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Research Article

Selection of Vendor Based on Intuitionistic Fuzzy Analytical Hierarchy Process

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Business environment is characterized by greater domestic and international competitive position in the global market. Vendors play a key role in achieving the so-called corporate competition. It is not easy however to identify good vendors because evaluation is based on multiple criteria. In practice, for VSP most of the input information about the criteria is not known precisely. Intuitionistic fuzzy set is an extension of the classical fuzzy set theory (FST), which is a suitable way to deal with impreciseness. In other words, the application of intuitionistic fuzzy sets instead of fuzzy sets means the introduction of another degree of freedom called nonmembership function into the set description. In this paper, we proposed a triangular intuitionistic fuzzy number based approach for the vendor selection problem using analytical hierarchy process. The crisp data of the vendors is represented in the form of triangular intuitionistic fuzzy numbers. By applying AHP which involves decomposition, pairwise comparison, and deriving priorities for the various levels of the hierarchy, an overall crisp priority is obtained for ranking the best vendor. A numerical example illustrates our method. Lastly a sensitivity analysis is performed to find the most critical criterion on the basis of which vendor is selected.

1. Introduction

In most industries the cost of raw materials and component parts constitutes the main cost of a product, such that in some cases it can account for up to 70% (Ghobadian and Stainer [1]). In high technology firms, purchased materials and services represent up to 80% of total product cost (Weber et al. [2]). Thus the purchasing department can play a key role in an organization's efficiency and effectiveness since the department has a direct effect on cost reduction, profitability, and flexibility of a company by selecting the right suppliers which significantly reduces the purchasing costs and improves corporate competitiveness (Ghodsypour and O'Brien [3]). The objective of supplier selection is to identify suitable supplier on the basis of comparison of suppliers using a common set of criteria and measures.

The first study on vendor selection was carried by Dickson [4] who identified 23 important evaluation criteria for supplier selection. Later Weber et al. reviewed, classified, and addressed the supplier selection problem and De Boer et al. [5] identified four stages for supplier selection including definition of the problem, formulation of criteria, qualification, and final selection, respectively. A number of methodologies have been proposed for solving vendor selection problem. Some adopted models specifically account for the imprecision of the rating mechanism. We will consider analytical hierarchy process for vendor selection problem. Narsimhan [6] used an analytical hierarchy process to select vendors for general industrial purchasing.Ghodsypour and O'Brien [7] combined AHP and LP in order to take into account tangible and intangible criteria and to optimize order allocation among suppliers. Yahya and Kingsman [8] used Saaty's analytic hierarchy process method into vendor rating system for a government sponsored entrepreneur development programme by describing a case study. Tam and Tummala [9] presented a real case study to select the best vendor for telecommunication systems by formulating analytic hierarchy process (AHP) based approach. It is seen that this approach is flexible and less time consuming. Zhang et al. [10] formulated AHP based model and presented a case study to examine the function of 3PL vendor selection of 4PL systems. This approach shows that computed quantitative evaluations can be applied to improve the precision of the vendor selection. Nydick and Hill [11], Barbarosoglu and Yazgac [12], Bevilacqua and Braglia [13], Tam and Tummala [9], Chan [14], and Sevkli et al. [15] propose the use of analytical hierarchy process to deal with imprecision in supplier choice. AHP has the advantages of simplicity and ease of use, but it does not take into account the uncertainty associated with the mapping of one's perception to a number (Deng [16]). Also conventional AHP is criticized forits inability to handle the uncertainty and imprecision in the pairwise comparison process. Therefore fuzzy AHP was designed to overcome the problem of uncertainty, imprecision, and multiplicity of meaning in hierarchical fuzzy problem. van Laarhoven and Pedrycz [17] were the first to discuss such a procedure by using triangular membership functions and comparing the fuzzy ratios. In a while, Buckley [18] showed how to derive the priorities from a set of fuzzy comparisons described by trapezoidal membership functions. Chang [19] introduced a novel methodology based on the synthetic extent values of the fuzzy pairwise comparisons. Then Mikhailov [20] introduced the method of deriving priorities from fuzzy preference programming. Practical applications of the fuzzy AHP methodology abound. The technique was successfully applied for evaluating the vendors by Morlacchi [21], Kahraman et al. [22], and Chan and Kumar [23]. The best condition for a decision making problem may still not be satisfied when decision situation involves fuzzy or crisp data. In fuzzy set theory, there is no means to incorporate the lack of knowledge with the membership degrees. A possible solution is to use intuitionistic fuzzy sets (IFSs for short), introduced by Atanassov [24]. It is characterized by two functions expressing the degree of membership and the degree of nonmembership, respectively. The theory of the IF set has been found to be more useful to deal with vagueness and uncertainty in decision situations than that of the fuzzy set. A very few approaches of vendor selection problem have been studied under intuitionistic fuzzy set approach. Shahrokhi et al. [25] gave an integrated method using intuitionistic fuzzy set and linear programming for supplier selection problem. Boran et al. [26] gave a multicriteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. Chamodrakas et al. [27] evaluated method involving two stages: initial screening of the suppliers through the enforcement of hard constraints on the selection criteria and final supplier evaluation through the application of a modified variant of the Fuzzy Preference Programming (FPP) method. Babić and Perić [28] solve vendor selection problem using an integration of analytic hierarchy process (AHP), weighted sum model (WSM), and fuzzy multiobjective mixed-integer programming to define the optimum quantities among the selected suppliers. The use of IF-AHP can help a decision maker to make more realistic and informed decisions based on available information, without making strong assumptions about the state of knowledge [29]. The combination of IFS and AHP is new in vendor selection problem and handles vagueness and ambiguity uncertainties in AHP involving degree of satisfiability and of nonsatisfiability of each vendor with respect to a set of criteria.

Table 1: Vendor selection criteria.

Criterion	Factor
Cost (C)	(i) Price (ii) Logistic costs (iii) Operating costs (iv) After-sales service costs
Quality (Q)	(i) Quality performance (ii) Marketability (iii) Durability (iv) Ergonomic qualities (v) Flexibility of operation (vi) Simplicity of operation (vii) Reliability
Cycle time (CT)	(i) Speed to market (ii) Delivery lead time (iii) Development speed (iv) On-time delivery (v) Fill rate
Service (S)	(i) Reaction to demand (ii) Ability to modify product (iii) Supply variety (iv) Technical support (v) After-sales services (e.g., warranties and claim policies) (vi) Flexibility (payment, Freight reduction, order frequency, and amount) (vii) Delivery frequency
Reputation (R)	(i) Position in the industry (ii) Dependability (iii) Trust (iv) Business references (v) Financial condition (vi) Market share

Table 2: Crisp data sets for the main comparison matrix.

Goal	C	Q	S	CT	R
C	1	1	1	4	1
Q	1	1	2	4	2
S	.25	.25	.2	1	.33
CT	1	.5	1	5	3
R	1	1	.33	3	1

The organization of the paper is as follows: Section 1 introduces the vendor selection problem along with the literature view of the problem. Section 2 gives an insight into some basic definitions on intuitionistic fuzzy sets. Section 3 explains the methodology followed by numerical example in

Table 3: Comparison matrix of cost with respect to the three alternatives.

Cost	Vendor A	Vendor B	Vendor C
Vendor A	1	.25	.5
Vendor B	4	1	3
Vendor C	2	.33	1

Table 4: Comparison matrix of quality with respect to the three alternatives.

Quality	Vendor A	Vendor B	Vendor C
Vendor A	1	.25	.2
Vendor B	4	1	.5
Vendor C	5	2	1

Table 5: Comparison matrix of service with respect to the three alternatives.

Service	Vendor A	Vendor B	Vendor C
Vendor A	1	.33	5
Vendor B	3	1	7
Vendor C	.2	.143	1

Table 6: Comparison matrix of cycle time with respect to the three alternatives.

Cycle time	Vendor A	Vendor B	Vendor C
Vendor A	1	3	3
Vendor B	.33	1	1
Vendor C	.33	1	1

Table 7: Comparison matrix of reputation with respect to the three alternatives.

Reputation	Vendor A	Vendor B	Vendor C
Vendor A	1	1	7
Vendor B	1	1	7
Vendor C	.143	.143	1

Section 4 and sensitivity analysis in Section 5. Section 6 deals with discussion followed by managerial implications. Finally Section 7 concludes the paper.

2. Preliminaries on Intuitionistic Fuzzy Sets

2.1. Definition 1. Given a fixed set $X = \{x_1, x_2, \ldots, x_n\}$, an intuitionistic fuzzy set (IFS) is defined as $\overline{\overline{A}} = (\langle x_i, t_A(x_i), f_A(x_i)\rangle / x_i \in X)$ which assigns to each element x_i a membership degree $t_A(x_i)$ and a nonmembership degree $f_A(x_i)$ under the condition $0 \leq t_A(x_i) + f_A(x_i) \leq 1$, for all $x_i \in X$.

2.2. Definition 2. A triangular intuitionistic fuzzy number (TIFN) $\overline{\overline{A}}$ is an intuitionistic fuzzy set in R with the following membership function $\mu_{\overline{\overline{A}}}(x)$ and nonmembership $\vartheta_{\overline{\overline{A}}}(x)$:

$$\mu_{\overline{\overline{A}}}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1}, & a_1 \leq x \leq a_2, \\ \dfrac{x - a_2}{a_3 - a_2}, & a_2 \leq x \leq a_3, \\ 0, & \text{otherwise}, \end{cases}$$
$$\vartheta_{\overline{\overline{A}}}(x) = \begin{cases} \dfrac{a_2 - x}{a_2 - a_1'}, & a_1' \leq x \leq a_2, \\ \dfrac{x - a_2}{a_3 - a_2'}, & a_2 \leq x \leq a_3', \\ 0, & \text{otherwise}, \end{cases} \tag{1}$$

where $a_1' \leq a_1 \leq a_2 \leq a_3 \leq a_3'$ and $\mu_{\overline{\overline{A}}} + \vartheta_{\overline{\overline{A}}} \leq 1$.

2.3. Arithmetic Operations of Triangular Intuitionistic Fuzzy Number. If $\overline{\overline{A}} = \{(a_1, a_2, a_3); (a_1', a_2, a_3')\}$ and $\overline{\overline{B}} = \{(b_1, b_2, b_3)(b_1', b_2, b_3')\}$ are two TIFNs, Then we define the following.

(1) *Addition* of two TIFNs

$$\overline{\overline{A}} + \overline{\overline{B}} = \left\{(a_1 + b_1, a_2 + b_2, a_3 + b_3)\left(a_1' + b_1', a_2 + b_2, a_3' + b_3'\right)\right\} \tag{2}$$

is also a TIFN.

(2) *Subtraction* of two TIFNs

$$\overline{\overline{A}} - \overline{\overline{B}} = \left\{(a_1 - b_3, a_2 - b_2, a_3 - b_1)\left(a_1' - b_3', a_2 - b_2, a_3' - b_1'\right)\right\} \tag{3}$$

is also a TIFN.

(3) *Multiplication* of two TIFNs

$$\overline{\overline{A}} \times \overline{\overline{B}} = \left\{(a_1 b_1, a_2 b_2, a_3 b_3)\left(a_1' b_1', a_2 b_2, a_3' b_3'\right)\right\} \tag{4}$$

is also a TIFN.

(4) If TIFN $\overline{\overline{A}} = (a_1, a_2, a_3)(a_1', a_2, a_3')$ and $y = ka$ (with $k > 0$), then

$$\overline{\overline{y}}' = k\overline{\overline{A}}' \text{ is a TIFN } \left\{(ka_1, ka_2, ka_3)\left(ka_1', ka_2, ka_3'\right)\right\}. \tag{5}$$

(5) *Division* of two TIFNs

$$\frac{\overline{\overline{A}}}{\overline{\overline{B}}} = \left\{\left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right)\left(\frac{a_1'}{b_3'}, \frac{a_2}{b_2}, \frac{a_3'}{b_1'}\right)\right\} \tag{6}$$

is also a TIFN.

Table 8: Intuitionistic fuzzy pairwise comparison of the main criteria.

Goal	C	Q	S	CT	R
C	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)	(3, 4, 5) (2.5, 4, 5.2)	(.8, 1, 2) (.5, 1, 2.1)
Q	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)	(1, 2, 2.5) (.85, 2, 2.7)	(3, 4, 5) (2.5, 4, 5.2)	(1, 2, 2.5) (.85, 2, 2.7)
S	(.1, .25, .9) (.08, .25, 1)	(.1, .25, .9) (.08, .25, 1)	(.8, 1, 2) (.5, 1, 2.1)	(4, 5, 6) (3.5, 6, 6.1)	(.15, .33, 1) (.1, .33, 1.1)
CT	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)	(.15, .33, 1) (.1, .33, 1.1)	(.8, 1, 2) (.5, 1, 2.1)	(.15, .33, 1) (.1, .33, 1.1)
R	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)	(.15, .33, 1) (.1, .33, 1.1)	(2, 3, 4) (1.5, 3, 4.1)	(.8, 1, 2) (.5, 1, 2.1)

Table 9: Intuitionistic fuzzy pairwise comparison for the vendors under cost.

Cost	Vendor A	Vendor B	Vendor C
Vendor A	(.8, 1, 2) (.5, 1, 2.1)	(.1, .25, .9) (.08, .25, 1)	(.2, .55, 1) (.15, .55, 1.5)
Vendor B	(3, 4, 5) (2.5, 4, 5.2)	(.8, 1, 2) (.5, 1, 2.1)	(2, 3, 4) (1.5, 3, 4.1)
Vendor C	(1, 2, 2.5) (.85, 2, 2.7)	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)

2.4. Proposed Accuracy Function for Defuzzification. Let $\overline{\overline{A}} = \{(a_1, a_2, a_3); (a_1', a_2, a_3')\}$ be a TIFN; then accuracy function [30] for defuzzification is defined as

$$\overline{\overline{A}}' = \frac{(a_1 + 2a_2 + a_3) + (a_1' + 2a_2 + a_3')}{8}. \quad (7)$$

2.5. Intuitionistic Analytical Hierarchy Process. The AHP is propounded by Saaty [31] and afterwards gained acceptance for selection phase of decision making process. In intuitionistic fuzzy AHP the pairwise comparison matrix is represented as triangular intuitionistic fuzzy numbers. The weights for the priorities are computed using simple arithmetic operations of triangular intuitionistic fuzzy numbers.

A step-by-step procedure for the intuitionistic fuzzy analytic hierarchy (IF-AHP) is provided in the algorithm below. To develop IF-AHP an example for vendor selection problem [32] is provided.

This section presents an algorithm for intuitionistic fuzzy AHP and pairwise comparison scale in evaluation. The algorithm of IF-AHP is presented as follows.

3. Methodology

Step 1. The AHP decision problem is structured hierarchically at different levels. The top level of the hierarchy represents the overall goal, while the lowest level is composed of all possible alternatives. One or more intermediate levels represent the decision criteria and subcriteria (Figure 1).

Step 2. Develop intuitionistic fuzzy judgement comparisons matrix $\overline{\overline{A}}$. Intuitionistic fuzzy judgment matrix $\overline{\overline{A}}$ is generated using pairwise comparisons during evaluation. The vagueness of decision makers is represented by triangular intuitionistic fuzzy numbers $(\overline{\overline{a_{ij}}})$. The triangular fuzzy number is represented as triplets $\overline{\overline{a_{ij}}} = (l_{ij}, m_{ij}, n_{ij})(l_{ij}', m_{ij}, n_{ij}')$.

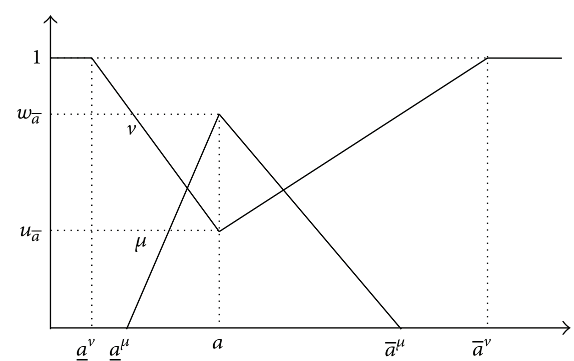

Figure 1: Triangular intuitionistic fuzzy number (TIFN).

Such notation will be used in our further exposition. Then construct the fuzzy pairwise comparison such that

$$\overline{\overline{A}} = \begin{bmatrix} 1 & \overline{\overline{a}}_{12} & \cdots & \overline{\overline{a}}_{1n} \\ \overline{\overline{a}}_{21} & 1 & \cdots & \overline{\overline{a}}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \overline{\overline{a}}_{n1} & \overline{\overline{a}}_{n2} & \cdots & 1 \end{bmatrix}, \quad (8)$$

where $\overline{\overline{a}}_{ji} = 1/\overline{\overline{a}}_{ij}$.

Step 3. AHP methodology provides a consistency index [31] to measure any inconsistency within the judgments in each comparison matrix as well as for the entire hierarchy. The AHP utilizes consistency index (CI) and consistency ratio (CR) to discern if there is any inconsistency in the fuzzy judgment matrix. The threshold of the CR is less than 10% for acceptable results.

Step 4. We calculate the intuitionistic fuzzy set priority weights for the hierarchy of subcriteria and alternative with respect to all criteria. The geometric mean method is used to compute the intuitionistic fuzzy priority weights. For each

Table 10: Intuitionistic fuzzy pairwise comparison of quality with respect to the three alternatives.

Quality	Vendor A	Vendor B	Vendor C
Vendor A	(.8, 1, 2) (.5, 1, 2.1)	(.1, .25, .9) (.05, .25, 1)	(.08, .2, .5) (.06, .2, .7)
Vendor B	(3, 4, 5) (2.5, 4, 5.2)	(.8, 1, 2) (.5, 1, 2.1)	(.2, .55, 1) (.15, .55, 1.5)
Vendor C	(4, 5, 6) (3.5, 6, 6.1)	(1, 2, 2.5) (.85, 2, 2.7)	(.8, 1, 2) (.5, 1, 2.1)

Table 11: Intuitionistic fuzzy pairwise comparison of service with respect to the three alternatives.

Service	Vendor A	Vendor B	Vendor C
Vendor A	(.8, 1, 2) (.5, 1, 2.1)	(.15, .33, 1) (.1, .33, 1.1)	(4, 5, 6) (3.5, 5, 6.1)
Vendor B	(2, 3, 4) (1.5, 3, 4.1)	(.8, 1, 2) (.5, 1, 2.1)	(6, 7, 8) (6, 7, 8.2)
Vendor C	(.08, .2, .5) (.06, .2, .7)	(.1, .14, .5) (.05, .14, .65)	(.8, 1, 2) (.5, 1, 2.1)

row geometric mean $\overline{\overline{P_i}}$ is determined using the following formula:

$$\overline{\overline{P_i}} = \left(\overline{\overline{P_{i1}}} \otimes \cdots \otimes \overline{\overline{P_{in}}}\right)^{1/n}. \quad (9)$$

Intuitionistic fuzzy weight after normalization is given by

$$\overline{\overline{w_i}} = \overline{\overline{P_i}} \otimes \left(\overline{\overline{P_1}} \oplus \cdots \oplus \overline{\overline{P_n}}\right)^{-1}. \quad (10)$$

Step 5. This includes aggregating the local priorities to get global priorities.

Step 6. Establish hierarchical layer sequencing for determining global priorities. The weighted intuitionistic fuzzy performance for each alternative on each criteria is evaluated.

In this step multiplication intuitionistic fuzzy triangular numbers are used for getting the weighted intuitionistic fuzzy decision matrix (see Table 23).

Step 7. This step includes defuzzification and ranking of vendors.

Ranking of alternative is as follows.

(1) Average score of alternatives with respect to criteria:

$$S(A_i) = \sum_{j=1}^{m} A_i(C_j). \quad (11)$$

(2) Defuzzification of average of alternatives:

$$D\{S(A_i)\} = \left[\frac{(a_1 + 2a_2 + a_3) + (a_1' + 2a_2 + a_3')}{8}\right]. \quad (12)$$

4. Numerical Example

A high technology manufacturing company desires to select suitable material vendor to purchase the key components of new products. Three potential vendors A, B, and C were shortlisted for evaluation after preliminary screening. The evaluation is based on five criteria (Table 1): (1) cost (C), (2) quality (Q), (3) cycle time (CT), (4) service (S), and (5) reputation (R). The hierarchical structure of this decision problem is shown in Figure 2. The crisp data used for evaluating the vendors is shown in Tables 2, 3, 4, 5, 6, and 7. The crisp data are converted into triangular fuzzy numbers to construct the fuzzy decision matrix (Tables 8, 9, 10, 11, 12, and 13) and determine the fuzzy weight of each criterion (Tables 14, 15, 16, 17, 18, and 19).

4.1. Algorithm

Step 1. Formulate the decision problem as a hierarchical structure (Figure 2). The first layer represents the goal of the problem, the second layer represents important decision criteria, and the third layer represents the alternative choices.

Step 2. Determine the fuzzy comparison judgment matrix by using intuitionistic triangular fuzzy numbers given as follows:

$$\begin{aligned} &\tilde{1} = (.8, 1, 2)\,(.5, 1, 2.1) \qquad \tilde{2} = (1, 2, 2.5)\,(.85, 2, 2.7) \\ &\tilde{3} = (2, 3, 4)\,(1.5, 3, 4.1) \qquad \tilde{4} = (3, 4, 5)\,(2.5, 4, 5.2) \\ &\tilde{5} = (4, 5, 6)\,(3.5, 6, 6.1) \qquad \tilde{7} = (6, 7, 8)\,(6, 7, 8.2). \end{aligned} \quad (13)$$

Step 3. Compute local priorities first from pairwise comparison of criteria and then pairwise comparison of vendors with respect to all criteria.

Step 4. Determine the weights of each criterion from the corresponding pairwise criteria comparison matrix for calculating overall priority of membership and nonmembership function of each vendor and final ranking of all vendors (see Table 20).

Step 5. Ranking the vendor with the highest priority score is chosen for allocation of order quantity.

5. Sensitivity Analysis

Every proposed model presented by different researchers should be subject to various analyses. Sensitivity analysis is a relationship between input parameter and the output parameter of the model. It is a technique used to determine

Table 12: Intuitionistic fuzzy pairwise comparison matrix of cycle time with respect to the three alternatives.

Cycle time	Vendor A	Vendor B	Vendor C
Vendor A	(.8, 1, 2) (.5, 1, 2.1)	(2, 3, 4) (1.5, 3, 4.1)	(2, 3, 4) (1.5, 3, 4.1)
Vendor B	(.15, .33, 1) (.1, .33, 1.1)	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)
Vendor C	(.15, .33, 1) (.1, .33, 1.1)	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)

Table 13: Intuitionistic fuzzy pairwise comparison of reputation with respect to the three alternatives.

Reputation	Vendor A	Vendor B	Vendor C
Vendor A	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)	(6, 7, 8) (6, 7, 8.2)
Vendor B	(.8, 1, 2) (.5, 1, 2.1)	(.8, 1, 2) (.5, 1, 2.1)	(6.5, 7, 8) (6, 7, 8.2)
Vendor C	(.1, .14, .5) (.05, .14, .65)	(.1, .14, .5) (.05, .14, .65)	(.8, 1, 2) (.5, 1, 2.1)

Table 14: Weights obtained from Table 2.

Goal	
C	(1.042, 1.31, 2.402) (.689, 1.31, 2.51)
Q	(1.1394, 1.74, 2.62) (.853, 1.74, 2.78)
S	(.1572, .33, .95) (.130, .38, 1.10)
CT	(1.00, 1.52, 2.49) (.472, 1.146, 2.23)
R	(.68, .99, 2.00) (.451, .998, 2.10)

Table 15: Weights for the vendors under cost from Table 3.

Cost	
Vendor A	(.255, .519, 1.214) (.1898, .519, 1.46)
Vendor B	(1.67, 2.27, 3.378) (1.23, 2.27, 3.50)
Vendor C	(.8631, 1.25, 2.138) (.599, 1.25, 2.26)

Table 16: Weights for the vendors under quality from Table 4.

Quality	
Vendor A	(.188, .372, .965) (.136, .372, 1.13)
Vendor B	(.784, 1.29, 2.13) (.575, 1.29, 2.51)
Vendor C	(1.467, 2.13, 3.07) (1.14, 2.27, 3.21)

Table 17: Weights for the vendors under service from Table 5.

Service	
Vendor A	(.784, 1.179, 2.27) (.562, 1.252, 2.394)
Vendor B	(2.16, 2.73, 3.94) (1.642, 2.731, 4.0748)
Vendor C	(.188, .307, .795) (.117, .307, .9851)

Table 18: Weights for the vendors under cycle time from Table 6.

Cycle time	
Vendor A	(1.467, 2.064, 3.138) (1.0396, 2.0649, 3.2417)
Vendor B	(.4615, .6936, 1.5801) (.6244, .6936, 1.6318)
Vendor C	(.4615, .6936, 1.5801) (.2960, .6936, 1.6318)

the effect of economic and technical parameters on the profitability of the model.

5.1. Algorithm. Let us consider a decision making problem which consists of M alternatives and N criteria. In this paper

Table 19: Weights for the vendors under reputation from Table 7.

Reputation	
Vendor A	(.7487, 1.9006, 3.138) (1.1432, 1.9006, 3.2676)
Vendor B	(1.6007, 1.9506, 3.138) (1.1432, 1.9006, 3.2676)
Vendor C	(.2032, .2732, .795) (.1101, .2732, .9613)

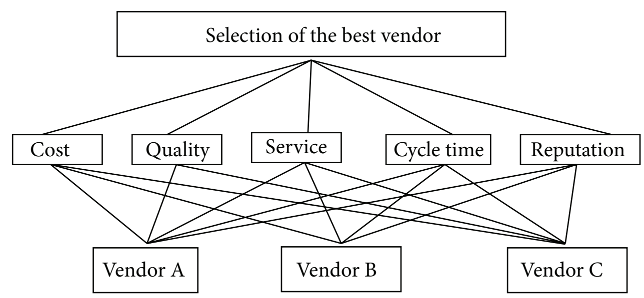

Figure 2: AHP model for vendor selection problem.

alternatives are denoted by A_i (for $i = 1, 2, 3, \ldots, M$) and criteria by C_j (for $j = 1, 2, 3, \ldots, N$). Weights of each criterion are given which determines its importance, or weight, W_j, where

$$\sum_{j=1}^{n} w_j = 1. \tag{14}$$

a_{ij} (for $i = 1, 2, 3, \ldots, M$ and $j = 1, 2, 3, \ldots, N$) determines the importance (or measure of performance) of alternative A_i in terms of criterion C_j.

Step 1. Calculate δ_{kij} using formula

$$\delta_{kij} = \frac{\left(P_j - P_i\right)}{\left(a_{jk} - a_{ik}\right)} \tag{15}$$

and calculate δ'_{kij} using formula

$$\delta'_{kij} = \frac{\left(P_j - P_i\right)}{\left(a_{jk} - a_{ik}\right)} \times \frac{100}{W_k}. \tag{16}$$

Table 20: Overall priority of membership and nonmembership function of each vendor.

	Criteria weights	Vendor A	Vendor B	Vendor C
Cost	(1.042, 1.31, 2.402)	(.255, .519, 1.214)	(1.67, 2.27, 3.378)	(.8631, 1.25, 2.138)
	(.689, 1.31, 2.5)	(.1898, .519, 1.46)	(1.23, 2.27, 3.50)	(.599, 1.25, 2.26)
Quality	(1.1394, 1.74, 2.62)	(.188, .372, .965)	(.784, 1.29, 2.13)	(.8631, 1.25, 2.138)
	(.853, 1.74, 2.78)	(.136, .372, 1.13)	(.575, 1.29, 2.51)	(.599, 1.25, 2.26)
Service	(.1572, .33, .95)	(.784, 1.179, 2.27)	(2.16, 2.73, 3.94)	(.188, .307, .795)
	(.130, .38, 1.10)	(.562, 1.252, 2.394)	(1.642, 2.731, 4.0748)	(.117, .307, .9851)
Cycle time	(1.00, 1.52, 2.49)	(.4615, .6936, 1.5801)	(.4615, .6936, 1.5801)	(.4615, .6936, 1.5801)
	(.472, 1.146, 2.23)	(.2960, .6936, 1.6318)	(.6244, .6936, 1.6318)	(.2960, .6936, 1.6318)
Reputation	(.68, .99, 2.00)	(.7487, 1.9006, 3.138)	(1.6007, 1.9506, 3.138)	(.2032, .2732, .795)
	(.451, .998, 2.10)	(1.1432, 1.9006, 3.2676)	(1.1432, 1.9006, 3.2676)	(.1101, .2732, .9613)

Table 21: Final weights for vendors.

	Vendor A	Vendor B	Vendor C
C	(.255, .6799, 2.916)	(1.67, 2.9737, 8.114)	(.83631, 1.6375, 5.1355)
	(.1292, 1.3027, 3.6646)	(.8598, 5.6977, 8.7850)	(.4187, 3.1375, 5.6726)
Q	(.2142, .6473, 2.5283)	(.8933, 2.2446, 5.5806)	(1.6715, 3.7062, 8.0434)
	(.1160, .6473, 3.1414)	(.4905, 2.2446, 6.9778)	(.9724, 3.9498, 8.9235)
S	(.1232, .3891, 2.1565)	(.3396, .9009, 3.7430)	(.0296, .1013, .7552)
	(.0731, .4758, 2.6334)	(.2135, 1.0378, 4.4814)	(.0152, .1167, 1.0538)
CT	(1.467, 3.1373, 7.8136)	(.4615, 1.0538, 3.9344)	(.4615, 1.0538, 3.9344)
	(.4907, 2.3653, 7.2274)	(.2947, .7949, 3.6389)	(.1397, 1.87, 3.6389)
R	(.5091, 1.8816, 6.26)	(1.0880, 1.8816, 6.276)	(.1382, .2705, 1.5900)
	(.5155, 1.8962, 6.8607)	(.5155, 1.8962, 6.8607)	(.0497, .2727, 2.0187)
Global weights	(2.5685, 6.7352, 21.67)	(4.4524, 9.0546, 27.64)	(3.1339, 6.7693, 19.4585)
	(1.3245, 6.6873, 23.5275)	(2.374, 11.6712, 30.7438)	(1.5957, 9.3467, 21.3078)
Crisp weights	8.6559	13.3327	9.7159

Table 22: Overall priority matrix.

	Priorities	Ranking
Vendor A	8.6559	III
Vendor B	13.3327	I
Vendor C	9.7159	II

Table 23: Decision matrix.

Alternative	Criteria				
	C_1	C_2	C_3	$\cdots$	C_N
	W_1	W_2	W_3	$\cdots$	W_N
A_1	a_{11}	a_{12}	a_{13}	$\cdots$	a_{1N}
A_2	a_{21}	a_{22}	a_{23}	$\cdots$	a_{2N}
A_3	a_{31}	a_{32}	a_{33}	$\cdots$	a_{3N}
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
A_M	a_{M1}	a_{M2}	a_{M3}	$\cdots$	a_{MN}

Step 2. Choose the criteria C_k which correspond to the smallest $|\delta'_{kij}|$ value.

Step 3. Calculate the degree of C_k denoted by D'_k :

$$D'_k = \min_{1\le i<j\le m} \left\{ \left| \delta'_{kij} \right| \right\}, \quad \forall n \ge k \ge 1. \tag{17}$$

Step 4. Calculate the sensitivity coefficient of criteria C_k denoted by sens(C_k):

$$\text{sens}\left(C_k\right) = \frac{1}{D'_k}, \quad \forall n \ge k \ge 1. \tag{18}$$

5.2. Numerical Example. Decision matrix for the considered numerical example is calculated (Table 24) from the value presented in Table 21. Converting the value of Table 22 we presented the current final preference value in Table 25. Using formula (15) and formula (16) we have calculated the value of all δ_{kij} and δ'_{kij} which is depicted in Tables 26 and 27. Finally sensitivity coefficient is given of five decision criteria in Table 28. Here it is seen that sensitivity analysis of quality criteria is higher than any other criteria used in our proposed problem definition. So we can say easily that this (quality) criterion is the most sensitive and effective criteria followed by cycle time, reputation, cost, and service, respectively.

Table 24: Decision matrix constructed from Table 21.

Alternative	Criterion				
	Cost (0.23427)	Quality (0.282953)	Service (0.074072)	Cycle time (0.22192)	Reputation (0.131513)
Vendor A	0.1843	0.1293	0.3101	0.518	0.4629
Vendor B	0.4513	0.345	0.5842	0.2225	0.4329
Vendor C	0.3644	0.5257	0.1057	0.2594	0.1047

Table 25: Current final preference constructed from Table 22.

Alternative	Preference (P_j)	Ranking
Vendor A	0.2914	3
Vendor B	0.4096	1
Vendor C	0.2987	2

6. Discussion and Managerial Implications

Sadiq and Tesfamariam [29]proposed IF-AHP methodology for selecting the best drilling fluid for drilling operations under multiple environmental criteria. The concept of IFS in AHP is introduced through pairwise comparisons. The geometric mean is used to compute the intuitionistic fuzzy weights. The intuitionistic fuzzy weights at each level are aggregated to obtain final ranking orders for the alternatives. In this paper, we proposed an IF-AHP based approach for the vendor selection problem. The concept of IFS was introduced by using triangular intuitionistic fuzzy numbers for pairwise comparison. Our aim was to obtain grade of membership for various criteria under various vendors. The grade of membership should be reliable with respect to the context. The consistency ratio was .007 less than .01, making the purchasers evaluation consistent. By applying AHP various priorities were derived for the various levels of the hierarchy. An overall crisp priority is obtained for ranking the best vendor. Lastly a sensitivity analysis is performed to find the most critical criterion on the basis of which vendor is selected. Sensitivity analysis showed that quality criteria followed by cycle time, reputation, cost, and service are more effective than any other criteria used in our proposed problem.

The vendor selection model developed in this study reveals that it can be put to use for both practitioners and researchers. Managers should focus on a set of supplier selection criteria that evaluates suppliers across various dimensions including product quality, product performance, and delivery reliability. A suitable and well-defined set of criteria helps to improve performances of vendors for customer satisfaction as well as its position in the market place. The model performs the ranking of vendors; it provides a means for purchasing managers to set certain level of comparison for selection of higher rated vendors and elimination of lower-ranked vendors. The advantage of this model is that it deals in a categorical, comprehensive, and detailed manner by arranging the vendor selection problem in a hierarchy. A good and efficient management increases the firm's competitive environment.

7. Conclusions

Since 1960s, many researchers have contributed their research interest in the field of vendor selection problem. In this paper we presented AHP based approach in vendor selection using triangular intuitionistic fuzzy numbers. AHP based approach can help a decision maker to make more efficient, flexible, and realistic decisions based upon the available criteria and alternatives. To develop the TIFN-AHP methodology properly a step-by-step algorithm with a simple numerical example is illustrated. Fuzzification was done for intuitionistic fuzzy pairwise comparison between criteria. Then intuitionistic fuzzy set of weights was calculated using intuitionistic fuzzy judgment matrix. Establish hierarchical layer sequencing to estimate global weights to obtain final ranking of the vendors. The intuitionistic defuzzification was done for converting the final IF-AHP score into a crisp value for ranking of vendors. Final calculated global weights and corresponding crisp weights are defined in Table 21. From the calculated final crisp weights ranking of alternatives (vendors) was done, which is shown in Table 22. The ranking of vendors is as vendor B, vendor C, and vendor A. This final result shows accuracy in analysis and ranking of alternatives. Also by sensitivity analysis we see that quality followed by cost was the reason behind the selection of the vendor B.

TIFN provides better optimization modeling in uncertain domain for decision maker. Basically AHP model is very much transparent because hierarchical structure in AHP is easy to understand and comparison between various criteria is easy to capture. AHP is useful when one is evaluating the various fields of a particular domain because this is based on criteria and alternatives.

Sensitivity analysis of criteria for vendor selection problem is very complex task. In our research work sensitivity analysis by using various criteria (quality, cycle time, reputation, cost, and service) was presented. From the result of sensitivity analysis we can collect the information about the input parameter of evaluated criteria that will be helpful in decision making of vendor selection problem. And also we

Table 26: All possible δ_{kij} values.

Pair of alternatives	Criterion				
	Cost	Quality	Service	Cycle time	Reputation
Vendor A and vendor B	0.442697	0.547983	0.431229	−0.4	−3.94
Vendor A and vendor C	0.040533	0.018416	−0.03571	−0.02823	−0.02038
Vendor B and vendor C	1.27618	0.613724	0.231766	−3.00542	0.337904

Table 27: All possible δ'_{kij} values.

Pair of alternatives	Criterion				
	Cost	Quality	Service	Cycle time	Reputation
Vendor A and vendor B	188.9686	193.6658	582.1761	−180.245	−2995.9
Vendor A and vendor C	17.30185	6.50841	−48.2156	−12.7203	−15.4963
Vendor B and vendor C	544.7473	216.8998	312.8928	−1354.28	256.9356

Table 28: Sensitivity analysis of criterion.

Sens. (cost)	Sens. (quality)	Sens. (service)	Sens. (cycle time)	Sens. (reputation)
0.057797	0.153647	−0.02074	−0.07861	−0.06453

will be able to collect the information about the evaluated criteria used in vendor selection problem.

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

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