

A weighted Additive Fuzzy Programming Approach for Logistics Outsourcing Selection in Car Industry

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ABSTRACT: Logistics outsourcing has been at the top of the management agenda during recent decades. The selection of the proper service supplier is the key to success in logistic outsourcing. Firms could select the right supplier by applying appropriate methods and selection criteria. In this paper a new framework is proposed on the basis of weighted additive fuzzy programming approach and linear programming in evaluation and selection of logistic outsourcing service supplier. In Proposed model linguistic value is expressed as trapezoidal fuzzy numbers and weight of each criterion is obtained based on the distance of each factor between fuzzy positive and negative ideal rating.

Keywords: *Weighted additive fuzzy programming, Logistics outsourcing, Trapezoidal fuzzy*

INTRODUCTION

Supplier selection is the multiple – criteria decision making (MCDM) problem that is affected by several conflicting factors. Supplier selection plays an important role in the supply chain process as it is crucial to the success of a manufacturing and service firms. Supply chain management (SCM) has generated a substantial amount of interest both among managers and researchers. SCM is now distinguished as a governing element in strategy and as an effective way of creating value for customers. A structure of supply chain is composed of potential suppliers, producers, distributors, retailers and customers, etc. (Fiala, 2005) Therefore, suppliers play an important role in achieving the objective of supply management. (Kumar et al., 2004). There is an abundance of supplier evaluation and selection models proposed in supply chain literature. The main methods are linear weighting methods (LW) (Timmerman, 1986; Thompson, 1990), analytic hierarchy

process (AHP) (Narasimhan, 1983; Barbarosoglu and Yazgac, 1997), analytic network process (Sarkis and Talluri, 2000), total cost approaches (Smytka and Clemens, 1993; Monezka and Trecha, 1998) and mathematical programming (MP) techniques (Buffa and Jackson, 1983; Chaudhry et al., 1993).

In all of these methods the objective of supplier selection is to identify suppliers with the highest potential for meeting a firm's needs consistently and at an acceptable cost (Kahraman et al., 2003). In the supplier selection process a pool of suppliers is chosen for procurement according to a predefined set of criteria (Aissaoui et al., 2007). While several methods have been proposed and utilized for evaluation and selection of suppliers, they have limitations including: evaluation solely based on operational metrics, simple weighted scoring methods based on subjective assessments, and lack of relative evaluation across various

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suppliers (Talluri and Narasimhan, 2004). According to this Arikan and Gungor (2007) are classified the approaches according to the fuzzy parameter in a multi objective programming model. When the model has fuzzy aspiration levels attained to the objective functions and/or right hand side constants then fuzzy programming models can be generated by using fuzzy operators (Suer et al., 2009). Faez, Ghodsypour, and O'Brien (2009) applied a model that adds fuzzy logic concept into Case Based Reasoning (CBR) method and integrates with a mixed integer programming model for supplier selection and order allocation. Chan and Kumar (2007) presented a Fuzzy Extended AHP (FEAHP) approach to select the best global supplier for a manufacturing firm to supply one of its most critical parts used in assembling process and applied triangular fuzzy numbers as a pair wise comparison scale for deriving the priorities of different selection criteria and attributes such as overall cost of the product, rejection rate of the product, response to changes, political stability and geographical location.

Fuzzy model parameters defined mathematically by using membership functions. The relationship between each membership function is defined by using fuzzy operators (Yager, 1980, 1988; Zimmermann and Zysno, 1980; Luhandjula, 1982; Pedrycz, 1983; Werners, 1988). Zimmermann's max–min approach (Zimmermann, 1978) uses min operator which corresponds to the set-theoretic intersection in fuzzy mathematical modeling. In the literature, due to the ease of computation, the most frequently used aggregate operator is min-operator. Tiwari, Dharmar, and Rao (1987) proposed an additive model in which membership functions are combined using the add operator. The model maximizes achievement levels in total and the solution may include zero level achievement(s). Then it is obtained an unbalanced fuzzy optimal solution (Lee and Li, 1993). In such a case, Lai and Hwang's augmented max–min operator (Lai and Hwang, 1993, 1996) will be appropriate for the solution (Arikan, 2011). Additive and augmented max–min models guarantee non-dominated solution whereas Zimmermann's max–min does not (Lee and Li, 1993). Rest of the approaches which are sequential quadratic

programming, fuzzy goal programming and fuzzy programming with modified Werner's fuzzy or operator, have some disadvantages. Wu et al. (2010) utilized sequential quadratic programming which does not consider objectives simultaneously. Lee et al. (2009) used traditional representation for fuzzy goal programming where total weighted deviation from each fuzzy aspiration is minimized. Although the solution is a non-dominated one, the model does not prohibit the unbalanced solution case. Furthermore, the traditional representation may restrict the types of the membership functions which are defined for the fuzzy aspirations. Madronero et al. (2010) used Werner's (1988) fuzzy or operator to define the fuzzy decision. In their model, demand is considered as a crisp value. Fuzzy model with Werner's fuzzy or operator has $\mu \in [0,1]$ parameter which represent the compensation level. When $\mu = 0$, the model becomes equivalent to the additive model; when $\mu = 1$, then the model becomes equivalent to Zimmermann's max–min model. Determination of gamma parameter makes the model implementation harder.

This model proposes a complete fuzzy multi objective linear model approach for selection of logistics outsourcing service supplier. In the proposed model the fuzzy logic and trapezoidal fuzzy numbers are utilized to deal with vagueness of human thought and then weight of each factor are calculated based in fuzzy positive ideal rating (FPIR) and fuzzy negative ideal rating (FNIR).

Literature Review

Logistics outsourcing and third-party logistics originated in the 1980s as important means of improving supply chain effectiveness (Maloni and Carter, 2006). Third-party logistics (TPL) was initially defined as "the use of external companies to perform logistics functions that have traditionally been performed within an organization. The functions performed by the third party can encompass the entire logistics process or selected activities within this process" (Lieb, 1992). Like other outsourcing arrangements third-party logistics expanded rapidly. Estimates indicate that the proportion of companies in the US implementing this approach has increased by 5–8% annually between 1996 and 2004 (Ashenbaum et al.,

2005). Moreover, in 2005 no less than 80% of the Fortune 500 Companies stated that they relied on TPL (Lieb and Bentz, 2005). Current predictions indicate growth rates in the range of 15–20% between 2009 and 2011 in both Western Europe and the US (Deepen et al., 2008).

Existing research focuses on ‘do or buy’ decision frameworks (e.g. Barrar et al., 2002; Barragan et al., 2003), the purchasing process (e.g. Day and Barksdale, 1994) and, to a lesser extent on performance evaluation and relationship management (Klepper, 1995; Lee, 2001). Overall, the process of (out) sourcing appears to be the dominant issue (Mahnke et al., 2005), with studies focusing on the description of stages, procedures and tasks involved in purchasing business services (figure 1). Researchers appear to be more interested in the pre-contract stages of requirements specification and service supplier selection (Stremersch et al., 2001; Day and Barksdale, 2003; Feeny et al., 2005).

The main research results about the choice of third party logistics suppliers are as follow. Kasilingamr (1998) thought that four factors for the third party logistics service supplier to choose: the perceived performance of logistics suppliers, the perception ability, the price, the strategy and external environment using the factor analysis method. Yahya and Kingsman (1999) set up evaluation index system including quality, response delivery and performance of financial management technical ability and facilities through the investigation and AHP. Yaohuang Guo (1999) established an AHP judgment matrix of supplier evaluation with quality, price, technical ability and distribution

reliability. Hongwei Jiang and Wenxiu Han (2001) set up evaluation index system including quality, price, delivery, service, product development and production, external environment, and other (sales and marketing staff in general) on the comprehensive analysis of the service . Lijuan Ma (2002) proposed 9 indexes on supplier selection standards: the product quality, the price, the post-sale service, the technical level, the geographical position, supply capacity, economic benefit, delivery and market effect. Weiqing Zhong etc. (2003) said that the specific vendor selection indexes should consider four aspects such as technical level, management ability, and service level and management environment to make the supply chain performance maximization according to the design principle. Jinghua Zhou etc (2005) set up a customer satisfaction index system from the customer's point of view to evaluate the third party logistics enterprise, and use SPSS11.0 to analyze 66 sample data. It is proved that the system has the high homogeneity, the reliability and validity of the structures. Ying Sun (2006) construct a third-party logistics operation efficiency evaluation index system including four aspects, such as the input-output efficiency, the equipment utilization efficiency, quality assurance, efficiency, market competition efficiency. Xianhua Wu etc. (1998) proposed to choose partners based on ANP. Pengju Ma etc (1999) used fuzzy analytic hierarchy process (F-AHP) to choose partners. Shihua Ma etc (2002) chose three common indexes, such as quality, cost and delivery time, and set up a weight correlation analysis model of supplier selection and evaluation.

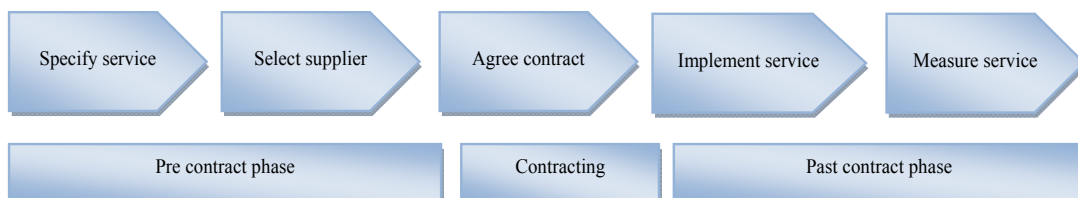


Figure 1: Business services (out) sourcing process

Basic Definitions and Calculation Model of Factors Membership Function

A positive trapezoidal number n can be defined as (n_1, n_2, n_3, n_4) shown in figure 2 and the membership function μ_n is expressed as: (Kaufmann and Gupta, 1991)

$$(1) \quad \mu_n x = \begin{cases} 0 & x < n_1 \\ (x-n_1) / (n_2 - n_1) & n_1 \leq x < n_2 \\ 1 & n_2 \leq x < n_3 \\ (x-n_4) / (n_3 - n_4) & n_3 \leq x \leq n_4 \\ 0 & n_4 > x \end{cases}$$

For a trapezoidal number if $n_1 = n_2$ then the number is called as triangular fuzzy number.

Aggregated Weights Fuzzy Weights W_j

A linguistic variable is a variable whose values are expressed in linguistic terms. For example, if ‘‘temperature’’ is interested as a linguistic variable, then its term set could be ‘‘very low’’, ‘‘low’’, ‘‘comfortable’’, ‘‘high’’ and ‘‘very high’’ (Zimmermann, 1991). In this paper, decision makers use the linguistic values shown in Fig. 3 to assess the weights of the factors in fuzzy multi objective linear model.

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. Then the distance between them can be calculated by using the vertex method as: (Chen, 2000).

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

Assume that a decision group has i decision makers as $i = 1, 2, \dots, i$ and considers a set of m criteria as $j = 1, 2, \dots, m$ for a supplier selection problem. The experience, authority and responsiveness of DMs are not equal in practice (Chou and Chang, 2008). Therefore, it is

necessary to determine the weights of DMs. Suppose the weight of DM n is r_n . This parameter can be calculated by linguistic variables. In this case study, experience index has been considered, and it is supposed that a DM with more experience is more reliable than others. Experience index can be presented as linguistic variables Then the aggregated fuzzy weights

W_j of each criterion can be calculated as: (Chen et al., 2006).

$$W_j = (w_{j1}, w_{j2}, w_{j3}, w_{j4})$$

Where

$$W_{jk} = r_i * W_{jki}$$

$$W_{j1} = \min \{ w_{jk1} \}, \quad W_{j2} = \frac{1}{k} \sum_{k=1}^k w_{jk2}$$

$$W_{j3} = \frac{1}{k} \sum_{k=1}^k w_{jk3}, \quad W_{j4} = \max \{ w_{jk4} \} \quad (3)$$

Similar to TOPSIS approach and considering the linguistic variables (lv), Fuzzy Positive Ideal Rating (FPIR A^*) and fuzzy negative-ideal rating (FNIR A^-) of a selection criterion can be defined as:

$$A^* = lv^*_1$$

$$A^- = lv^- \quad (4)$$

According to the linguistic variables shown in Fig. 3, FPIR and FNIR of a selection criterion can be expressed as respectively, ‘‘very high’’ (0.8, 0.9, 1.0, 1.0) and ‘‘very low’’ (0.0, 0.0, 0.1, 0.2).

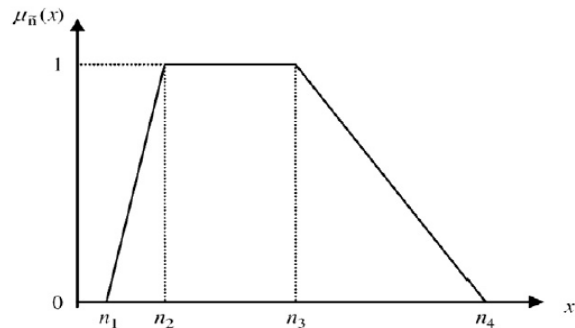


Figure 2: Trapezoidal fuzzy number n

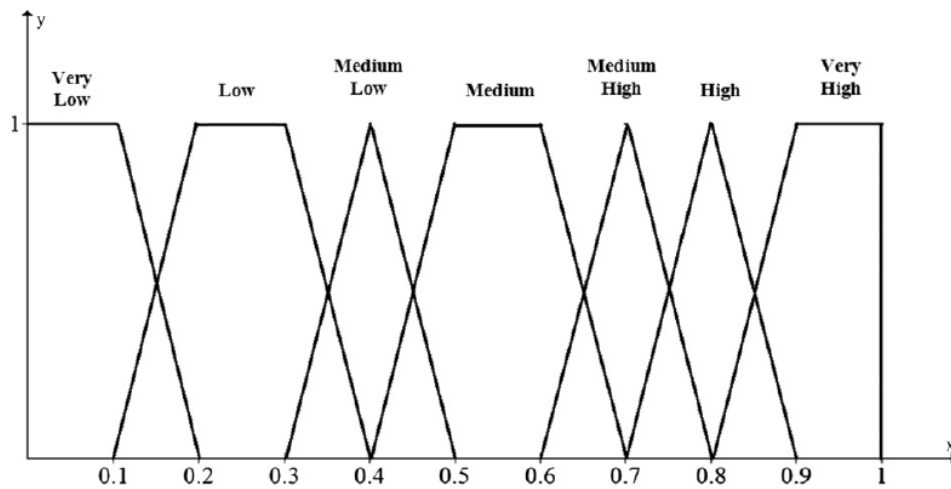


Figure 3: Linguistic variables for importance weight of each factor

Defuzzification

To defuzzify of aggregated weights w_j of each criterion calculation of the distance between aggregated fuzzy weights w_j and ideal ratings by applying vertex method is adopted (2).

A closeness coefficient is determined to calculate the weights of each factor for the developed fuzzy multi-objective linear model.

$$CC_j = d_j^- / (d_j^* + d_j^-) \quad j = 1, 2, 3, \dots, m \quad (5)$$

Where d_j^- is distance to FNIR d_j^* is distance to FPIR.

By applying normalization to closeness coefficients obtained from (5), final weights (w_j) of each factor can be calculated as:

$$W_j = CC_j / \sum_{j=1}^m CC_j \quad (6)$$

Fuzzy Multi-Objective Linear Model

The classical linear programming problem is to find the minimum or maximum values of a linear function under constraints represented by linear inequalities or equations. The formulation of linear model can be expressed as:

$$\begin{aligned} \text{Min } z &= cx \\ \text{s.t: } Ax &\leq b \\ x &\geq 0; \end{aligned} \quad (7)$$

Where $x = [x_1, x_2, \dots, x_n]^T$ is a vector of variables, s.t. means "subject to" and z is the objective function. The set of vectors x that satisfy all given constraints is called as feasible set (Klir and Yuan, 1995). Zimmermann (1978) adopted fuzzy version of the linear programming model as:

$$\begin{aligned} cx &\leq z_0 \\ &\sim \\ Ax &\leq b \\ &\sim \\ x &\geq 0 \end{aligned} \quad (8)$$

Where z_0 expresses aspiration level of the decision-maker. Then, Zimmermann (1978) defined membership function of minimization objective given as follows where Z_1^+ and Z_1^- represents maximum and minimum values of related objective respectively.

$$\mu_{Z_1}(x) = \begin{cases} 1 & \text{for } Z_1 \geq Z_1^+ \\ (Z_1^+(x) - Z_1^-) / (Z_1^+ - Z_1^-) & \text{for } Z_1^- \leq Z_1(x) \leq Z_1^+ \\ 0 & \text{for } Z_1 \leq Z_1^- \end{cases} \quad (9)$$

The linear membership function for the fuzzy constraint is defined as

$$\mu_{gr}(x) = \begin{cases} 1 & \text{for } g_2(x) \leq b_2 \\ (1 - g_2(x) - b_2) / d_2 & \text{for } b_2 \leq g_2(x) \leq b_2 + d_2 \\ 0 & \text{for } g_2(x) \geq b_2 + d_2 \end{cases} \quad (10)$$

d_r is the subjectively chosen constant of admissible violation of the r th inequalities constraints.

Finally, the weighted additive model for supplier selection problem is expressed as follows (Zimmermann, 1978; Amid et al., 2006; Kumar et al., 2006):

$$\text{Max } \sum_{j=1}^q W_j \lambda_j + \sum_{r=1}^h \beta_r y_r \quad (11)$$

st:

$$\lambda_j \leq \mu_{Z_j}(x) \quad j=1, 2, 3, \dots, q \quad (12)$$

(for all objective functions)

$$y_r \leq \mu_{gr}(x) \quad r=1, 2, 3, \dots, h \quad (13)$$

(for fuzzy constraints)

$$g_p(x) \leq b_p \quad p=h+1, \dots, m \quad (14)$$

(for deterministic constraints)

$$\lambda_j, y_r \in [0,1] \quad (15)$$

$$\sum_{j=1}^q W_j + \sum_{r=1}^h \beta_r = 1 \quad (16)$$

$$X_i \geq 0, \quad i=1, 2, \dots, n \quad (17)$$

Where $\mu_{Z_j}(x)$ and $\mu_{gr}(x)$ are membership functions of each objective and fuzzy constraint. In addition, w_j and β_r are the weighting coefficients that obtained from (3)–(6) represent the relative importance of fuzzy goals and constraints. In summation, computational procedure and algorithm of presented model is given as follows:

Step 1: Form a committee of decision makers and then identify selection criteria and constraints.

Step 2: Choose the appropriate linguistic variables for the importance weight of the criteria and fuzzy constraints.

Step 3: Calculate the coefficients of criteria (w_j) and fuzzy constraints (β_r) according to (3)–(6).

Step 4: Build multi-objective model according to selected criteria and constraints.

Step 5: By applying lower and upper bounds of each objective and given values of fuzzy constraints compute membership functions with respect to (9), (10).

Step 6: From Step 5 and coefficients obtained from Step 3, constitute fuzzy multi-objective structure of the problem according to (11)–(17).

Step 7: Solve the fuzzy multi-objective linear model and assign optimum order quantities.

Numerical Example

INDAMIN SAIPA is the first and greatest shock absorber manufacture in IRAN that has been founded in 1974. 441 personnel work in INDAMIN. This company has decided to chooses a Third party logistics company Let $U = \{VL, L, ML, M, MH, H, VH\}$ be the linguistic set used to express opinions on the group of criteria. The linguistic variables of U can be quantified using trapezoidal fuzzy numbers Each of the three decision-makers used the linguistic variables shown in Fig. 3 to assess the importance of criteria and demand constraint. The linguistic values determined by decision makers are shown in table 2. The experience, authority and responsiveness of DMs are not equal in practice (Chou and Chang, 2008). Therefore, it is necessary to determine the weights of DMs. Suppose the weight of DM_n is r_n . This parameter can be calculated by linguistic variables. In this case study, experience index has been considered, and it is supposed that a DM with more experience is more reliable than other.

Level of experience of each three decision makers are shown in table 1.

Table 1: Level of experience of each three decision makers

| Decision makers | experience index |
|-----------------|------------------|
| D1 | M |
| D2 | MH |
| D3 | H |

Table 2: Importance weights of criteria and constraint from three decision makers

| Criteria and constraint | D1 | D2 | D3 |
|-------------------------|----|----|----|
| Logistic cost | H | H | VH |
| Logistic speed | VH | VH | H |
| Operating efficiency | MH | H | VH |
| Capacity | H | H | H |

Firstly, applying (3), aggregate weights of each criterion and fuzzy constraint are calculated and show in table 3. The distances between aggregate weights and fuzzy ideal ratings are obtained by using vertex method (2). Then closeness coefficients and final weights are calculated respectively (5), (6). Results are shown in table 4.

The logistic cost, logistic speed, operating efficiency and capacity constraints of each candidate supplier, s_1 , s_2 and s_3 , are presented in table 5. In selection problem, demand is treated as a fuzzy number and predicted to be about 1200. The data set for membership functions is shown in table 6.

The multi-objective linear formulation of numerical example is presented as min Z_1 and max Z_2, Z_3 :

$$Z_1 = 15X_1 + 20 X_2 + 18 X_3$$

$$Z_2 = 95X_1 + 115 X_2 + 102 X_3$$

$$Z_3 = 0.65X_1 + 0.75 X_2 + 0.45 X_3$$

St.

$$X_1 + X_2 + X_3 = 1200$$

$$X_1 \leq 850$$

$$X_2 \leq 450$$

$$X_3 \leq 460$$

$$X_i \geq 0 \quad i = 1, 2, 3$$

Three objective functions Z_1, Z_2, Z_3 are respectively net price, quality and on-time delivery goals; X_i is the number of units purchased from the supplier. Upper and lower bounds in table 6 are used to construct membership functions expressed as:

$$(a) \quad \mu_{z1}(x) = \begin{cases} 1 & Z_1 \leq 1250 \\ (1480 - Z_1)/230 & 1250 < Z_1 < 1480 \\ 0 & Z_1 \geq 1480 \end{cases}$$

$$(b) \quad \mu_{z2}(x) = \begin{cases} 1 & Z_2 \geq 850 \\ (Z_2 - 540)/310 & 540 < Z_2 < 850 \\ 0 & Z_2 \leq 540 \end{cases}$$

Table 3: Aggregated weights of each criterion and constraint

| Criteria and constraint | aggregated weight |
|-------------------------|-------------------------------|
| Logistic cost | (0.28 , 0.56 , 0.61 , 0.9) |
| Logistic speed | (0.32 , 0.57 , 0.65 , 0.81) |
| Operating efficiency | (0.24 , 0.54 , 0.59 , 0.90) |
| Capacity | (0.28 , 0.53 , 0.56 , 0.81) |

Table 4: Distances, coefficients and final weight of each criterion and constraint

| Criteria and constraint | d_j^- | d_j^+ | closeness coefficient | final weight |
|-------------------------|---------|---------|-----------------------|--------------|
| Logistic cost | 0.37 | 0.54 | 0.59 | 0.256 |
| Logistic speed | 0.35 | 0.52 | 0.6 | 0.259 |
| Operating efficiency | 0.39 | 0.52 | 0.57 | 0.247 |
| Capacity | 0.4 | 0.49 | 0.55 | 0.238 |

Table 5: Suppliers' quantitative information

| Suppliers | Logistic cost (average per each pack in dollar) | Logistic speed (average per each pack in minute) | Operating efficiency | Capacity |
|-----------|--|---|----------------------|----------|
| S1 | 15 | 95 | 65% | 850 |
| S2 | 20 | 115 | 75% | 450 |
| S3 | 18 | 102 | 45% | 460 |

Table 6: The data set for membership functions

| Criteria and constraint | $\mu =0$ | $\mu =1$ | $\mu =0$ |
|-------------------------|----------|----------|----------|
| Logistic cost | - | 1250 | 1480 |
| Logistic speed | 540 | 850 | - |
| Operating efficiency | 875 | 1050 | - |
| Capacity | 650 | 800 | 925 |

$$(c) \quad \mu_{z_3}(x) = \begin{cases} 1 & Z_3 \geq 1050 \\ (Z_2 - 875)/175 & 875 < Z_1 < 1050 \\ 0 & Z_3 \leq 875 \end{cases}$$

$$(d) \quad \mu_{gd}(x) = \begin{cases} (d(x) - 650)/150 & 650 < d(x) < 800 \\ (925-d(x))/125 & 800 \leq d(x) < 925 \\ 0 & d(x) \leq 650, d(x) \geq 925 \end{cases}$$

Applying membership functions and the final weights obtained from Table 3, fuzzy multi-objective linear structure of the numerical example is expressed as follows:

$$\text{Max } 0.256 \lambda_1 + 0.259 \lambda_2 + 0.247 \lambda_3 + 0.238 y_1$$

$$\lambda_1 \leq (1480 - (15X_1 + 20X_2 + 18X_3))/230$$

$$\lambda_2 \leq ((95X_1 + 115X_2 + 102X_3) - 540)/310$$

$$\lambda_3 \leq ((0.65X_1 + 0.75X_2 + 0.45X_3) - 875)/175$$

$$y_1 \leq ((X_1 + X_2 + X_3) - 650)/150$$

Microsoft Excel Solver is used to solve the problem. The optimal solution for the model is obtained as follows:

$$X_1=340, X_2=0, X_3=0, Z_1=5100, Z_2=32300, Z_3=221$$

CONCLUSION

Supplier selection orienting long-term collaborative relationships in multi-service outsourcing is a very important decision problem. In this model a weighted additive fuzzy multi-objective linear model is presented to capture the vagueness of the problem and decision makers' preferences the developed model presents a point of view for fuzzy multi-objective linear models appeared in literature by integrating a new calculation procedure for

weights of the factors to the fuzzy multi-objective linear model. The algorithm of model applies linguistic variables to assess weights of each factor in the fuzzy multi-objective linear model

Finally the principal advantages of our model are in fourfold:

First we focused on supplier selection and evaluation in service industries especially logistic outsourcing problem, second the proposed approach can adequately deal with the inherent uncertainty and imprecision of human decision-making third the proposed model can select suitable suppliers effectively finally this research investigated the differences among decision-makers by devoting unequal weights.

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