO in Turkey. International Journal of Production Research, vol. 45, 9, 1973 – 2003, 2007.

[27] H. Min, Selection of software-the analytic hierarchy process, International Journal of Physical Distribution and Logistics Management, vol. 22, 1, 42–52, 1992.

[28] V. Mummalaneni, K.M. Dubas, C. Chao, Chinese purchasing managers' preferences and trade-offs in supplier selection and performance evaluation, Industrial Marketing Management, vol. 25,115–124, 1996.

[29] D.S. Negi, Fuzzy analysis and optimization. Ph.D. Dissertation, Department of Industrial Engineering, Kansas State University, 1989.

[30] R.L. Nydick, R.P. Hill, Using the analytic hierarchy process to structure the supplier selection procedure, International Journal of Purchasing and Materials Management, vol. 28, 2, 31-36, 1992.

[31] C. O'Neal, Concurrent engineering with early supplier involvement: a cross functional challenge. International Journal of Purchasing and Materials Management, vol. 29, 2, 3–29, 1993.

[32] F. Roodhooft, J. Konings, Vendor selection and evaluation—an activity based costing approach. European Journal of Operational Research, vol. 96, 97–102, 1996.

[33] D. Riccardo, V. Mininno, Supplier selection using a multi-criteria decision aid method. Journal of Purchasing & Supply Management, vol. 9, 177–187, 2003.

[34] T.L. Saaty, A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology, vol. 15, 2, 234–281, 1977.

[35] T.L. Saaty, The Analytic Hierarchy Process. McGraw-Hill, New York, 1980.

[36] H.S. Shih, C.H. Wang, E.S. Lee, A multiattribute GDSS for aiding problem solving, Mathematical and Computer Modelling, vol. 39, 11–12, 1397–1412, 2004.

[37] W.R. Soukup, Supplier selection strategies, Journal of Purchasing and Materials Management, vol. 23, 3, 7–12, 1987.

[38] C.O. Swift, Preference for single sourcing and supplier selection criteria. Journal of Business Research, vol. 32, 105–111, 1995.

[39] R. Verma, M.E. Pullman, An analysis of the supplier selection process. Omega, vol. 26, 739–750, 1998.

[40] R.J. Vokurka, J. Choobineh, L. Vadi, A prototype expert system for the evaluation and selection of potential suppliers, International Journal of Operations and Production Management, vol. 16, 12, 106–127, 1996.

[41] J. Wang, Ching-Hsue Cheng, Huang Kun-Cheng., Fuzzy hierarchical TOPSIS for supplier selection. Applied Soft Computing, under press. doi:10.1016/j.asoc.2008.04.014, 2008.

[42] C.A. Weber, A data envelopment analysis approach to measure vendor performance, Supply Chain Management, vol. 1, 1, 28–39, 1996.

[43] C.A. Weber, J.R. Current, W.C. Benton, Vendor selection criteria and methods. European Journal of Operational Research, vol. 50, 2–18, 1991.

[44] C.A. Weber, A. Charles, J.R. Current, R. John, A multiobjective approach to vendor selection, European Journal of Operational Research, vol. 68, 173-184, 1993.

[45] C.A. Weber, J.R. Current, A. Desai, Non-cooperative negotiation strategies for vendor selection. European Journal of Operational Research, vol. 108, 208–223, 1998.

[46] S. Wei, J. Zhang, Z. Li, A supplier-selecting system using a neural network, in: IEEE International Conference on Intelligent Processing System, 28–31 October, Beijing, China, vol. 1, , pp. 468–471, 1997.

[47] L.A. Zadeh, Fuzzy sets, Information and Control, vol. 8, 3, 338–353, 1965.

[48] G. Zenz, Purchasing and the Management of Materials, Wiley, New York, 1981.

[49] H.J. Zimmermann, Fuzzy Set Theory – And its Application, 2nd ed., Kluwer, Boston, 1991.