Supplier Selection and Evaluation in Supply Chain Management

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Abstract: ***This paper presents an integrated method for dealing with such problems using correlated Analytic Hierarchy– and the techniques of linear physical programming. The proposed method demonstrates selection of appropriate supplier and is to create a model of the supplier relationship management process, which can be applied in business organizations. besides this, paper examines the benefits of a supplier relationship management process, how to measure the success of the process as well as the relevant stakeholders of the process. The correlation between criteria is commonly observed in the realistic problems. The correlated Analytic Hierarchy considers the correlation effect between criteria in the Analytic Hierarchy process. LPP is a multi-objective optimization method that develops an aggregate objective function of the criteria in a piecewise, Archimedean-goal-programming fashion. A decision maker is enable by linear physical programming model to consider multiple criteria (i.e., cost, customer service, and intangible benefits) and also to find out how firms set evaluation criteria for their suppliers, and how they use the evaluation system in practice, if they have one.***

Keywords: Analytic Hierarchy process ,linear physical programming, supplier selection, supplier evaluation

1. Introduction

In the present times, organizations that desire to carry on the sustainable growing need a strong strategic performance measurement and evaluation system because of changing demands of consumers, reduced product life cycle, competitive and world markets. Supplier selection with order allocation shows one of the most important functions to be performed by the purchasing decision makers, which determines the long-term viability of the company a good supplier selection makes a significant difference to an organization's future to reduce operational costs and improve the quality of its end products.

The selection of Supplier (vendor) is a remarkable issue in supply chain management (SCM) field for many enterprises, therefore its objective is an identification of suppliers with the highest capability of responding desirably to firm's needs. Initially, there are two dimensions in the issue of the supplier selection problem: first dimension is a specification of criteria used for evaluation of suppliers, and the other one is an applied procedure or method to rank these suppliers. Several factors are depending on Evaluation of a supplier. Some criteria such as price, quality, delivery, reputation are frequently selected for comparison and appraisement. These criteria can influence the outcome of the decision-making process for vendor selection and they can also affect each other. An appropriate supplier may become and develop into a cooperative and long term partnership in SCM for decision maker (DM)'s interests, which can help the growth of a corporation and can be crucial to the success of the DM's business. Hence, systematic and effective procedure or technique to select the most efficient supplier is compulsory. The objective of the study includes Identifying the criteria for supplier selection Study of the factors whether they influence each other to find the correlation matrix between the criteria)To find the weights considering the correlation by multi objective programming) To find the relative weight age factors to find the scores among the suppliers using AHP the quantity to be ordered on each supplier using linear physical programming.

The term Supplier evaluation is used in business and refers to the process of evaluating and approving potential suppliers by quantitative assessment. The purpose of supplier evaluation is to ensure a portfolio of best in class suppliers is available for use. The main objective of the supplier evaluation process is to reduce purchase risk and maximize the overall value of the purchaser. It typically involves evaluating, at a minimum, supplier quality, cost competitiveness, potential delivery performance and technological capability. Financial risk analysis, evaluation of previous performance, and evaluation of supplier provided information are the criteria which are used in the preliminary evaluation of suppliers.

2. Supplier Evaluation Methods and Models

The methods and Supplier evaluation divide into two main groups; namely
1. Individual approaches
2. Integrated approaches

Common for both groups is their Multi-criteria decision making approaches, considering several criteria in the same model. How they internally value the criteria vary from model to model. We will now shortly look at the main models within the two groups. For further explanation of the most common models

2.1 Individual approaches

The individual approaches consists of data envelopment analysis (DEA), different kinds of mathematical programming, analytic hierarchy process (AHP), case-based reasoning, analytic network process (ANP), fuzzy set theory, simple multi-attribute rating technique and genetic algorithm (GA). Ho et al. (2010) find that the DEA is the most popular one out of the 78 methods and models that were investigated, with almost 18% representation Integrated approaches.

In order to utilize the strengths of each method the integrated approaches use multiple methods. Several of the above mentioned methods are here widely represented, and overall the AHP is the most preferred method for evaluating suppliers. AHP seems to be suited for combining with several other approaches (Ho et al., 2010; de Boer et al., 2001), like the DEA or goal programming. The other main integrated approaches according to Ho et al. (2010) are the integrated fussy approaches like e.g. Integrated fuzzy and GA, or integrated fuzzy and SMART. As we have seen there are many different approaches to supplier evaluation systems, and each company probably has an internal and local system adapted to their own needs.

2.2 Supplier Evaluation Criteria

Factors	*Explanation*
Quality	Supplier product might support buyers operation by being reliable, easy to use and easy to maintain
Trust	When buyers have high levels of trust in the supplier, they are likely to pursue more co-operative negotiations and open communication.
commitment	Ability of supply chain partners to meet the set requirements within the specified period of time. Mutual commitment creates opportunities; relationships are mutually demanding besides being mutually rewarding
Satisfaction	Each party involved in the exchange of relationship are happy and satisfied with the performance of the other.
safeguard	Contacts with potential suppliers can be seen as insurance or a back up but can also decrease the dependence of the customer on the supplier.
Innovation development	By using suppliers resources, customers can speed up their development process, engage in larger, riskier and long-term oriented projects and also have more technological input.
Information exchange	Suppliers have more insight into particular areas or have a long standing experience in their industry that they can share with a customer.
Inter-dependence	Interdependence motivates buyers and suppliers to develop long- term relationships characterized by stability, co-operation, and mutual benefit. It reflects the degree of dependability on each other without which either organization encounters loss of opportunity or business or sales.
Social support	Social aspects are important because the mutual orientation among firms is principally a mutual orientation among individual actors in those firms. Working with cooperative and supportive partners will create a good working atmosphere
Increased volume to suppliers	The volume of the business given to selected supplier should be steadily increased depending upon their performance.

Explanations of buyer supplier evaluation factors (Subramanian et al., 2010)

Basic Blocks	Delay	Area
XOR	3	5
2:1 MUX	3	4
Half Adder	3	6
Full Adder	6	13

3. The Problems of Multi Attribute Decision Making

3.1 The analytic hierarchy process (AHP)

A fuzzy multiple criteria decision-making method for supplier selection problems is suggested byb Chen et al., 2006 (1)) ,. A mixed integer non-linear programming model was proposed to address the multi-criteria sourcing problem by Ghodsy pour & O'Brien, 2001[2]).A survey of Multiple Attribute Decision Making Methods (MADM) and Applications was done by Hwang, C.L., and Yoon, K., (1981)[3]. the basic features that govern MADM are construction of hierarchy system considering the nature of problem, selection of proper multiple criteria decision-making technique, finding relative weights with respect to each alternative and finally choosing the best alternative based on scores calculated against each alternative(ref fig1). The method to calculate the relative weights is devised by Saaty [4]. The AHP is used to calculate the weights of independent criteria and related with the upper-level criteria**.**

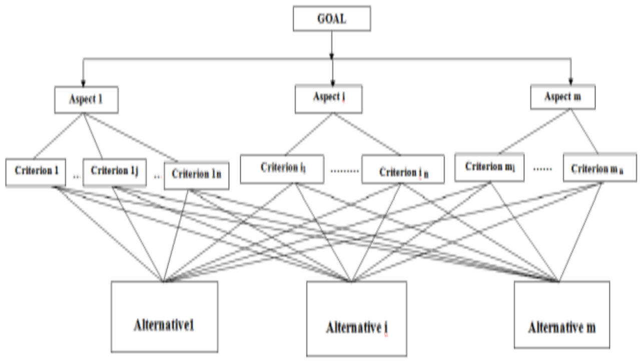

Figure 1: Multi Criteria Decision

The effects of outer-dependence, inner dependence and feedback are also taken into consideration by saaty and developed analytical network process. Besides this In reality correlation also exists between criteria such as quality of product versus after sales service, initial cost of vehicle versus reliability etc.

3.2 Multi objective programming:

Linear programming techniques of operation research address optimization of single objective. But in real situation, problems often bounded by multi objectives, which can be expressed mathematically as

Objective function

$$\text{Max } z(x) = [z_1(x), z_2(x), \ldots\ldots, z_n(x)] \text{ -----------[1]}$$

and

Subject to constraints $-g(x) \leq b$, and $x \geq 0$

Such *Multi objective* can be solved by optimizing each objective as follows:

$$\text{Objective function Max} z_j(x) \text{ ---------[2]}$$

and Subject to constraints

$g(x) \leq b$, and $x \geq 0$.

Assuming we can get the ideal point as **z**∗, the point located on the Pareto solutions is closest to the ideal point as the optimal solution .Hence the distance between objective values and the ideal point can be calculated using lp norm concept which can be expressed as

$$\text{Min dp}=\left\{\sum_{j=1}^{n} w_j^p\left[z_j^*(x)-z_j(x)\right]^p\right\}^{1/p},$$

p=1,2,……,∞ --------[3]

s.t g(x) ≤ b, and x ≥ 0,

The minimum value of the j[th] goal is denoted by (**x**),W_j^p = weightage of j th objective and lp –norm p;x is variable and b refers to boundary limit

3.3 Correlation

Correlation is a statistical relationships involving dependence, in simple terms linear relationship between two variables.. Correlations can be used for idenifying of relationship and its value varies from -1 to +1 .T the Pearson correlation coefficient. It is calculated multiplying the standard deviations and the result is divided by the covariance of the two variables. The sum of squares for first variable say SS_{xx}, the sum of square for second variable say SS_{yy}, and the sum of the the product of mean deviations (SS_{xy}). The sum of squares for variable X is:

$$SS_{XX}=\sum(x_i-\bar{x})^2 \quad \ldots\ldots\ldots\ (4)$$

The sum of squares for variable Y is:

$$SS_{YY}=\sum(y_i-\bar{y})^2 \quad \ldots\ldots\ldots(5)$$

Finally, the sum of the product of mean deviations (SS_{XY}) is:

$$SS_{XY}=\sum(x_i-\bar{x})(y_i-\bar{y}) \quad \text{-----------}(6)$$

The correlation coefficient r is

$$r=\frac{SS_{XY}}{\sqrt{(SS_{XX})(SS_{YY})}} \quad \text{----------}(7)$$

4. Literature Survey

Dickson [5], performed comprehensive literature reviews performed for supplier selection application. Weber et al. [6], De Boer et al. [7] and Sanayei et al. [8]. Ayhan [9]. Dickson"s [4] stated 23 creteria for supplier selection. Dickson"s criteria with 13 more was updated by Cheraghi et al. [10] updated. As a brief of all criteria price, quality, and delivery performances are found as the most significant selection criteria's. Various MCDM are put into practice , which can be catagorised broadly into into three 1) Value Models: AHP and multi attribute utility theory (MAUT) fall in this group.2) Goal, Models: Goal programming, TOPSIS. VIKOR belong to the group.

Outranking Methods: PROMETHEE and ELECTRE etc belong to this group.

Ghodsypour, S.H., and O"Brien, C [11] proposed. A Decision Support System for Supplier Selection Using an Integrated AHP and Linear Programming. Kilic,[12] suggested anAn integrated approach for supplier selection in multi item/multi supplier environment .Xia, W. and Wu, Z., [13] considered Supplier selection with multiple criteria.AHP, which was first developed by Saaty integrates experts" opinions and evaluation scores into a simple elementary hierarchy system. Yahya and Kingsman [14] used AHP to determine priorities in selecting suppliers. The book by Lambert and Gupta [15] presented the importance of the area of disassembly. Gungor and Gupta [16] cited a comprehensive study in manufacturing industry. Kongar and Gupta [17] presented a multi-criteria decision making approach. Imtanavanich and Gupta [18] modeled the supply chain problem with stochastic yields LPP technique is used in solving the supply chain problem by Imtanavanich and Gupta [19]. Massoud and Gupta [20] considered the multi-period order problem. Kongar and Gupta [21] proposed a LPP model for environmental and financial goals.

5. Methodology

For supper selection the study is done in three phases. interrelation ship among factors is considered before proceeding to different phases. the weights among the factors considered in the second phase. linear physical programming is considered in the third phase.

5.1 Mathematical Model

The Figure2 general form of AHP has been depicted. The ahp procedure involves devising the

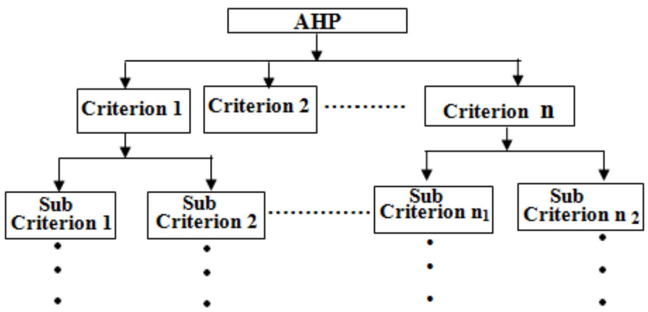

Figure 2: ahp diagram

Hierarchical system by decomposing the problem and compare the comparative weight between the attributes of the decision elements using satty score. calculation of the relative weight estimation and determine the best alternatives after aggregation. If we wish to compare a set of n attributes pair wise according to their relative weights (importance), where the weights (Wij) ratio of pair wise compared value between i and j ,are

$$W=[w_{ij}]_{n\times n}, \text{ ------------------ [8]}$$

Where Wij = w_{ij}^{-1}, $w_{ij}=w_{ik}w_{kj}$, and $w_{ij}=w_i/w_j$.

$$W_w=\begin{bmatrix}\frac{w_1}{w_1} & \cdots & \frac{w_1}{w_j} & \cdots & \frac{w_1}{w_n}\\ \vdots & \cdots & \vdots & \cdots & \vdots\\ \frac{w_i}{w_1} & \cdots & \frac{w_i}{w_j} & \cdots & \frac{w_i}{w_n}\\ \vdots & \cdots & \vdots & \cdots & \vdots\\ \frac{w_n}{w_1} & \cdots & \frac{w_n}{w_j} & \cdots & \frac{w_n}{w_n}\end{bmatrix}\begin{bmatrix}w_1\\ \vdots\\ w_i\\ \vdots\\ w_n\end{bmatrix}=n\begin{bmatrix}w_1\\ \vdots\\ w_i\\ \vdots\\ w_n\end{bmatrix}=nw$$

$$\text{Or } (w\text{-}nI)w = 0 \quad \text{--------[9]}$$

The approximate weights we can find by calculating theeigen vector w with respect to λ_{max} which satisfies

$$Aw = \lambda_{max} w \quad \text{----[10]}$$

Where λ_{max} is the largest eigen value of the matrix A. in addition , calculate the consistency indexes (C.I.) to check if the consistency condition is almost satisfied for A:C.I = $\frac{\lambda_{max} - n}{n-1}$ ...11 Where λ_{max} the largest eigen value and n denotes the numbers of the attributes. Satty suggested that the value of the C.I. should not exceed 0.1 for a confident result. On the other hand as per .Liu, Hsiang[22]the problem of deriving the relative weights among criteria in the AHP is equivalent to solving the following mathematical programming to obtain w_i:

$$\text{Min} \sum_{j=1}^{n} \left\| a_{ij} - \frac{w_i}{w_j} \right\|_p$$

$$\text{s.t} \sum_{i=1}^{n} w_i = 1, \forall 1 \leq i < j \leq n, \qquad (12)$$

Where $\|.\|_p$ denotes the p-norm and p $\in \{1,2,\ldots.\}$..

5.2 Correlated AHP

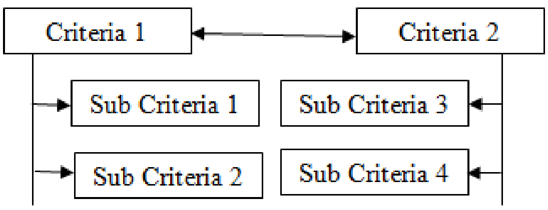

Figure 3: Relation between criteria

As shown in Figure3, it can be seen that Criteria 1 and 2 are considered to affect the decision of the problem in order to consider the correlation effect in the AHP, we should first quantify the correlation matrix between criteria. Ex correlation matrix $\mathbf{R}ji$ = correlation between i and jIn addition, it should be highlighted that $\mathbf{R}ji$== $\mathbf{R}ij$, $\forall i, j$

$$R = \begin{vmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \\ r_{41} & r_{42} & r_{43} & r_{44} \end{vmatrix} R_{11} = \begin{vmatrix} r_{11} & r_{12} \\ r_{21} & r_{22} \end{vmatrix}$$

$$, R_{12} = \begin{vmatrix} r_{13} & r_{14} \\ r_{23} & r_{24} \end{vmatrix}, R_{21} = \begin{vmatrix} r_{31} & r_{32} \\ r_{41} & r_{42} \end{vmatrix}, R_{11} = \begin{vmatrix} r_{33} & r_{34} \\ r_{43} & r_{44} \end{vmatrix}$$

because the correlation effect is symmetric. Then, we assume that if Criterion i is highly correlated to Criterion j, they have similar weights or influence to the problem. Hence, if we obtain the correlation matrix between criteria, we can objective to maximize the correlation, that is, $w'\mathbf{R}\mathbf{w}$. if there is no correlation it will be 0.

Biobjectiveproblem(as per Hsiang-Hsi Liu,[22])

$$\text{Max } w'Rw, \qquad (13)$$

$$\text{m in} \left\| a_{ij} - \frac{w_1}{w_j} \right\|_p + \left\| a_{ij} - \frac{w_i}{w_j} \right\|_p \qquad (14)$$

$$\text{s.t.} \sum_{i=1}^{L} wi = 1$$

Where a_{IJ}denotes the given estimated weight ratio of the upper-level Criteria I and J, $w_I$denotes the true weight of the upper-level I^{th} criterion, In the upper-level I^{th} criterion can be divided into $k$ilower-level criteria

Model: In order to place orders on on each manufacturer as we call as "supplier" a study was conducted to identify the key selection criteria in a manufacturing industry in. constructed a decision hierarchy, identified the factors whether they influence each other to find the correlation matrix between the criteria. Normalized weights of factors are found considering the correlation by multi objective programming. The scores among the suppliers using correlated ahp are found. Finally the quantity to be ordered on each supplier using LPP taking into consideration of target levels are obtained

Phase one: The selection of criteria scores are obtained as per satty guide lines

7.1 ahp weight calculation: The meaning of the terminology used.

- Operation speed: It indicates generally which supplier will deliver fast because of the process capability
- Operating Readiness: Prepation of stores which can be used straightaway without a bit of damage.
- Operation accuracy: It includes many aspects like adherence to transportation time, on-time delivery
- Order processing: Order processing starts from picking, packaging and packed items delivery
- Operating cost: Operating costs are the expenses for conducting the a business or facility
- Storage cost &Transportation cost: it includes the cost of moving and storing possessions
- Information technology: It is the application of computers and data acquisition and data management for conduct of business or other manufacturing and allied activities.
- Storage Technology: the technology implemented for storage
- Transportation technology: the technology implemented for transporting
- Customer satisfaction: It is a measure of how goods and services supplied by a company
- Compatibility : it is the ability of the manufacturer, its vendors and their customers work in collaboration
- Financial easiness: Ensures continuity in services., better cash flow, sound balance sheet are indicators

Operating efficiency, cost, technology level and service quality are represented by B1, B2, B3 and B4 respectively.

Step 1: Column sum s(table 5). After considering the relations between different aspects .the column Sum for the normalization purpose is performed, ex Sum 1 = B11+B21+B31+B41 = 1+0.5+0.333+0.5 = 2.3333

Table 3: Factors of Suppliers Selection

Operating efficiency (B1):	C1. Operation speed
	C2. Operating readiness
	C3. Operation accuracy
Cost(B2)	C4. Transportation cost
	C5. Storage cost
	C6. Order processing cost
Technology level satisfaction (B3):	C7. Information technology
	C8. Storage technology
	C9. Transportation technology
Service Quality (B4)	C10. Customer satisfaction
	C11. Compatibility
	C12.Financial easiness

Table 4: Relation between various factors (first level)

	B1	B2	B3	B4
B1	1	2	3	2
B2	½	1	2	1
B3	1/3	½	1	½
B4	½	1	2	1

Table 5: Column sum of the various factors

A	B1	B2	B3	B4
B1	1	2	3	2
B2	½	1	2	1
B3	1/3	½	1	½
B4	½	1	2	1
SUM	2.3333	4.5	8	4.5

Step 2: Column normalization see table 6B11= $^1/_{2.3333}$=0.4285; … the remaining all calculated.

Table 6: Column normalization of factors

A	B1	B2	B3	B4
B1	0.4285	0.4444	0.375	0.4444
B2	0.2142	0.2222	0.25	0.2222
B3	0.1428	0.1111	0.125	0.1111
B4	0.2142	0.2222	0.25	0.2222

Table 5: Row sum of the various factors

A	B1	B2	B3	B4	SUM
B1	0.4285	0.4444	0.375	0.4444	1.6923
B2	0.2142	0.2222	0.25	0.2222	0.9086
B3	0.1428	0.1111	0.125	0.1111	0.49
B4	0.2142	0.2222	0.25	0.2222	0.9086
TOTAL					3.9995

Step 3: Row sums (table 7): row wise totaling ex Sum1 = (0.4285+0.4444+0.375+0.4444) = 1.6923 .
Step 4: (table 8). The individual row sums are divided by the total sum to get weights.$W_1 = s_1/s$ = 1.69/3.99 = 0.4231
Step 5: Consistency index: The consistency index (CI) measures the consistency set of data .consistence ratio (cr).oo4 which is acceptable for first level. Ahp weights are considerd for next level B1, B2, B3, B4

Phase 2: *7.2: Correlation Matrix* :By considering individual operation speed and corresponding Order processing cost rate are in correlation with each other (table 14).The correlation is calculated as mentioned below. The correlation coefficient is r = $\frac{SSxy}{\sqrt{(SSxx)(SSyy)}} = \frac{6.5}{\sqrt{(11)(84)}}$ =0.213 ≈ 0.2all correlation coefficients(table13)

.3 multi objective programming: Multi Objectives function is performed to find out correlation weights

Min n= -((.2 * w11 * w21) +(.3 * w11 * w22) +(.2 *w11 *w23) +(.4 *w12 * w21) +(.5 *w12 * w22) + (.3 * w12 * w23) + (.2 *w13 * w21) +(.4 *w13 *w22) + (.3 *w13 *w23));

Table 8: Row normalization of the factors

A	B1	B2	B3	B4	Weights
B1	0.4285	0.4444	0.375	0.4444	0.4231
B2	0.2142	0.2222	0.25	0.2222	0.2271
B3	0.1428	0.1111	0.125	0.1111	0.1225
B4	0.2142	0.2222	0.25	0.2222	0.2271

Table 9: Relation between internal factors of BI

B1	C1	C2	C3	Normal ahp Weights
C1	1	3	2	0.55
C2	1/3	1	1	0.21
C3	½	1	1	0.2422

Table 9 the consistency ratio are found in order Cr = .001

Table 10: Relation between internal factors of B2

B2	C4	C5	C6	Normal ahp Weights
C4	1	2	3	0.55
C5	1/2	1	1	.25
C6	1/3	1	1	.20

Table 11: Relation between internal factors of B3

B3	C7	C8	C9	W
C7	1	.25	2	0.20
C8	4	1	4	0.66
C9	.5	1/4	1	0.14

The table 10 consistency ratio are found in order Cr=.001

Table 11 the consistency ratio found in order Cr =.05

Table 12: Relation between internal factors of B4

B4	C10	C11	C12	Normal ahp weights ahpW
C10	1	.2	2	.19
C11	5	1	3	0.69
C12	½	1/3	1	0.12

Table 13: Correlation table

	C4	C5	C6
C1	.2	.3	.2
C2	.4	.5	.3
C3	.2	.4	.3

The consistency ratio found in order .cr =.09

Table 14. correlation data for c1 and c6

	C1	C6		C1	C6		C1	C6
Serial No.	Operation Speed (Days)	Order Processing Cost (Rs)	Serial No.	Operation Speed (Days)	Order Processing Cost (Rs)	Serial No.	Operation Speed (Days)	Order Processing Cost (Rs)
1	3	4	7	4	11	13	4	8
2	4	5	8	3.5	8	14	5	9
3	5	6	9	4.5	9	15	3	11
4	4	7	10	3	4	16	4	10
5	5.5	10	11	4	5	17	3	7
6	3	9	12	5	7	18	4.5	8

Min m = -

$$\left\|\left(2-\frac{w_1}{w_2}\right)+\left(3-\frac{w_1}{w_3}\right)+\left(2-\frac{w_1}{w_4}\right)+\left({}^1/_2-\frac{w_2}{w_1}\right)+\left(2-\frac{w_2}{w_3}\right)+\left(1-\frac{w_2}{w_4}\right)+\right.$$
$$\left({}^1/_3-\frac{w_3}{w_1}\right)+\left({}^1/_2-\frac{w_3}{w_2}\right)+\left({}^1/_2-\frac{w_3}{w_4}\right)+\left({}^1/_2-\frac{w_4}{w_1}\right)+\left(1-\frac{w_4}{w_2}\right)+$$
$$\left.\left(2-\frac{w_4}{w_3}\right)\right\|+\left\|\left(3-\frac{w_{11}}{w_{12}}\right)+\left(2-\frac{w_{11}}{w_{13}}\right)+\left({}^1/_3-\frac{w_{12}}{w_{11}}\right)+\left(1-\frac{w_{12}}{w_{13}}\right)+\left({}^1/_2-\frac{w_{13}}{w_{11}}\right)\right.$$
$$+\left(1-\frac{w_{13}}{w_{12}}\right)+\left(2-\frac{w_{21}}{w_{22}}\right)+\left(3-\frac{w_{21}}{w_{23}}\right)+\left({}^1/_2-\frac{w_{22}}{w_{21}}\right)+\left(1-\frac{w_{22}}{w_{23}}\right)+\left({}^1/_3-\frac{w_{23}}{w_{21}}\right)+\left(1-\frac{w_{23}}{w_{22}}\right)+$$
$$\left(0.25-\frac{w_{31}}{w_{32}}\right)+\left(2-\frac{w_{31}}{w_{33}}\right)+\left(4-\frac{w_{32}}{w_{231}}\right)+\left(4-\frac{w_{32}}{w_{33}}\right)+\left({}^1/_2-\frac{w_{33}}{w_{31}}\right)+$$
$$\left(0.25-\frac{w_{33}}{w_{32}}\right)+\left(0.2\frac{w_{41}}{w_{42}}\right)+\left(2-\frac{w_{41}}{w_{43}}\right)+\left(5-\frac{w_{42}}{w_{41}}\right)+\left(3-\frac{w_{42}}{w_{43}}\right)+$$
$$\left.\left({}^1/_2-\frac{w_{43}}{w_{41}}\right)+\left({}^1/_3-\frac{w_{43}}{w_{42}}\right)\right\|$$

W1+w2+w3+w4=1; W1 =w11 + w12 + w13; W2 =w21 +w22 +w23; W3 =w31 +w32 +w33; w4 =w41+w42 +w43;W1 > =0; w2 >=0; w3 >= 0; w4 >=0;W11 > =0; w12 >=0; w13 >= 0;W21 > =0; w22 >=0; w23 >= 0; W31 > =0; w32 >=0; w33 >= 0;W41 > =0; w42 >=0; w43 >= 0; Where w1 ,w2,w3,w4 are weights of b1,b2.b3,b4 respectively . and w11,w12,w13 w21,w22,w23,w31,w32,w33,w41,w42,w43are weights of c1, c2, c3, c4, c5, c6, c7, c8, c9, c10, c11, c12, c23 respectively.

Table 15: The results of correlated weights

Top-Level Factors	Weights	Second Level	Weights	Second Level	Weights	Second Level	Weights
B1	0.1142675	c1	0.062939	c5	0.04732	c9	0.029755
B2	0.1421024	c2	0.023208	c6	0.071051	c10	0.18665
B3	0.1814302	c3	0.027676	c7	0.060235	c11	0.2811
B4	0.5621999	c4	0.023731	c8	0.090715	c12	0.092201

The table (15) clearly demonstrates the correlated ahp values are different from normal ahp values. First normal ahp is performed to check the consistency.

Supplier wise ranks are calculated

Each supplier is given weight with respect to each factor. On a scale of 1 ---10.Supplier weights are calculated in table 16 and 17

Table 16: Supplier global weighed scores

	Supplier 1 (1)	Weights (2)	Product (1*2)	Supplier 2 (4)	Weights (5)	Product (4*5)	Supplier 3 (7)	Weights (8)	Product (7*8)	Supplier 4 (10)	Weights (11)	Product (10*11)
Operating Efficiency	8	0.1143	0.9141	5	0.1143	0.5713	7	0.1143	0.7999	6	0.1143	0.68561
Order Processing Cost	5	0.1421	0.7105	8	0.1421	1.1368	6	0.1421	0.8526	8	0.1421	1.13682
Technology Satisfaction	7	0.1814	1.27	6	0.1814	1.0886	6	0.1814	1.0886	8	0.1814	1.45144
Service Quality	7	0.5622	3.9354	7	0.5622	3.9354	5	0.5622	2.811	6	0.5622	3.3732
Total			6.8301			6.7321			5.5521			6.6471
Normalized Weights			0.2651			0.26134			0.21553			0.25804

Phase 3

7.5 linear physical programming: the data considered for this part of section is mentioned in tables18, 19, 20.

Formulation of equation

Operating efficiency Goal = g_1 = 0 .78 x_1 +0.81 x_2 +0.80 x_3 + 0.81 x_4

Technology satisfaction Goal = g_2= 0.84 x_1 +0.82 x_2 +0.82 x_3 +0.85 x_4

service quality Goal = g_3 = 0.7 x_1 +0.7 x_2 +0.5 x_3 +0.6x_4

cost Goal = g_4 = 110 x_1 +150 x_2 +145 x_3 +120 x_4

Subject toTotal quantity to be procured$x_1 + x_2 + x_3 + x_4$= 1500 ;

The maximum limit that can be procured from supplier x_1<800 , x_2<500 , x_3<700 , x_4<600 ; $x_1 \geq 0$, $x_2 \geq 0$; , $x_3 \geq 0$, $x_4 \geq 0$

x_1 , x_2, x_3, x_4 are the quantities to be ordered on suppliers1,2,3 and 4

Table 17: Supplier weighed scores of individual factors

	Supplier 1 (1)	Weights (2)	Product (1*2)	Supplier 2 (4)	Weights (5)	Product (4*5)	Supplier 3 (7)	Weights (8)	Product (7*8)	Supplier 4 (10)	Weights (11)	Product (10*11)
Operation Accuracy	8	0.02768	0.2214	5	0.02768	0.13838	7	0.02768	0.19373	6	0.02768	0.166054
Operating Efficiency	5	0.071051	0.35526	8	0.071051	0.56841	6	0.071051	0.42631	8	0.071051	0.568408
Transportation Technology	7	0.029755	0.20829	6	0.071051	0.42631	6	0.029755	0.17853	8	0.029755	0.23804
Financial Easiness	7	0.092201	0.64541	7	0.092201	0.64541	5	0.092201	0.46101	6	0.092201	0.553206

Table 18: Data of product

Suppliers	Cost (rupees)	Operating efficiency fraction	Technology satisfaction fraction	service quality (fraction)	Capacity in numbers
Supplier 1	110	.78	.84	.7	800
Supplier2	150	.81	.82	.7	500
Supplier 3	145	.80	.82	.5	700
Supplier 4	120	.81	.85	.6	600

Table 19: Soft criteria

goals	ideal	desirable	tolerable	undesirable	Highly undesirable	unacceptable
operating efficiency	>950	900-950	700-900	500-700	300-500	<300
Technology satisfaction	>900	800-900	700-800	600-700	300-600	<300
service quality	>900	800-900	700-800	500-700	400-500	<400

Table 20: Hard criteria

goals	unacceptable	acceptable
cost	>200000	<200000

Goal constraints: Soft constraints for class 2s function (maximum is better)

g1 + $d_{12}^{-} \geq$ 950;g1 + $d_{13}^{-} \geq$ 900;g1 + $d_{14}^{-} \geq 700$;g1 + $d_{15}^{-} \geq 500$;g1 ≥ 300g2 + $d_{22}^{-} \geq$ 900;g2 + $d_{23}^{-} \geq 800$; g2 + $d_{24}^{-} \geq$ 700;g2 + $d_{25}^{-} \geq$ 600;g2 $\geq$ 300 ;g3 + $d_{32}^{-} \geq$ 900;g3 + $d_{33}^{-} \geq$ 800;g3 + $d_{34}^{-} \geq$ 700;g3 + $d_{35}^{-} \geq$ 500; g3 $\geq$ 400;

$d_{12}^{-}, d_{13}^{-}, d_{14}^{-}, d_{15}^{-}, d_{22}^{-}, d_{23}^{-}, d_{24}^{-}, d_{25}^{-} d_{32}^{-}, d_{33}^{-}, d_{34}^{-}, d_{35}^{-}$ all are deviation variables greater than zero.

Hard constraint; The total cost shall be less than 200000 rupees; G4 <200000;

The ahp total score of supplier and sub factor scores shall be greater than boundary limits.

X_1* . 0.2651 + x_2 *0.26134+x_3 *0.21553+x_4 *00.25804>300;

X_1 * 0.2214+ x_2 *0.13838+x_3 *0.19373+x_4 *0.166054>250;

X_1 * 0.35526+ x_2 *0.56841+x_3 *0.42631+x_4 *0.568408>785;

X1 * 0.20829 + x_2 *0.42631+x_3 *0.17853+x_4 *0.23804>430;

X_1 * 0.64541+ x_2 *0.64541+x_3 *0.46101+x_4 *0.553206>865;

Total quantity to be ordered is 1500 units; ie$\mathbf{x_1 + x_2 + x_3 + x_4}$**= 1500**

The limitation of production capacityx_1<800, x_2<500, x_3<700, x_4<600; $x_1 \geq 0$, $x_2 \geq 0$; $x_3 \geq 0$, $x_4 \geq 0$;

Results :the quantities to be ordered against each supplier and goal values achieved are mentioned

x1	x2	x3	x4	goal1	goal2	goal3	goal 4
143	500	257	600	1208	1250	938	199595

For the remaining group's the arrival time of mux selection input is always greater than the arrival time of data inputs from the BEC's. Thus, the delay of the remaining groups depends on the arrival time of mux selection input and the mux delay.

6. Conclusion

The problem is solved using software lingo 11 Multi objective technique is used to find out the correlated weights of criteria in supplier selection. Implementation of linear physical programming technique which has the capability to represent decision maker preference by using a utility function and to manage problem in multi criteria environment for order allocation is presented. The study gives ample scope for Future scope: such as The model can be further extended accommodating more variables such as power requirements infrastructure requirements, product recycling etc. this can be extended to new areas with fuzziness in consideration

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