AN INTUTIONISTIC FUZZY OPTIMIZATION APPROACH FOR THE VENDOR SELECTION PROBLEM

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Abstract

Vendor selection decisions are often driven by multiple criteria, involving single vendor or multiple vendors that might not have the best performance on all the criteria. Therefore, the decision maker must compare performance on the various criteria and make judgement for selection. These criteria are either fuzzy or deterministic; they might not represent exactly the real problem. In fuzzy sets there is no means to incorporate lack of knowledge with membership degree. Intuitionistic fuzzy set suitable way to deal this problem combined with membership function, non-membership function and hesitation margin. We have reformulated the model of **Ghodsypour and O'Brien (1998)** by using intuitionistic fuzzy sets in the model for choosing the best suppliers and order quantities to place with these suppliers so as to maximize the total value of purchasing (TVP). Also a score function has been used to determine the score of vendors for ranking. A numerical example illustrates our results.

Keywords: Intutionistic fuzzy sets, Vendor selection, Score function, Accuracy function

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1. Introduction

The objective of vendor selection is to identify vendors with the highest potential for meeting customers' needs and at an acceptable cost. Selection is a broad comparison of vendors using a common set of criteria and measures. However, the level of detail used for examining potential vendors may vary depending on customers' needs. The overall goal of selection is to identify high potential vendors.

According to literature review many researchers have contributed their innovations in vendor selection problems. Starting with **Dickson (1966)** he laid the foundation of vendor selection problem .Weber et al. (1991), presented a detailed review based on researchers used criteria and applied methods for vendor selection problems. The most commonly used method being linear weighting method with extensions like AHP etc, mathematical programming, fuzzy approaches like fuzzy AHP, fuzzy mathematical and multiobjective programming and lastly integration of IFS with mathematical programming. **Wind and Robinson (1968)** were the first to state about the multiple criteria and first to give a generalized linear weighting model in vendor selection problem. **Lamberson, Diederich and Wuoriu (1976)** gave a quantitative vendor evaluation decision analysis worksheet of the linear weighting model. A number of adaptations have been suggested in order to make linear weighting models better capable of dealing with uncertainty and imprecision. **Partovi, Burton and Banerjee (1989), Nydick and Hill (1992), Yahya and Kingsman (1999)** and **Bayazit and Karpak (2005)** proposed the use of analytical hierarchy process(AHP) to deal with imprecision in supplier selection problem. The traditional AHP cannot be applied to solving uncertain decision-making problems. In order to eliminate this limitation, fuzzy set theory was used by researchers for tackling the uncertainty and imprecision. **Kahraman et al. (2003), Feng et al (2005) , Chan et al. (2007) and Peric et.al.(2013)** introduced an AHP based on fuzzy set theory. Mathematical programming models approach the VSP in a more effective manner than the linear weighting model due to their ability to optimize the explicitly stated objective (**Kumar et. al.(2004)**). The literature survey reveals that in mathematical programming models, Linear Programming(**Moore & Fearon, 1973**), mixed integer programming (**Jayaraman et al. (1999),Ghodsypour and O'Brien (2001))** , goal programming (**Buffa and Jackson (1983),Sharma, Benton, & Srivastava, 1989**,**Karpak et al. (1999))** and multiobjective approach (**Weber and Current (1993), Gao and Tang (2003),Wadhwa and Ravindran (2007) , Xu and Yan (2011))** have been used extensively.

Approaches employing only exact numerical values cannot support decision-making procedure for such evaluation problem. Fuzzy set theory proposed by **Zadeh(1965)** is a classical two-valued logic for reasoning under uncertainty. It provides a mechanism to utilize subjective or imprecise determination of preferences, constraints and goals. In our problem of Vendor Selection conflicting criteria used for evaluating Vendor are best represented by fuzzy sets. A number of studies have been devoted to examining fuzzy approach to Vendor Selection methods (**Bevilacqua and Petroni (2002) ,Kumar et al. (2004, 2006) ,Chou et al. (2006)**). **Madronero, Peidro and Vasant (2010)**.**Yu, Goh and Lin (2012)** used a fuzzy multi objective approach for vendor selection problem.

.However, a human being who expresses the degree of membership of given element in a fuzzy set very often does not express corresponding degree of non-membership as the complement to 1. That is to say, there may be some hesitation degree. As an extension of the fuzzy set, the concept of intuitionistic fuzzy set (IFS) was introduced (**Atanassov (1986,1989**)). It is characterized by two functions expressing the degree of membership and the degree of non-membership, respectively. In many complex decision making problems, the decision information provided by a decision maker is often imprecise or uncertain due to time pressure, lack of data, or the decision maker's limited (**Wu and Zang(2011)**) attention and information processing capabilities **(Xu & Yager(2006))**. Accordingly, IFS is a very suitable tool to describe the imprecise or uncertain decision information and deal with the uncertainty and vagueness in decision making.

The first serious attempt to use IFS in optimization problems was made by **Angelov (1997)** who formulated an intuitionistic fuzzy optimization (IFO) model by adopting the approach of maximizing the degree of acceptance of intuitionistic fuzzy (IF) objective(s) and of constraints and minimizing the degree of rejection of IF objective(s) and constraints. **Dubey et al.(2012)** studied the symmetric model for linear programming set up in the intuitionistic fuzzy scenario. **Deng Feng Li (2008)** extended the linear programming techniques for multidimensional analysis of preference (LINMAP) for solving multiattribute decision making (MADM) problems under Atanassov's intuitionistic fuzzy (IF) environments. So far very few works have been carried out in optimization of vendor selection problem under intutionistic fuzzy sets. **Shahrokhi , Bernard and shidpour(2011)** used IFS and LP to select suppliers for manufacturing firms.Our work is handling linear programming problem (LPP) with data as intuitionistic fuzzy sets. The advantage of Mathematical Programming (MP) models is that they take into account the quantitative criteria, allowing decision makers to consider different constraints in selecting the best set of suppliers. The optimal solutions obtained from these deterministic models may not serve the real purpose of modelling the problem. Moreover deterministic model fail to handle linguistic vagueness like "very good in quality, "low cost" etc of fuzzy type.IFS is a good tool to describe linguistic vagueness using the degree of rejection (non-membership) simultaneously with degree of acceptance (membership) in the objective function or constraints of a LPP. The remaining portion of the paper is organized as follows. In section 2 we discuss the preliminaries of intuitionistic fuzzy sets. Section 3 demonstrates model formulation, Section 4 discusses the numerical example. Finally, the conclusions are presented in section 5.

2.0 Preliminaries

Intuitionistic fuzzy set theory is an extension of fuzzy set theory introduced by **Atanassov (1986)**, which is a suitable way to deal with vagueness.

Definition 1: An intuitionistic fuzzy set (IFS , for short) A on a universe U is defined as an object of the following form: $A=\{(x, \mu_A(x),v_A(x))/x \in U\}$ where the functions μ_A:U→[0,1] and v_A :U→[0,1] define the degree of membership and the degree of non membership of the elements $x \in U$ in A, respectively, and for every $x \in U : 0 \le \mu_A(x) + v_A(x) \le 1$.

Definition 2: The value of $\pi_A(x)= 1 - \mu_A(x) - v_A(x)$ represents the degree of hesitation(or uncertainty) associated with the membership of elements $x\in$ U in IFS A. We call it intutionistic fuzzy index of A with respect of element u.

Definition3:Standard addition operations on IFS

$$A+B=[\mu_A(x)+\mu_B(x)-\mu_A(x)\cdot\mu_B(x), v_A(x)\cdot v_B(x), \pi_A(x)\cdot\pi_B(x)]$$

Definition4: Let $\tilde{A}$ = (μ,v) be an intuitionistic set, an accuracy function H [32]of an intuitionistic fuzzy value can be represented as follows :

$$H(A)=[\mu_A(x)+v_A(x)]$$

Definition5: Score function

Let $\tilde{A}$=(μ,v) be an intuitionistic set, a score function S[32] of an intuitionistic fuzzy value can be represented as follows :

$$\mathbf{S(\tilde{A}) = \mu - v\ ,\ S(\tilde{a}) \in [-1,1]}$$

If S is the largest value among the values $\{S(\tilde{A})\}$, then the alternative A_i is the best choice.

3.0 METHODOLOGY

3.1MODEL FORMULATION

3.1.1THE LINEAR CRISP MODEL FOR VENDOR SELECTION

(Ghodsypour and O'Brien (1998))

Notations:

R_i Final ratings of i^{th} supplier

X_i Order quantity for i^{th} supplier

V_i Capacity of i^{th} supplier

D' Demand for the period

q_i Defect percent of i^{th} supplier

Q Buyer's maximum acceptable defect rate

The objective function

The objective here is to maximize the total value of purchasing (TVP).

$$\textbf{Max (TVP)} = \sum_{i=1}^{n} R_i X_i \qquad \dots (1)$$

Subject to

1. **Capacity constraints**

As vendor **i** can provide up to $\mathbf{V_i}$ units of the product and its order quantity ($\mathbf{X_i}$) should be equal or less than its capacity, these constraints are:

$$X_i \leq V_i,\ i=1, 2 \dots n. \qquad \dots (2)$$

On the other hand, aggregate Vendors' capacity should be equal or greater than demand, therefore,

$$\sum_{i=1}^{n} V_i \geq D' \qquad \dots (3)$$

2. **Demand constraints**

As the sum of the assigned order quantities to n vendors should meet the buyer's demand, it can be stated that

$$\sum_{i=1}^{n} X_i = D' \qquad \text{… (4)}$$

3. **Quality constraints**

Since **Q** is the buyer's maximum acceptable defect rate and $\mathbf{q_i}$ is the defect rate of the $\mathbf{i^{th}}$ vendor, the quality constraint can be written as

$$\sum_{i=1}^{n} X_i q_i \leq QD' \qquad \text{… (5)}$$

Final model

The final integrated linear programming model can be shown as

$$\text{Max (TVP)} = \sum_{i=1}^{n} R_i X_i \qquad \text{…(6)}$$

Subject to:

$$\left.\begin{array}{ll} \sum_{i=1}^{n} X_i = D' & \text{(Demand constraint),} \\ \sum_{i=1}^{n} X_i q_i \leq QD' & \text{(Aggregate quality constraint)} \\ X_i \leq V_i,\ i = 1, 2, \ldots, n & \text{(Vendor's capacity constraints)} \\ X_i \geq 0,\ i = 1,2, \ldots, n & \text{(Non-negativity constraint)} \end{array}\right\} \text{… (7)}$$

3.1.2 CONSTRUCTION OF IFS FOR QUALITATIVE ATTRIBUTES

Assume that a_{ij} be a value of alternative A_j ε A on qualitative attributes x_i ε X.The formulae for relative degrees of membership and relative degrees of non-membership[33] are chosen as follows:

$$\mu_{ij} = \begin{cases} \alpha_i \dfrac{a_{ij}}{a_i^{max}} \; (i \, \varepsilon F^1) \\ \delta_i \dfrac{a_i^{min}}{a_{ij}} \; (i \, \varepsilon \, F^2) \end{cases} \qquad \textbf{...8(a)}$$

$$v_{ij} = \begin{cases} \beta_i \dfrac{a_{ij}}{a_i^{max}} \; (i \, \varepsilon \, F^1) \\ \gamma_i \dfrac{a_i^{min}}{a_{ij}} \; (i \, \varepsilon \, F^2) \end{cases} \qquad \textbf{... 8(b)}$$

Respectively, where F^1 and F^2 are the set of benefit qualitative attributes and cost quantitative attributes respectively and

$$a_i^{max} = \max \{a_{ij}\}, 1 \le j \le n \ ,$$

$$a_i^{min} = \min\{a_{ij}\}, 1 \le j \le n$$

and α_i ε [0,1] , β_i ε [0,1], δ_i ε [0,1] γ_i ε [0,1] satisfying conditions $0 \le \alpha_i + \beta_i \le 1$ and $0 \le \delta_i + \gamma_i \le 1$.Values of parameters α_i , β_i , δ_i , γ_i are chosen a prior by the decision maker according to characteristics and needs in real- life situations.

3.1.3 INTUITIONISTIC FUZZY MODEL

In problem formulation we define the objectives and constraints by IF sets, i.e. by pairs of membership ($\mu_i(x)$) and rejection ($v_i(x)$) functions (**Atanassov (1995)**).The final model is as follows:

$$\textbf{Max (TVP)} = \sum_{i=1}^{n} R_i \, [\mu(x_i), v(x_i)] \, X_i$$

Subject to:

$$\sum_{i=1}^{n} X_i = \text{D}$$

$$\sum_{i=1}^{n} X_i \, q_i[\mu(x_i), v(x_i)] = \text{QD} \qquad \textbf{... (9)}$$

$$X_i \le V_i \, [\mu(x_i), v(x_i)] \ , \ i=1,2,\ldots,n$$

$$X_i \ge 0 \ , \ i=1,2,\ldots,n.$$

Numerical Example

Assume that the management of a JIT manufacturer decides to choose their best suppliers and assign their optimum order quantities to maximize the TVP. The main criteria for supplier selection are cost, quality and service. According to the corporate strategies the quality includes defects and process capability while service involves on-time delivery, response to changes and process flexibility. Four suppliers are included in the evaluation process and their cost, quality, On time delivery and capacities are presented in Table 1. The demand is 1000 units and the maximum acceptable defect rate is 0.02.

Table 1: The crisp data for the various suppliers

Supplier	Cost	Quality	one time delivery	capacity
A_1	30	.03	.95	400
A_2	40	.05	.98	700
A_3	50	.01	.85	600
A_4	45	.06	.92	500

Step-1: The relative degrees of membership and relative degrees of non-membership(Table 2) for table 1 are calculated using equations 8(a) and 8(b).

Table 2: The intuitionistic fuzzy data for various suppliers

Supplier	Cost	Quality	one time delivery	Capacity
A_1	(.65,.30)	(.425,.025)	(.85,.1)	(.42,.11)
A_2	(.48,.22)	(.75,.041)	(.85,.1)	(.75,.2)
A_3	(.39,.18)	(.84,.008)	(.76,.089)	(.64,.17)
A_4	(.42,.19)	(.85,.05)	(.82,.096)	(.53,.14)

Step 2: The score of alternatives are calculated as follows:

A_1= (.97, .009) , A_2= (.99,.00018) , A_3= (.98,.000013) , A_4= (.99,.0001)

Step 3: Applying accuracy function for computing the rating of alternatives are as follows;

$H(A_1)$=.97, $H(A_2)$=.99 , $H(A_3)$=.98 , $H(A_4)$=.97

Step 4: The score for capacity is as follows:

$H(A_1)$=.53 , $H(A_2)$=.95 , $H(A_3)$=.81 , $H(A_4)$=.67

Step 5: The score of quality is as follows:

$H(A_1)=.45$, $H(A_2)=.79$, $H(A_3)=.85$, $H(A_4)=.90$

Step 6: Using equation (9) of intuitionistic fuzzy programming model we get the model as:

$$
\begin{aligned}
&Max\ .97x_1 + .99x_2 + .98x_3 + .97x_4 \\
&s.t \\
&x_1 + x_2 + x_3 + x_4 = .99 \\
&.45x_1 + .79x_2 + .85x_3 + .90x_4 <= .99 \\
&x_1 <= .53 \\
&x_2 <= .95 \\
&x_3 <= .81 \\
&x_4 <= .67 \\
&x_1, x_2, x_3, x_4 >= 0
\end{aligned}
$$

Step 7: We use TORA 2.0 for solving the model. The final results are

$z=.99$ $x_1=0, x_2=.95, x_3=.04, x_4=0$

TABLE 3: Comparison of our model with Ghodsypour and O'Brien (1998) model.

Settings	Their Model	Our model
The demand is 1000 units and the maximum acceptable defect rate is 0.02.	1.The value of the objective function Z=276.4 2.Allocation of order is $x_1=400$,$x_2=0$,$x_3=600$,$x_4=0$. 3.Does not consider accuracy function for computing. 4.Uses AHP+LPP.	1.Value of Z =.99 i.e. . 2.Allocation of order $x_1=0$,$x_2=.950$,$x_3=.40$,$x_4=0$. i.e. allocation of order is $x_1=0$,$x_2=700$,$x_3=300$,$x_4=0$. 3.The accuracy function for computing the rating of alternatives are as follows; $H(A_1)=.97$, $H(A_2)=.99$, $H(A_3)=.98$, $H(A_4)=.97$ 4.Uses IFS+LPP.

4.0 Conclusions

This work presents an optimization and an application of IF sets in vendor selection problem. An approach of solving the problem and illustrative example is proposed. We have used **Tora 2.0** for solving our intuitionistic fuzzy optimization problem (IFOP).The proposed formulation has the advantages that any commercially available software such as LINDO/LINGO may be used for solving it. The results show that the solution satisfies the objective function with degree .99.It implies that the optimal solution is a 99% satisfaction. The results also imply that IFOP problems satisfy the objective function better but the price is the worst satisfaction of some constraints (**Angelov (1997)**).

The largest order went to supplier 2(i.e.700) and the lowest to supplier 3(i.e.300).The supplier 1 and supplier 4 got no order. The reason for highest allocation to supplier 2 was due to medium cost, quality above average, delivery status being excellent and higher capacity. The remaining order was given to supplier 3 because of low cost, high quality and poor delivery status. For small orders a compromise can be made if we are getting goods at cheaper price. Table 3 gives a comparison of the two approaches, in the comparison we see that allocation of order for **Ghodsypour and O'Brien (1998)** model was 60% and 40% and our model ordering to the supplier was 70 % and 30% respectively .The ordering was based on cost and quality. A lower price range was given maximum order and a higher price range very few orders.Our paper takes into account the accuracy function for computing the rating of alternatives,which was highest for second and then third vendors. There are a number of opportunities to expand the proposed research. The results obtained from the proposed method can be verified by applying a real case. The practicality of using proposed method is its flexibility, ease of use and can be executed with any data range. Application of the method does not require any expertise field. As for different decision problems, the proposed model can be modified by changing objectives or adding constraints before it is applied. The proposed approach has the capability to handle realistic situations in an intutionistic fuzzy environment and provides a better decision tool for the vendor selection decision in a supply chain.

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