*IOSR Journal of Business and Management (IOSR-JBM)*
*e-ISSN: 2278-487X, p-ISSN: 2319-7668. Volume 19, Issue 6. Ver. I (June 2017), PP 62-68*
*www.iosrjournals.org*

# A Case Study Based Simulation of Green Supplier Selection Using Fmcdm and Order Allocation through Molp

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***Abstract*:** *The purpose of this paper is to select Green Supplier using Integrated Fuzzy Multi Criteria Decision Making (FMCDM) and allocates order through Multi Objective Linear Programming (MOLP) approach along with and Supplier Selection Software development. To select supplier this paper investigates various qualitative and quantitative criteria. For that, this paper integrates Fuzzy Analytic Hierarchy Process (FAHP), Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS), and Fuzzy MOLP to solve the problem of supplier selection and order allocation. At first the authors used Fuzzy AHP to calculate the relative weights of supplier selection criteria; then, the authors used Fuzzy TOPSIS for ranking of suppliers according to the selected criteria. Finally, the weights of the criteria and ranks of suppliers were incorporated into the MOLP model to determine the optimal order quantity from each supplier while being subjected to some resource constraints. Research provides the weight and rank of the suppliers and also optimum order quantity among them according to their rank.*

***Keywords*:** *Fuzzy AHP, Fuzzy TOPSIS, Order Allocation, Software, Green Supplier*

## I. Introduction:

In the face of acute global competition, supplier management is rapidly emerging as a crucial issue to any companies striving for business success and sustainable development. To optimize competitive advantages, a company should incorporate ‘‘suppliers” as an essential part of its core competencies. In developing countries like Bangladesh, for most of the company cost is often considered as a major concerned in their procurement strategy. Others important criteria like quality, reliability, defect rate, environmental competency have been skipped in their recent procedure of supplier selection. But it is not accepted for a company. As a result most often they failed to choose their correct eco-friendly supplier. Supplier selection is a Multiple Criteria Decision-making (MCDM) problem which is affected by several conflicting factors. MCDM techniques support the decision makers DMs in evaluating a set of alternatives. MCDM refers to finding the best opinion from all of the feasible alternatives in the presence of multiple, usually conflicting, decision criteria. Depending upon the purchasing situations, criteria have varying importance and there is a need to weight criteria. In the supplier selection process, if suppliers have limited capacity or other constraints, it is necessary to determine the best supplier and order quantity of each supplier. In other words not only one supplier can satisfy the buyer’s total requirements and the buyer needs to purchase some part of demand from one supplier and the other part from another supplier to compensate for the shortage of capacity or low quality of the first supplier. In this paper, we use an integrated approach; of fuzzy set theory, FAHP and fuzzy TOPSIS and multi-objective programming, for rating and selecting the best green suppliers according to economic and environmental criteria and then allocating the optimum order quantities among them.

## II. Literature Review

Supplier selection is a MCDM problem containing both quantitative and qualitative criteria which, together, are in conflict. Over the last few years, many researchers have worked on the supplier selection problem to develop suitable decision making methods which can deal with the problem effectively (Zeydan et al., 2011).Regarding the analytical methods employed in the supplier selection process, De Boer et al. (2001) and Ha and Krishnan (2008) performed an extensive review of decision methods for supporting supplier selection. Ho et al. (2010) reviewed the literature of the MCDM approaches for supplier evaluation and selection. Extensive single model approaches have been proposed for supplier selection, such as the AHP (Kannan et al., 2010), analytic network process (ANP) (Choy et al., 2003), interpretive structural modeling (ISM) (Ghodsypour and O‟Brien, 2001) case based reasoning (CBR), data envelopment analysis (DEA) (Zeydan et al., 2011), genetic algorithm (GA) (Kannan and Murugesan, 2011), neural networks (Ding et al., 2005) Fuzzy TOPSIS (Rao, 2005) Fuzzy extent analysis (Hong, et al., 2005) and mathematical programming (MPm) and their hybrids. In multiple sourcing, many researchers have applied different methods of MP such as linear programming (LP), mixed integer (Rezaei and Davoodi, 2011), multi-objective programming (MOP) (Lee et al., 2009), and goal programming (GP) (Wu and Barnes, 2011). An MPm model formulates the decision problem in terms of a mathematical objective function that needs to be maximized or minimized by varying the values of variables in the objective function (Hong et al., 2005). In his review work, (Kull and Talluri, 2008) mentioned that there are several hybrid techniques that have been used for solving supplier selection in multiple sourcing environments and order allocation, such as AHP and (Govindan et al., 2012), DEA and MOP (Talluri et al., 20 08), AHP and GP (Haq and Kannan, 2006), AHP, DEA, and neural networks (Ha and Krishnan, 2008), AHP and grey relational analysis (Huang and Keskar, H., 2007 ) and ANP and GP and ISM and TOPSIS. Amin and Zhang (2012) have summarized the modelsused for a supplier selection and order allocation problem currentlyavailable in literature.

## III. Methodology

**3.1The proposed integrated approach for green supplier evaluation**

This study integrates fuzzy AHP, fuzzy TOPSIS, and fuzzy MOLP to solve the problem of supplier selection and order allocation. Fuzzy set theory was conceived. to resolve the vagueness and ambiguity of human cognition and judgment; it is a way of processing data by providing mathematical strengths to resolve such uncertainties associated with human thinking and reasoning and allowing partial set membership rather than crisp set membership. Fuzzy MCDM theory can strengthen the comprehensiveness and reasonableness of the decision-making process presented some applications of fuzzy theories to the various decisions making processes in a fuzzy environment, and introduced the fuzzy MCDM methodology. Triangular fuzzy numbers are used in this paper to assess the preferences because it is easy for the DMs to use and calculate. A triangular fuzzy number is defined as (a, b, c) where a ≤ b ≤ c. The parameters a, b, and c represent the smallest possible value, the most promising value, and the largest possible value, respectively. Let X is a set of items, known as the universe, and its elements are denoted byx. A fuzzy subset A in X is represented by a membership function $f_A(x)$ and is associated with each element x in A and a real number between 0 and 1.

$$f_A(x) = \begin{cases} 0; & x < a, x > c \\ \frac{x-a}{b-a}; & a \leq x \leq b \\ \frac{c-x}{c-b}; & b \leq x \leq c \end{cases}$$

**3.2 FAHP methodology for determining criteria weights**:

AHP was first developed by Saaty (1980) who mainly conducts a MCDM problem by examining the pair-wise comparison of decision criteria. The hierarchical structure of the AHP model can enable users to imagine the problem in terms of criteria and subcriteria. The steps are described below

- Identifying DMs‟ supplier selection criteria and modeling the problem as a hierarchy containing the decision goal.
- Performing the pair-wise comparison about the relative importance of the supplier selection criteria by using a geometric mean method to integrate the opinions of DMs as follows:

<u>Geometric mean</u>: R= (a, b, c), K=1, 2 … K (R: Triangular fuzzy number; K: No. of DMs)

Where $a= (a_1 * a_2 * a_3 \ldots\ldots * a_k)^{1/k}$, $b= (b_1 * b_2 * b_3 \ldots\ldots * b_k)^{1/k}$, $c= (c_1 * c_2 * c_3 \ldots\ldots * c_k)^{1/k}$

- Aggregating all the DMs matrix of pair-wise comparisons and synthesize these judgments to yield a set of overall priorities for the hierarchy.
- To make sure that the DMs do not make mistakes which may cause conflicting ratings, a final consistency of the judgments is calculated. If the consistency ratio (CR) is less than 0.1, the judgment is true for criteria weights.
- Transforming pair-wise comparison matrix of criteria weights into linguistic variables using Table 1. Calculate priority weights of each criterion using Chang (1996) method. The basic concept of FAHP for finding triangular fuzzy number weights is presented as follows:

(i). Let X = {x1, x2, x3,., xn}an object set, and G ¼ {g1, g2,g3,., gn}be a goal set and Mj gi (i =1,2, .,n , j = 1,2, .,m ) all are triangular fuzzy numbers. The value of fuzzy synthetic extent of the ith object form goals is defined as:

$$S_i = \sum_{j=1}^{m} M_{g\,i}^{j} * \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g\,i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right. \ldots\ldots\ldots\ldots (1)$$

(ii). The degree of possibility$M_2 = (l_2, m_2, u_2) \geq M_1= (l_1, m_1, u_1)$ is defined as:

V (M1 ≥ M2) = supx≥y[min (µM1 (x), µM2 (y))]……………………………………..(2)

$$V(M1 \geq M2) = \begin{cases} 1 \\ 0 \\ \frac{l_1 - u_1}{(m_2 - u_2) - (m_1 - u_1)} \end{cases}$$

(iii). The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i$ (i= 1,2, ., k) can be defined by:

V(M1, M2, .MK) =min V ($M \geq M_i$), i= 1,2, .,k can be defined by:

d (Ai) = min V ($S_i \geq S_k$ ); k= 1, 2 ….. n; k ≠ I……………………….....………...………..(3)

(iv). The weight vector is given by: W = (d( $A_1$) ; ($A_2$) ; .d ($A_n$))$^T$; $A_i$ ( i = 1…, n) are n elements.

(v). The normalized weight vector is calculated as:

$$NW_i = \frac{W_i}{\sum W_i} \quad \text{…………………………………………………………………. (4)}$$

**3.3 The fuzzy TOPSIS method for ranking suppliers:**

Step 1: The normalized fuzzy-decision matrix can be represented as

$$R=[r_{ij}]_{m*n} \quad \text{……………………………………………...……….…...(5)}$$

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), j \in B \quad \text{………………………………………………. (6)}$$

$$c_j^* = \max_i c_{ij}, j \in B$$

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), j \in C \quad \text{………..……………………………..…… .(7)}$$

$$a_j^- = min_i\, a_{ij}, j \in C$$

Step 2: Weighted normalized decision matrix $v_{ij}$ is calculated bymultiplying normalized matrix with the weights of the criteria

V = $[v_{ij}]_{m*n}$ i = 1, 2, 3 ……………… m and j= 1, 2 ………n

Where $[v_{ij}]$=$r_{ij} * w_j$ and $w_j$ is the weight of the jth attribute or criterion.

Step 3: The positive-ideal solution (PIS,$A^*$) and negative-ideal solution (NIS,$A^-$) can be calculated as:

$$A^* = (v_1^*, v_2^*, \dots, v_n^*)$$

$$A^- = (v_1^-, v_2^-, \dots, v_n^-)$$

Where $v_j^* = max_i\{ v_{ij\,3}\}$ and $v_j^- = min_i\{ v_{ij\,1}\}$ , i=1,2 ,…….,m, j =1,2,….. n.

Step 4: The distance of each alternative from PIS and NIS is calculated as:

$$d_i^{\,*} = \sum_{j=1}^{n} d_v(v_i, v_j^*), \quad \text{i=1,2…m……………………………………..…..(8)}$$

$$d_i^{\,-} = \sum_{j=1}^{n} d_v(v_i, v_j^-), \quad \text{i=1,2…m……………………..……….…….(9)}$$

Step 5: The closeness coefficient ($CC_i$) of each alternative is calculated as:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \quad \text{i=1, 2…, m………………..……….. ……………….…... (10)}$$

Step 6: At the end of the analysis, the ranking of alternatives is determined by comparing CCi values. Alternative Ai is closer to the FPIS ($A^*$) and farther from FNIS ($A^-$) CCi approaches to 1. The ranking order of all alternatives determines according to the descending order of CCi

.

**3.4 The proposed fuzzy MOLP model for order allocation:**

The following assumptions are used in formulating the MOLP model:

**Assumptions:**

(i) Only one item is purchased from one supplier; (ii) Quantity discounts are not taken into consideration;.(iii) No shortage of the item is allowed for any supplier;(iv) Demand for the item is constant and known with certainty.

In order to formulate this model the following notations are defined:

Parameters:

N =the number of suppliers; D = Demand for the planning period; $X_i$ = Order quantity from the ith supplier; $C_i$ =Capacity of the ith supplier; $W_i$ = the overall weight (priority value) of the ith supplier (Obtained from the fuzzy TOPSIS model); $P_i$ =Unit purchasing price from the ith supplier; $O_i$= Unit ordering cost from the ith supplier; $T_i$ = Unit transportation cost from the ith supplier; Q = Maximum acceptable defect ratio (percent); $q_i$ = Average defect percent from the ith supplier; H= unit holding cost for planning period and $Y_i$ = 0 if $X_i$ = 0& $Y_i$ = 1 if $X_i$> 0

Objective functions:

Total cost of purchasing: The total costs of purchasing considered in the MOLP model including product price, ordering, and transportation and holding costs. The objective function can be formed as follows:

$$\text{Min (TCP)} = \sum_{i=1}^{N} P_i X_i + O_i * \sum_{i=1}^{N}(Y_i) + \sum_{i=1}^{N} T_i X_i + \text{H} * \sum_{i=1}^{N} P_i((X_i)/2)$$

Total value of purchasing: we used the supplier's weights as coefficients of an objective function to allocate order quantities among the suppliers such that the total value of purchasing (TVP) becomes a maximum. The mathematical model is as follows:

$$\text{Max (TVP)} = \sum_{i=1}^{N} W_i * X_i$$

**Constraints:**

Quality control e the total defect quantity of each item cannot exceed maximum total acceptable defect quantity:

$$\sum_{i=1}^{N} q_i * X_i \leq Q * D$$

Production demand e the total order quantity of each item from all suppliers must meet the demand quantity for the item:

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

Suppliers' capacity e the order quantity of each item from the ith supplier cannot exceed each supplier's capacity:

$$X_i \leq C_i$$

Variable non-negativity constraints e the final constraints are non-negativity restrictions on the decision variables:

$$X_i \geq 0, X_i \text{ integers}; \quad \text{i = 1, 2... N}$$

The above MOLP model can be converted into a single objective model by using a maxi-min formulation.

This case study has been done on a pharmaceuticals company in Bangladesh. Finally ten criteria such as Cost, Quality, Backlog, Wrapping Quality, Packaging Size, Arranging Presentation, Defect Rate, Supplier Location, Environmental Competency, and Experience have been determined by experts, and four possible suppliers Metro Foils Limited, Fairbiz Ltd., Kabir Foils Limited, and Trendy Foils Limited thought to have green competencies are engaged for supplier selection and order allocation decision making. The criteria(C) C1, C3, C7 and C8 are the cost criteria and the others are the benefit criteria.

**FAHP methodology for determining criteria weight:**

The DMs use the linguistic weighting variables to assess the importance of the criteria. The consistency property of each expert's comparison results is examined by calculating the CR. The value of CR must be less than 0.10 to make the comparison trustworthy and consistency. In our approach we got CR = 0.04, 0.05 respectively for DMs1, 2 it shows that the judgment matrix processes consistency. The values of fuzzy synthetic extents with respect to the criteria weights are calculated by using (Eq. (1)) :

S1= (0.094062, 0.15515, 0.252); S2 = (0.117, 0.186, 0.291); S3 = (0.07, 0.11672, 0.18974); S4 = (0.103, 0.16162, 0.25283) ; S5= (0.047, 0.076, 0.122); S6 = (0.025, 0.042, 0.068); S7= (0.0805, 0.12616, 0.203); S8 = (0.044, 0.08, 0.13); S9 = (0.033, 0.047, 0.072); S10 = (0.00952, 0.01329, 0.02006)

The final FAHP importance criteria weights are calculated as**:**W1= (0.094062, 0.15515, 0.252); W2= (0.117, 0.186, 0.291); W3= (0.07, 0.11672, 0.18974); W4= (0.103, 0.16162, 0.25283); W5= (0.047, 0.076, 0.122) ;W6= (0.025, 0.042, 0.068); W7= (0.0805, 0.12616, 0.203); W8= (0.044, 0.08, 0.13); W9= (0.033, 0.047, 0.072); W10= (0.00952, 0.01329, 0.02006)

Using fuzzy TOPSIS for evaluating suppliers:

The linguistic variables are used for rating of criteria. The two DMs express their opinions on the ratings of each supplier with respect to the ten criteria independently.

**Table 1**: The aggregated fuzzy pair-wise comparison matrix of criteria (for all DMs)

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 1,1,1 | 0.33,0.5,1 | 2,3,4 | 1.73,2.82,3.87 | 4,5,6 | 5, 6, 7 | 1, 2, 3 | 1, 2, 3 | 4,5,6 | 4.47,5.47, 6.48 |
| C2 | 1,2, 3.03 | 1,1,1 | 5.47, 6.48, 7.48 | 1,1.41,1.73 | 5,6,7 | 4.89,5.91, 6.92 | 1.41,2.44,3.46 | 2.44,3.46, 4.47 | 4,5,6 | 4.47,5.47, 6.48 |
| C3 | 0.25, 0.3,0.5 | 0.12,0.14, 0.167 | 1,1,1 | 0.57,1,1.73 | 3.46,4.47, 5.47 | 4.47,5.47, 6.48 | 0.408,0.63, 0.86 | 1, 2,3 | 3,4,5 | 4,5,6 |
| C4 | 0.25,0.35,0.57 | 1,1,1 | 1,2,3.03 | 1,1,1 | 6, 7, 8 | 4.47,5.47, 6.48 | 1, 2, 3 | 4, 5,6 | 4, 5, 6 | 4.47,5.47, 6.48 |
| C5 | 0.167,0.2,0.25 | 0.142,0.166,0.2 | 0.2,0.25,0.33 | 0.12,0.14,0.167 | 1, 1,1 | 4, 5,6 | 0.167,0.2,0.25 | 0.57, 1,1.73 | 2.44,3.46,4.47 | 3.4, 4.47, 5.47 |
| C6 | 0.142,0.16,0.2 | 0.125,0.142, 0.167 | 0.167,0.2, 0.25 | 0.167,0.2,0.25 | 0.167,0.2, 0.25 | 1, 1,1 | 0.154,0.182,0.22 | 0.18,0.23, 0.31 | 1.41,2.44,3.46 | 2.82, 3.87, 4.9 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| C7 | 0.33, 0.5, 1 | 0.25,0.33, 0.5 | 0.33,0.5,1 | 0.33,0.5,1 | 4,5,5.98 | 4, 5,5.98 | 1, 1, 1 | 2.44,3.46, 4.47 | 4, 5, 6 | 4.47, 5.4, 6.48 |
| C8 | 0.33, .5, 1 | 0.2,0.25,0.33 | 0.33,0.5,1 | 0.167,0.2,0.25 | 1,2,3.03 | 2, 3.03, 4 | 0.2, 0.25, 0.33 | 1, 1, 1 | 2.82,3.87,4.89 | 3.46,4.47, 5.47 |
| C9 | 0.167,0.2,0.25 | 0.167,0.2, 0.25 | 0.2,0.25,0.33 | 0.167,0.2,0.25 | 0.25,0.33, 0.5 | 0.25, 0.33, 0.5 | 0.167,0.2,0.25 | 0.25,0.33, 0.5 | 1,1,1 | 6, 7, 8 |
| C10 | 0.15,0.18,0.22 | 0.167,0.2, 0.25 | 0.1667,0.2,0.25 | 0.167,0.2,0.25 | 0.2,0.25,0.33 | 0.167,0.2, 0.25 | 0.167,0.2,0.25 | 0.2,0.25,0.33 | 0.125,0.142, 0.167 | 1, 1, 1 |

In Table 1, the aggregated fuzzy pair-wise comparison matrix of criteria comes from the geometric mean of the relative fuzzy number

**Table 2**: Fuzzy aggregated decision matrix and fuzzy weights of critera

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Weights | 0.094, 0.16, 0.252 | 0.117, 0.186, 0.291 | 0.07, 0.12, 0.19 | 0.10, 0.16, 0.25 | 0.047, 0.076, 0.122 | 0.025, 0.042, 0.068 | 0.0805, 0.12616, 0.203 | 0.044, 0.08, 0.13 | 0.033, 0.047, 0.072 | 0.009, 0.01, 0.02 |
| SP1 | 3.87,5.92,7.93 | 9,10,10 | 7.93, 9.49, 10 | 7.93, 9.49, 10 | 5, 7, 9 | 7, 9 10 | 7, 9, 10 | 7, 9, 10 | 7, 9, 10 | 7, 9, 10 |
| SP2 | 5.92,7.92,9.49 | 5, 7, 9 | 7, 9, 10 | 7, 9, 10 | 7, 9, 10 | 5, 7, 9 | 1.73, 2.24, 4.58 | 9, 10, 10 | 7.94, 9.48, 10 | 7, 9, 10 |
| SP3 | 1, 1, 3 | 37, 9, 10 | 5, 7, 9 | 5, 7, 9 | 7, 9, 10 | 7, 9, 10 | 7.94, 9.486, 10 | 3.87, 5.92, 7.92 | 7, 9, 10 | 5.92, 7.94, 9.5 |
| SP4 | 7.94, 9.49, 10 | 1.73, 2.23, 4.58 | 3, 5 ,7 | 5, 7, 9 | 9, 10, 10 | 5, 7, 9 | 5, 7, 9 | 1.73, 2.236, | 3.87, 5.91, 7.93 | 9, 10, 10 |

In Table 2, fuzzy aggregated decision matrix and fuzzy weights of criteria comes from the geometric mean of the fuzzy numbers of the linguistic variable assigned to each criterion by each decision maker

**Table 3**: Normalized fuzzy-decision matrix

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| SP1 | 0.126, 0.169, 0.26 | 0.9, 1, 1 | 0.3, 0.32, 0.38 | 0.79, 0.95, 1 | 0.5, 0.7, 0.9 | 0.7, 0.9, 1 | 0.17, 0.19, 0.25 | 0.17, 0.19,0.25 | 0.7, 0.9, 1 | 0.7, 0.9, 1 |
| SP2 | 0.11, 0.13, 0.17 | 0.5, 0.7, 0.9 | 0.3, 0.33, 0.43 | 0.7, 0.9, 1 | 0.7, 0.9, 1 | 0.5, 0.7, 0.9 | 0.38, 0.78, 1 | 0.17, 0.17,0.19 | 0.79, 0.95, 1 | 0.7, 0.9, 1 |
| SP3 | 0.33, 1, 1 | 0.7, 0.9, 1 | 0.33, 0.43, 0.6 | 0.5, 0.7, 0.9 | 0.7, 0.9, 1 | 0.7, 0.9, 1 | 0.17, 0.18, 0.22 | 0.22, 0.29,0.44 | 0.7, 0.9, 1 | 0.59, 0.79, 0.95 |
| SP4 | 0.1, 0.11, 0.13 | 0.17, 0.22, 0.46 | 0.43, 0.6, 1 | 0.5, 0.7, 0.9 | 0.9, 1, 1 | 0.5, 0.7, 0.9 | 0.19, 0.25, 0.35 | 0.38, 0.78, 1 | 0.38, 0.59, 0.79 | 0.9, 1, 1 |

Normalized fuzzy-decision matrix comes by following the equation (6) and (7).
Here C1 is the cost criteria, so that the value of $a_j^-$ $(a_j^- = min_i\, a_{ij}, j \in C)$for the C1 column is 1
Here C2 is the benefit criteria, so that the value of $c_j^*$ ($c_j^*$=$\max_i c_{ij}$, $j \in B$) for the C2 column is 10

**Table 4:** Weighted normalized fuzzy-decision matrix

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| SP1 | 0.012, 0.02, 0.06 | 0.11, 0.19, 0.3 | 0.02, 0.04, 0.072 | 0.082, 0.15, 0.25 | 0.023, 0.05, 0.11 | 0.018, 0.037, 0.07 | 0.014, 0.02, 0.05 | 0.008, 0.015, 0.03 | 0.02, 0.04, 0.07 | 0.007, 0.012, 0.02 |
| SP2 | 0.009, 0.0195, 0.043 | 0.06, 0.13, 0.3 | 0.02, 0.04, 0.08 | 0.07, 0.14, 0.25 | 0.033, 0.069, 0.122 | 0.0125, 0.029, 0.061 | 0.03, 0.097, 0.203 | 0.007, 0.013, 0.03 | 0.026, 0.04, 0.07 | 0.007, 0.02, 0.02 |
| SP3 | 0.031, 0.155, 0.25 | 0.08, 0.167, 0.29 | 0.02, 0.05, 0.113 | 0.05, 0.113, 0.23 | 0.033, 0.069, 0.122 | 0.02, 0.04, 0.07 | 0.014, 0.02, 0.044 | 0.0097, 0.022, 0.06 | 0.02, 0.04, 0.07 | 0.006, 0.012, 0.019 |
| SP4 | 0.009, 0.016, 0.032 | 0.02, 0.04, 0.133 | 0.0302, 0.07, 0.19 | 0.052, 0.11, 0.23 | 0.043, 0.076, 0.122 | 0.01, 0.03, 0.06 | 0.02, 0.03, 0.07 | 0.017, 0.06, 0.13 | 0.012, 0.03, 0.06 | 0.009, 0.013, 0.02 |

In Table 4**,** weighted normalized fuzzy-decision matrix is achieved by multiplying each value of normalized fuzzy-decision matrix with the corresponding criteria weight.

**Table 5**: Distances between suppliers and $A^{*}, A^{-}$ with respect to each criterion

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| d(SP1,A*) | 1.67 | 1.40 | 1.66 | 1.46 | 1.63 | 1.66 | 1.68 | 1.7 | 1.65 | 1.71 |
| d(SP2,A*) | 1.69 | 1.47 | 1.65 | 1.47 | 1.60 | 1.67 | 1.55 | 1.71 | 1.65 | 1.71 |
| d(SP3,A*) | 1.48 | 1.42 | 1.62 | 1.51 | 1.60 | 1.66 | 1.69 | 1.68 | 1.65 | 1.72 |
| d(SP4,A*) | 1.69 | 1.62 | 1.57 | 1.51 | 1.59 | 1.67 | 1.66 | 1.62 | 1.68 | 1.71 |

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 |
|---|---|---|---|---|---|---|---|---|---|---|
| d(SP1,A-) | 0.071 | 0.36 | 0.08 | 0.31 | 0.12 | 0.079 | 0.06 | 0.036 | 0.086 | 0.024 |
| d(SP2,A-) | 0.048 | 0.29 | 0.09 | 0.3 | 0.144 | 0.069 | 0.23 | 0.029 | 0.088 | 0.024 |
| d(SP3,A-) | 0.29 | 0.34 | 0.13 | 0.26 | 0.144 | 0.079 | 0.051 | 0.063 | 0.086 | 0.022 |
| d(SP4,A-) | 0.037 | 0.14 | 0.20 | 0.26 | 0.15 | 0.069 | 0.078 | 0.143 | 0.065 | 0.025 |

Table 5 contains the distances between suppliers and $A^{*}$, $A^{-}$ with respect to each criterion. The values d (SP1, $A^{*}$) are obtained by determining the distance from the point (1, 1, 1). And so on. The values d (SP1, $A^{-}$) are obtained by determining the distance from the point (0, 0, 0).

**Table 6:** Computations of $d^{+}$, $d^{-}$ and $CC_i$

| | $d^{+}$ | $d^{-}$ | $CC_i$ | Rank |
|---|---|---|---|---|
| Metro Foils Limited (SP1) | 1.621918202 | 0.12311627 | 0.070552342 | 3 |
| Fairbiz Ltd. (SP2) | 1.617483629 | 0.132183769 | 0.075547941 | 2 |
| Kabir Foils Limited (SP3) | 1.604708085 | 0.147638665 | 0.08425197 | 1 |
| Trendy Foils Limited.(SP4) | 1.633125508 | 0.117369619 | 0.067049383 | 4 |

**Model development for order allocation:**

In this step we set the parameter values that are used in the LP model. The crisp formulation of the numerical example by using a maxi-min formulation is presented as follows:

Objective function

Min (TCP)= $\sum_{i=1}^{2} PX_i + O_i * \sum_{i=1}^{2}(Y_i) + \sum_{i=1}^{2} T_i X_i + \text{H} * \sum_{i=1}^{2} P_i((X_i)/2)$……………………………...….. (11)

Max (TVP) =$\sum_{i=1}^{2} W_i * X_i$…………………………………………………………..………………. (12)

MINIMIZATION

Total Cost Purchase: $2639.25 X_1 + 2634.75 X_2 + 160$

Subjected to,

Production Demand:

$$X_1 + X_2 = 1000$$

Capacity:

$$X_1 \leq 700,\ X_2 \leq 800$$

Quality Control:

$$0.02X_1 + 0.05X_2 \leq 35$$

$$X_1 \geq 0,\ X_2 \geq 0$$

Above problem has been solved by using Tora software. From the output of Tora software it has been seen that the order quantity among each supplier is 500 units.

## IV. Conclusion

Green trends are the need of the hour to strike a balance in our ecological system. Selecting the right suppliers and splitting lot-sizes to the selected suppliers over multi-period decision horizon become a major challenge for a buyer when suppliers offer quantity discounts with unreliable quality and delivery performance. This work presents framework of environmental criteria that a company can consider during their supplier selection process. . Inventory lot-sizing with supplier selection and carrier selection are important decisions any buyer has to make. A buyer cannot optimize them separately due to inherent interdependency among these decisions. A fuzzy TOPSIS approach applied here to evaluate performance of green suppliers because there is an increasing need to develop appropriate green supplier selection. Supplier selection is a complex multi-criteria decision-making problem, and its complexity is further aggravated if the highly important interdependence among the selection criteria is taken into consideration. Fuzzy AHP and Fuzzy TOPSIS, providing a systematic approach to set priorities among alternative suppliers, can effectively capture the interdependencies among various criteria. The advantages of the integrated method include its abilities to consider the interdependencies among various criteria and uncertain situation for ranking suppliers; Minimize the end customer's level of dissatisfaction based on demandand capacity limiting; and Facilitate the most efficient allocation of an order. In this paper a case study has been performed, where the suppliers' selection and order allocation problem of a renowned pharmaceutical company has been solved. In this paper, software for supplier selection purpose has been also developed which eliminate the excessive effort required for manual calculation of fuzzy analytic hierarchy process and fuzzy technique.

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