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# APPLYING FUZZY LOGIC APPROACHS TO SUPPLIER SELECTION PROBLEM IN SUPPLY CHAIN MANAGEMENT

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## ABSTRACT
*Supplier selection problem is an important issue in supply chain management and includes both tangible and intangible factors. Within the effect of the intangible factors, decision making in supplier selection problem includes a high degree of fuzziness and uncertainties in practice. In academic research to handle this uncertainty and vagueness, Fuzzy Set Theory is used as an effective tool. This paper is aimed to present a summary of fuzzy logic oriented approaches applied in literature to solve supplier selection problem. A "fuzzy Multi-objective Integer Programming Vendor Selection Problem" (f-MIP_VSP) model developed by Kumar, Chen's hierarchy multiple criteria decision-making (MCDM) model based on fuzzy set theory (FST) with the concept of TOPSIS and a fuzzy multi-objective linear model developed by Ghodsypour are briefly analyzed in the paper.*
**Keywords:** Fuzzy logic, TOPSIS, Supplier selection, MCDM

## 1. INTRODUCTION
Within the effect of globalization and facing in a competitive environment, supplier selection problem is a very critical activity for firms to gain competitive advantages in the market. Firms build effective strategic partnerships with its suppliers will reduce their costs and maximize their benefits. On average, manufacturers' purchases of goods and services constitute up to 70% of product cost and in high technology firms, purchased materials and services represent up to 80% of total product cost [1].

As its nature, supplier selection is a multiple criteria decision-making problem (MCDM) and includes both tangible and intangible conflicting factors. The value of many factors expressed in linguistic terms such as very high in quality or very low in delivery performance make the decision making process complicated. In literature, to handle this uncertainty and vagueness in the problem, various methods are applied within the fuzzy logic approach and fuzzy set theory. Ghodsypour et al. [2] proposed a fuzzy multi-objective linear model with an asymmetric approach. Kumar et al. [3] applied a "fuzzy Multi-objective Integer Programming Vendor Selection Problem" (f-MIP_VSP) model that incorporates the three important goals: cost-minimization, quality-maximization and maximization of on-time-delivery. Chen et al. [4] presented a hierarchy MCDM model based on fuzzy-sets theory and the concept of TOPSIS.

Next three sections, we present the summary of these three methods applied in the articles stated above and finally in last section conclusions are drawn regarding to fuzzy logic approach.

## 2. FUZZY MULTI-OBJECTIVE LINEAR MODEL FOR SUPPLIER SELECTION IN A SUPPLY CHAIN

For the first time in a fuzzy supplier selection problem, Ghodsypour et al. [2] proposed an asymmetric fuzzy decision making technique and by applying this new technique, decision makers could easily assign different weights to various criteria for the supplier selection problem. Also, the developed model enables the decision makers to consider the limitations of buyer and supplier into to calculate the order quantity assigned to each supplier.

In numerical example of the model, net price, quality and cost are considered as selection criteria and also capacity constraint is integrated to the linear model to select the best supplier in three available suppliers. The multi-objective linear formulation of numerical example is presented as:

$$Z_1 = 3x_1 + 2x_2 + 5x_3 \text{ (Minimizing cost objective)} \quad (1)$$

$$Z_2 = 0.85x_1 + 0.8x_2 + 0.95x_3 \text{ (Maximizing quality objective)} \quad (2)$$

$$Z_3 = 0.75x_1 + 0.9x_2 + 0.85x_3 \text{ (Maximizing service level objective)} \quad (3)$$

$$x_1 + x_2 + x_3 = 1000 \text{ (Total demand constraint)} \quad (4)$$

$$x_1 \leq 500 \text{ (Capacity constraint of first candidate supplier)} \quad (5)$$

$$x_1 \leq 600 \text{ (Capacity constraint of second candidate supplier)} \quad (6)$$

$$x_1 \leq 550 \text{ (Capacity constraint of third candidate supplier)} \quad (7)$$

$$x_i \geq 0 \text{ i = 1, 2, 3.} \quad (8)$$

Fuzzy cost goal $\lambda_1$ is formulated as:

$$\lambda_1 \leq \frac{4100 - (3X_1 + 2X_2 + 5X_3)}{1700} \quad (9)$$

4100 is calculated as worst case of cost goal [550*5 + 450*3] and 1700 [(550*5 + 450*3) – (600*2 + 400*3)] is calculated as difference between best and worst case of cost goal. This computational procedure is applied to other variables, quality and service level. To build the objective function of the fuzzy multi-objective linear model, different weights assigned to each fuzzy goal of variables according to decision makers' experience.

$$\max 0.2\lambda_1 \; + \; 0.35\,\lambda_2 \; + \; 0.25\,\lambda_3 \; + \; 0.2\gamma_1 \quad (10)$$

The objective function - $\lambda_1$: cost goal $\lambda_2$: quality goal $\lambda_3$: service level goal $\gamma_1$: demand constraint
The model is solved by using LINDO/LINGO software. After the optimal solution obtained, Ghodsypour and his friends applied α-cut approach to ensure the degree of cost goal achievement varies 0.187 ($\alpha^-$) to 0.645 ($\alpha^+$). At the end of the paper, results obtained from three different approaches, Zimmermann's [5] symmetric model, Ghodsypour's asymmetric model and Ghodsypour's asymmetric model with α-cut approach compared. Result of asymmetric model with α-cut approach best fits the problem.

*Table 1. Solutions to numerical example by different approaches*

| | Asymmetric model with α-cut approach | Asymmetric model | Zimmermann's symmetric model |
|---|---|---|---|
| $X_1$ | 351 | 86 | 187 |
| $X_2$ | 401 | 386 | 600 |
| $X_3$ | 300 | 550 | 247 |
| $Z_1$ (cost) | 3355 | 3780 | 2969 |
| $Z_2$ (quality) | 904 | 904 | 865 |
| $Z_3$ (service) | 879 | 880 | 880 |

## 3. A FUZZY PROGRAMMING APPROACH FOR VENDOR SELECTION PROBLEM IN A SUPPLY CHAIN

In this article, different from the approach stated in Section 2 Kumar et al. [3] used Zimmerman's [5] fuzzy programming and linear programming symmetric model. The computational procedure of the model has the following steps:

Step 1: Transform the Vendor Selection Problem (VSP) into the Multi-objective Integer Programming Vendor Selection [MIP_VSP] form of the problem. In the illustrative example, net cost, rejection and late deliveries are the objectives of the MIP model and also budgeting and capacity constraints considered in the model.

Step 2: Select first objective. Solve this linear programming problem and obtain the value of first objective. This value is the lower bound of the optimal value of first objective.

Step 3: Repeat the process for the remaining objectives one by one. Determine the lower bound and upper bound of the optimal values for each of the objectives corresponding to the set of constraints.

Step 4: Use these values as the lower bound and upper bound of the optimal values for crisp formulation [c-MIP_VSP] of the problem. The crisp formulation:

$$\begin{aligned}
&\text{Maximize } \lambda \\
&\text{Subject to} \\
&\lambda(Z_j^{\max} - Z_j^{\min}) + Z_j(x) \le Z_j^{\max} \quad \text{for all j, j = 1, 2, …… , J, (objectives)} \\
&\lambda(d_x) + g_k(x) \le b_k + d_k \quad \text{for all k, k = 1, 2, …… , K, (constraints)} \\
&Ax \le b \quad \text{for all deterministic constraints,} \\
&x \ge 0 \quad \text{and integer,} \\
&0 \le \lambda \le 1.
\end{aligned} \tag{11}$$

$Z_j^{\max}$ : Upper bound of objective j. $Z_j^{\min}$ : Lower bound of objective j. $d_k$ : tolerance level

Step 5: Formulate the equivalent crisp formulation of the fuzzy optimization problem. In numerical example, the values of the level of uncertainties for all the fuzzy parameters are taken as 10% of the deterministic model.

Step 6: Solve the crisp formulation of the fuzzy optimization problem.

Vagueness of the problem has been captured by using a dataset obtained from a multi-national group in automobile sector. The main advantage of the model is that decision maker can handle uncertainty in decision parameters such as capacity and budgeting constraints shown in numerical example.

## 4. A FUZZY APPROACH FOR SUPPLIER EVALUATION AND SELECTION IN SUPPLY CHAIN MANAGEMENT

In this paper, Chen et al. [4] extended the concept of the Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) and developed a MCDM model based on fuzzy set theory and the concept of TOPSIS. Linguistic values (medium low, high, medium poor, very good etc.) are used to assess the importance of each supplier selection criterion and ratings of each alternative suppliers respect to each criterion in the proposed model. The algorithm of model is given as follows.

Step 1: Form a committee of decision-makers and then identify the evaluation criteria. In numerical example, three decision makers constituted a decision-making committee to solve the problem and the committee considered profitability of supplier, relationship closeness, technological capability, conformance quality and conflict resolution as selection criteria.

Step 2: Choose the appropriate linguistic variables for the importance weight of the criteria and the linguistic ratings for suppliers. Positive trapezoidal linguistic variables are used in illustrative example. A positive trapezoidal fuzzy number (PTFN) can be defined as ($n_1$, $n_2$, $n_3$, $n_4$) in formula (12).

Step 3: Aggregate the weight of criteria to get the aggregated fuzzy weight $\hat{w}_j$ of criterion $C_j$, and pool the decision-makers' ratings to get the aggregated fuzzy rating $x_{ij}$ of supplier $A_i$ under criterion $C_j$.

$$\mu_{\tilde{n}}(\mathrm{x}) = \begin{cases} 0, & x < n_1, \\ \dfrac{x - n_1}{n_2 - n_1}, & n_1 \le x \le n_2, \\ 1, & n_2 \le x \le n_3, \\ \dfrac{x - n_4}{n_3 - n_4}, & n_3 \le x \le n_4, \\ 0, & x > n_4. \end{cases} \tag{12}$$

Step 4: Construct the fuzzy-decision matrix and the normalized fuzzy-decision matrix.
Step 5: Construct weighted normalized fuzzy decision matrix.
Step 6: Determine Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS).
Step 7: Calculate the distance of each supplier from FPIS and FNIS, respectively. To calculate the distance vertex method is applied to the problem. Let m = ($m_1$, $m_2$, $m_3$, $m_4$) and n = ($n_1$, $n_2$, $n_3$, $n_4$) be two trapezoidal fuzzy numbers.

$$\mathrm{d_v}\ (\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{4}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2 + (m_4 - n_4)^2]}. \tag{13}$$

Step 8: Calculate the closeness coefficient of each supplier. The closeness coefficient ($CC_i$) of each alternative supplier is calculated as

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, \qquad \text{i = 1, 2, ………, m.} \tag{14}$$

$d_i^-$ : Calculated distance to FNIS. $d_i^*$ : Calculated distance to FPIS.

Step 9: According to the closeness coefficients, we can understand the assessment status of each supplier and determine the ranking order of all suppliers. In numerical example, according to the closeness coefficients, the assessment status of supplier divided into five classes as do not recommend, recommend with high risk, recommend with low risk, approved and approved and preferred.
The developed model presents decision makers to handle uncertainty and vagueness in the supplier selection problem effectively.

## 5. CONCLUSION

Three different fuzzy oriented approaches have been presented in this paper to handle the uncertainties and vagueness in supplier selection problem effectively. Each method has different strengths and weaknesses. In practice, decision makers try to select the suitable method according to characteristics of problem. In conclusion, due to complexity and ambiguity, interest on developing new models based on fuzzy set theory will continue.

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