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A Fuzzy Multi Criteria Decision Making Approach for Vendor Evaluation in a Supply Chain

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Abstract – Manufacturing enterprises face enormous competitive pressures in today's business environment and to make full use of inside and outside resources in a competitive globalization market, many manufacturers and service providers are seeking a strategic cooperation with suitable vendors to improve their supply chain management (SCM) so that they can concentrate their efforts on their own core business. Hence, there is a necessary to select the best suppliers among various suppliers available. The decision parameters in vendor selection contains vague and uncertainty. The fuzzy theory able to handle this uncertainty, vague, imprecision and subjectivity present in vendor selection process and makes decision process more effective.

In the research, we have analyzed an existing system of vendor rating and proposed a better system of vendor rating for the organization. Most organizations use simple additive weighting for vendor rating. However, we have attempted to use the fuzzy decision making method for the purpose. In the proposed approach, linguistic values are used to assess the ratings and weights for these factors. These linguistic ratings can be expressed in trapezoidal or triangular fuzzy numbers. Then, a hierarchy multiple criteria decision-making (MCDM) model based on fuzzy theory is proposed to deal with the supplier selection problems in the supply chain system.

Keywords – *Simple additive weighting (SAW); TOPSIS (Technique for Order Preference Similarity to Ideal Solution; Fuzzy TOPSIS; Linguistic variables; Supply chain management; Vendor selection.*

I. INTRODUCTION

Supplier selection is becoming increasingly important as companies continue to develop more collaborative and long-term relationships with their suppliers. As discussed by Robinson and Timmerman (1987), close working relationships with high performing suppliers are essential in modern production environments. The interaction between the organization and the suppliers should be two way so as to make the suppliers aware of their performance so that it would be helpful for them to cope up with the organization's need. When a supplier selection decision needs to be made, the organization should develop a set of evaluation criterions that can be used to evaluate the suppliers and to find out the potential suppliers by rating them. Traditionally, supplier evaluation models were based on financial measures with less emphasis on other tangible and intangible criteria. However, with the widespread use of manufacturing philosophies such as just-in-time (JIT) emphasis has shifted to the simultaneous consideration of multiple supplier attributes in the supplier evaluation process. Application of various attributes varies with situations and the organization should give proper weightages to each attribute as per the situation. Proper evaluation and rating of suppliers helps the organization not only in benchmarking the suppliers but it also helps the organization to reduce purchase risk, maximize overall value to the purchaser. The supplier selection problem is basically a multi-criteria decision making problem. There are many MADM (Multi Attribute Decision Making) methods which are useful to solve this problem. The method used by us is Fuzzy TOPSIS (Technique for Order Preference using Similarity to Ideal Solution). Under many conditions, crisp data are inadequate to model real-life situations. Since human judgments including preferences are often vague and cannot estimate his preference with an exact numerical value. A more realistic approach may be to use linguistic assessments instead of numerical values. In other words, the ratings and weights of the criteria in the problem are assessed by means of linguistic variables (Bellman and Zadeh, 1970; Chen, 2000; Delgado et al., 1992; Herrera et al., 1996; Herrera and Herrera-Viedma, 2000). The proposed method is extending the TOPSIS method. Considering the fuzziness in the decision data and group decision-making process, linguistic variables are used to assess the weights of all criteria and the ratings of each alternative with respect to each criterion.

II. METHODOLOGY

Fuzzy SAW method: Churchman and Ackoff (1954) firstly utilized the Simple Additive Weighting (SAW) method to cope with portfolio selection problem. Simple additive weighting (SAW) method is the most often used technique for tackling spatial multi attribute decision taking. The technique is also referred to as weighted linear combination) or scoring methods. They are based on the concept of a weighted average. The decision maker directly assigns weights of relative importance to each attribute. A total score is then obtained for each alternative by multiplying the importance weight assigned for each attribute by the scaled value given to the alternative on that attribute, and summing the products over all attributes. When the overall scores are calculated for all the alternatives, the alternative with the highest overall score is chosen. Formally, the decision ruler evaluates each alternative, Ai, by the following formula:

$$A_i = \sum_j w_i X_{ij}$$

Where Xij is the score of the i th alternative with respect to the j th attribute, and the weight Wi is the normalized weight, so that sum of all weights is equal to one. The weights represent the relative importance of the attributes. The most preferred alternative is selected by identifying the maximum value of Ai (i = 1, 2...., m).The steps involved in SAW method are:

a. Define the set of evaluation criteria and set of feasible alternatives.

b. Standardize each criterion map layer.

c. Define the criterion weights; that is, a weight of "relative importance" is directly assigned to each criterion map.

d. Construct the weighted standardized map layers; that is, multiply standardized map layers by the corresponding weights.

e. Generate the overall score for each alternative using the add overlay operation on the weighted standardized map layers.

f. Rank the alternatives according to the overall performance score; the alternative with the highest rank is the best alternative.

SAW method is probably the best-known and very widely used method for MADM. In fuzzy saw method, we will assume that the performance value of the i th alternative in terms of the j th criterion is a fuzzy triangular number which is denoted as

$$\hat{a}_{ij} = (a_{ijl}, a_{ijm}, a_{ijn})$$

It is assumed that the decision maker will use fuzzy triangular numbers in order to express the weights of importance of the criteria. These weights are denoted as

$$\hat{W}_j = (W_{jl}, W_{jm}, W_{jn})$$

Also, to be consistent with the basic requirement that the weights usually add up to one (in a crisp environment), now it is required that the sum of W_{jm} (the modal values of the fuzzy triangular numbers which represent the criterion weights) be equal to one. From the above considerations it follows that now the best alternative is the one which satisfies the conditions.

The SAW method is the simplest method and can be applied without difficulty in single-dimensional cases where all units of measurement are identical (for example, dollars, hours, etc.). Because of the additively utility assumption, a conceptual violation occurs when the WSM is used to solve multidimensional problems in which the units are different.

III. FUZZY TOPSIS METHOD

TOPSIS (Technique for Order Preference using Similarity to Ideal Solution) is a useful MADM (Multi Attribute Decision Making) tool which is used to provide a ranking of the technologies. TOPSIS is based on an algorithm, which ranks the technologies according to their Euclidean distance to an ideal solution i.e. the selected Design Options should have the shortest distance from the ideal solution and the farthest from the negative-ideal solution (in a geometric sense). TOPSIS assumes that each Design Option wants to either be maximized or minimized, so the positive-ideal solution for a Criterion that wants to be maximized is the maximum value of all the design options considered and the negative-ideal solution is the minimum values of all the design options considered. Usually we consider the MCDM problems with *n* attribute (or criteria), here we reduce *n* dimension problems to two dimension for reason to comprehend the operation of this method. If there are only two attribute 12(,)*XX* in our evaluation process for MCDM problem; then it is easy to locate the "ideal" solution which is composed of all best performance value on both attribute, on the other hand, the "negative-ideal" solution which is composed of all worst performance value on both attribute also be found easily.

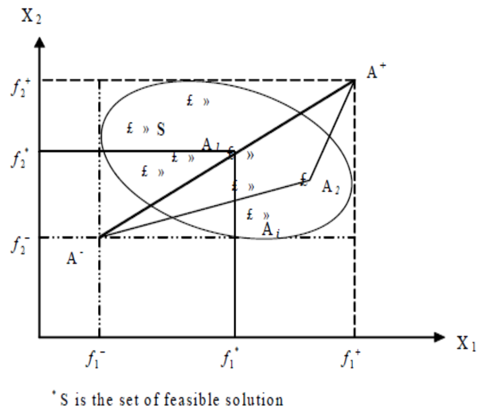

Fig. 1: TOPSIS to find the compromise solution for two dimensional case

For example, an alternative 1*A* has shorter distances both to ideal solution **A* and to the negative-ideal solution *A*− than the other alternative 2*A*.Then it is very difficult to justify the selection of1*A*. TOPSIS is to take an alternative, called compromise solution, which has the weighted minimum Euclidean distance to the ideal solution in a geometric sense and also has the maximum Euclidean distance to the negative-ideal solution. Sometimes the chosen alternative, which has the weighted minimum Euclidean distance to the ideal solution, has the shorter distance to the negative-ideal solution than the other alternative(s).

TOPSIS have various advantages over existing methods which are: TOPSIS provides the ranks of available alternatives according to the best and worst combinations of characteristics. It gives the ranks based on the Closeness value. The benchmark that TOPSIS used for grading of alternatives is obtained as follows: (1) For the first criteria, it scans through the marks awarded to all the alternatives and the best and the worst entries in the column are recorded, (2) This procedure is carried over for all the parameters (3) Thus we have the "best of all" (positive ideal) and "worst of all" (negative ideal) combinations. Each alternative is compared with these positive and negative ideals and marks are awarded on the basis of the offset of the alternatives from the positive and negative ideals. The stand out point of TOPSIS is that the positive ideal is the best possible realistic benchmark and hence every vendor can possibly achieve it. The benchmark is also progressive in nature i.e. as the vendors' progress, the benchmark progresses as well thus making sky the limit. Under many conditions, crisp data are inadequate to model real-life situations. Since human judgments including preferences are often vague and cannot estimate his preference with an exact numerical value. A more realistic approach may be to use linguistic assessments instead of numerical values. In other words, the ratings and weights of the criteria in the problem are assessed by means of linguistic variables. Considering the fuzziness in the decision data and group decision-making process, linguistic variables are used to assess the weights of all criteria and the ratings of each alternative with respect to each criterion.

Linguistic variable	Triangular fuzzy number
Very Poor(VP)	(0,0,0.2)
Poor(P)	(0,.2,.4)
Fair(F)	(.3,.5,.7)
Good(G)	(.6,.8,.10)
Very Good(VG)	(.8,.10,.10)

Table. 1: Linguistic variables and corresponding fuzzy numbers

We can convert the decision matrix into a fuzzy decision matrix and construct a weighted-normalized fuzzy decision matrix once the decision-makers' fuzzy ratings have been pooled. According to the concept of TOPSIS, we define the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS).And then, a vertex method is applied in this paper to calculate the distance between two fuzzy ratings. Using the vertex method, we can calculate the distance of each alternative from FPIS and FNIS, respectively. Finally, a closeness coefficient of each alternative is defined to determine the ranking order of all alternatives. The higher value of closeness coefficient indicates that an alternative is closer to FPIS and farther from FNIS simultaneously.

IV. NEW SYSTEM PROPOSED (FUZZY TOPSIS)

We have programmed this procedure in a MS Excel file as it is the most user friendly and effective tool for performing such simple additive operations.

The method that we proposed to be used for vendor rating is Fuzzy TOPSIS. The major fundamental benefit of using approach over using SAW is that while SAW is method that grades an alternative on absolute scale and whereas Fuzzy TOPSIS handles uncertainty in decision parameters and it can effectively handles vague and imprecise information present in decision making and performs the rating on relative method and also provides the ranks of available alternatives according to the best and worst combinations of characteristics.

We have made an executable file in MATLAB. This file directly takes the elements of the decision matrix from a data file and evaluates the result, displays the result showing the ranking of various vendors and their class they belong.

New marking Scheme:

1. Infrastructure Facilities & QA System

Marks will be given as per the initial and annual supplier appraisal done. In case of foreign suppliers, this will not be applicable.

2. Conformance Test Certificate

x = Lots with which conformance report received.

Z = Total lots received in the period.

Point obtained = x/Z x Maximum points x Quality Ratio

Marks will be given only when quality ratio > 80%.

This clause will not be applicable for Foreign suppliers.

3. a) Quality Rating: QR

X = Lots accepted directly without any segregation/MRC/Deviation.

Y = Number of lots against which Quality complaint registered.

Z = Total number of lots received in the period.

Points obtained = $\frac{X-Y}{Z}$ x Maximum points

Where $\frac{X-Y}{Z}$ x 100 can be defined as % Quality Ratio.

b) In process Rejection, I.P.Q.R: In process Quality Rating

Q1 = Total Quantity / Lots drawn on shop floor for usage.

Q2 = Quantity rejected after having been found faulty in the process; Cumulative shop floor rejection over the period.

% In process Rejection = $\frac{Q2}{Q1}$ x 100

Points Obtained (IPQR i.e. In process Quality Rating)

If process Rejection : >1% - No points.

>0.5% but <1% - 25% points.

>0.2% but <0.5% - 50% points

< 0.2% - Full Points

Maximum points =10.

4. Delivery Rating

q1 = Quantity Received.

q2 = Quantity Scheduled.

Delivery Ratio = $\frac{q1}{q2}$

Delivery ratio to be calculated monthly and then averaged over the time period.

Points obtained (Delivery Ratio) = $\frac{q1}{q2}$ x Maximum points

5. a) Co-operation with organization.

The assessment shall be based upon the helpfulness shown by the supplier in dealing over the specified period of time. (Out of 10)

b) Response on Quality Complaints =

$\frac{\text{No of Quality Complaints responded}}{\text{No. of Quality complaints forwarded}}$ *10

If no complaint is forwarded, 0 marks will be awarded.

c) Flexibility in implementing changes

Marks will be given based on the attitude of the supplier in implementing changes suggested by organization for improvement of the products (out of 10).

d) Information on Major Design / Component changes carried out

If any change is carried out and informed to organization = 10.

Any change carried out which affects the performance of components without organization's knowledge = 5 marks if the change enhances the performance

=1 marks if the change is Negative.

If no change is carried out =0.

e) Attitude to develop

The assessment will be done taking into consideration his responsiveness towards suggestions given in due course of Day to Day dealings / Activities for Development / Improvement over specified time frame (out of 10).

The weightages that Fuzzy TOPSIS will use are:

Indian Vendors:

.05, .05, .40, .10, .30, .02, .02, .02, .02, .02

The weightages that are to be assigned to various criterions should be revised and updated from time to time using the systematic Delphi procedure that captures the tacit knowledge of the experts of the organization.

For the process of calculating supplier satisfaction index, case organization sends a Performa to its vendors which grade organization on different parameters mentioned in the Performa. For calculating the SSI, organization adds up the grades given by different vendors and calculates an average SSI by dividing the sum by the total number of suppliers that participated in the process of SSI generation. We have used the software that we have made for a sample data and compared it with the procedure organization is using currently.

V. DISCUSSION OF RESULTS

A Program is developed in MATLAB for Fuzzy SAW approach and the results of the company are compared with the results obtained by the Fuzzy SAW approach and a graph is drawn for vendors rating for the two approaches.

Existing system(SAW)		
Vendor No.	Rating	Class
1	59	B
2	85.7	A
3	47.81	C
4	83.44	A
5	79.19	A
6	72.68	A
7	84	A
8	46.9	C
9	46.8	C
10	78.07	A
11	79.3	A
12	66.07	B
13	69.57	B
14	88.84	A
15	80.73	A

Fuzzy SAW		
Vendor No.	Rating	Class
1	56.23	B
2	75.388	A
3	53.031	B
4	75.442	A
5	74.513	A
6	68.415	B
7	75.388	A
8	44.602	C
9	48.371	C
10	71.706	A
11	72.854	A
12	65.428	B
13	69.01	B
14	80.207	A
15	70.947	A

Table 2: Vendors rating for SAW Table 3: Vendors rating for Fuzzy SAW

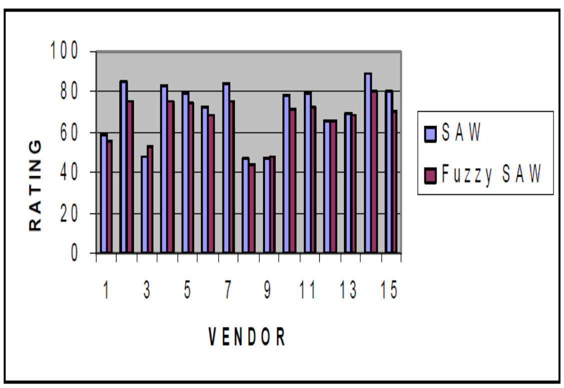

Fig. 3: Graph between vendors and rating (SAW Vs Fuzzy SAW)

Hence, as results shown above, the Fuzzy simple additive weighting (FSAW) gives results different from simple additive weighting (SAW).The reason being that, the FSAW able to handle effectively vague and uncertainty available in decision parameters and deals effectively with imprecise data available. Therefore we see more number of B grades and lesser C grades in proposed system when compared to existing system. Thus, we can say, the fuzzy approach is better than the conventional methods.

VI. COMPARISON BETWEEN SAW, FUZZYSAW AND FUZZY TOPSIS

In this section, we will compare the three methods. A program code is developed in MATLAB for Fuzzy TOPSIS approach and results obtained are shown in the table below. The results obtained for the Fuzzy TOPSIS are different from those of SAW and Fuzzy SAW. A graph is drawn showing the ratings for all the three approaches. Hence, as results shown above, the Fuzzy TOPSIS gives different results from simple additive weighting (SAW) and Fuzzy SAW. The reason is that, the method gives realistic benchmarking criteria as it performs benchmarking of performance on the basis of real life best performances that the vendors have achieved amongst themselves.

Proposed system(Fuzzy TOPSIS)		
Vendor No.	Rating	Class
1	34.82	C
2	76.56	A
3	24.1	C
4	77.27	A
5	59	B
6	49.15	C
7	77.14	A
8	13.22	C
9	10.23	C
10	74.24	A
11	58.25	B
12	73.59	A
13	69.54	B
14	96.28	A
15	74.07	A

Table 3: Vendors rating for Fuzzy TOPSIS

The benchmark is inherently progressive in nature. Thus the solution obtained will have shortest distance from the positive ideal solution and largest distance from negative ideal solution.

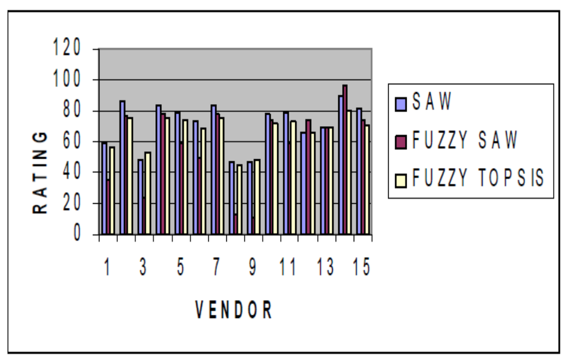

Fig. 4: Graph between vendors and rating (SAW, Fuzzy SAW and Fuzzy TOPSIS)

Thus, we see from the above graph that the Fuzzy TOPSIS gives lower ratings than other approaches due to its method of approaching to the solution. Therefore we see more number of C grades and lesser A grades in proposed system when compared to existing system. Thus, we can say, the fuzzy TOPSIS approach can be helpful for rating the vendors. Based on the results obtained, we have made comparison between the three approaches showing that Fuzzy TOPSIS is more helpful in rating the vendors effectively. The table shows the comparison of each technique based on the different criteria. From the table; the Fuzzy TOPSIS is more useful when they are large number of criteria and alternatives.

Criteria	SAW	Fuzzy SAW	Fuzzy TOPSIS
Principle	Getting the final score by summing up the weighted performance ratings.	Ratings and weights of criterion are expressed in linguistic scales.	The solution will have shortest distance from positive ideal solution and largest distance from negative ideal solution.
Complexity	Low	Medium	High
Criteria	Less	Medium	More
Alternatives	Less	Medium	High
Foreknowledge	Less	High	High
Uncertainty	No	Yes	Yes
Vagueness	No	Yes	Yes
Flexibility in decision	Less	More	More
Method of grading	Absolute scale	Absolute scale	Relative grading

Table 4: Comparison between SAW, FUZZY SAW and FUZZY TOPSIS

VII. CONCLUSION

Due to uncertain and imprecise data in vendor selection problem, fuzzy decision making is adequate to deal with them. Here the existing vendor rating system is SAW, which is a simple technique for solving multi criteria decision problems. We have analyzed the fuzzy SAW and fuzzy TOPSIS approaches and finally fuzzy TOPSIS is found to be best method. The major advantage of the proposed method is that it can be used for qualitative as well as quantitative criteria. The proposed method can deal with decision making problems in linguistic environments. The salient features of the proposed approach are:

(a) The proposed approach effectively handles the imprecise information we have and gives better results.

(b) The involvement of experts and their experience makes this approach to be more realistic.

(c) The method gives realistic benchmarking criteria as it performs benchmarking of performance on the basis of real life best performances that the vendors have achieved amongst themselves.

(d) The vague and uncertainty available in decision parameters during decision making can easily be tackled by this approach.

(e) The decision making will be similar to that of human thinking.

(f) The results are ideal for management reporting.

(g) The strong and weak points of each vendor and vendors marked out.

(h) The approach gives more flexibility in terms of taking decision in giving performance values to various vendors under each criterion.

(i) In deciding the weights capture the tacit knowledge of experts involved.

(j) Results can be shared as such with the vendors assisting in knowledge sharing.

(k) The software can be used effectively both for supplier rating by customer and customer rating by supplier.

The results show that the model has the capability to be flexible and apply in different types of industries to choose their vendors. Not only the model makes tradeoffs between qualitative and quantitative factors, but it also enables decision makers to deal with inconsistent judgments systematically.

VIII. SCOPE FOR FUTURE WORK

Though Fuzzy TOPSIS, being a relative method of grading, is progressive in nature and encourages more competition amongst vendors but sometimes it can be a bit harsh in awarding grade C to vendors. This happens primarily when the performances of the vendors vary uniformly. In that case, almost 30 % of the vendors will be awarded a C grade. To get rid of this problem, one can take help of statistical tools. One can use Chi–square method to overcome this problem. There are several fuzzy approaches which can be used for solving multi criteria decision making problems. These fuzzy approaches can be analyzed and can be applied in these types of decision making situations.

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