Development of Fuzzy Decision Model using Balanced Scorecard

Dr.Nagabhushan SV (Associate Professor)
Dept. of CSE, BMSIT&M

ABSTRACT

Strategic Sourcing is the process of careful evaluation and selection of a firm's supply base so that the overall value of a firm's procurement function can be improved. With majority of the manufacturing cost going towards materials, it is essential to ensure maximum returns for the investment in terms of quality and cost. Evaluating equally good suppliers on multiple conflicting criteria and strategically selecting the best, is a complex decision-making process. Though decision models offer a systematic aid to strategic sourcing, they have to be tailored to the manufacturer's requirements to be effective. In this paper," the Balanced Scorecard (BSC) is used as a framework on which a Fuzzy-Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) based model has been proposed for ranking the supplier's". BSC helps translate the strategy into measures which helps identify the factors on which the suppliers are evaluated. Linguistic variables are proposed to capture the decision maker's assessments which are in-turn represented as triangular fuzzy numbers to retain the ambiguity essential in decision making. The ranking of the suppliers is separately obtained for each BSC perspective rather than an overall ranking thus aiding in more effective decision making. An application of the model in selecting the best supplier for an automobile manufacturing firm has been presented.

Keywords: MCDM, fuzzy TOPSIS, Balanced Scorecard, supplier selection

I. INTRODUCTION

Supplier selection is among the most important supply chain decisions for firms. Strategic sourcing is critical as it forms the backbone for the quality of a company's products. With techniques such as just in time manufacturing, six sigma and balanced scorecard getting absorbed into mainstream manufacturing, strategic sourcing and long-term supplier relationships become all the more important in securing a competitive advantage for firms. More and more companies are looking at their suppliers to help them secure a more competitive position in the market (Ganesan 1994)**.** Vendor evaluation and selection has been widely researched over the years and most of the work in this area consists of quantitative hierarchy-based models, where the alternatives are evaluated on a set of evaluation criteria and the highest-ranking alternative is chosen. This approach is known as Multi Criteria Decision Making (MCDM). The evaluation criteria list for supplier selection was developed as early as Dickson (1966) who identified 23 selection criteria. Further work in this area came from Weber et.al (1991) that reviewed 74 articles on supplier selection and the Dickson criteria and concluded that quality was the most important criteria followed by cost and delivery. Haleem et al. (2009) found that reliability of the vendor, product quality and vendor experience are the top three criteria in the vendor selection problem.

Need for integrating the Balanced Scorecard into the supplier evaluation model

As rightly pointed out by (Boer et.al 2001), most of the work in this area does not concentrate on the problem definition and criteria formation phases. Literature that addresses evaluation criteria separately exists where the authors present vast comprehensive lists of metrics and criteria for supplier evaluation. Sometimes the criteria mentioned cannot be used in practice, as merely evaluating suppliers using a long list of criteria only leads to more confusion. The metrics and criteria need to be chosen according to the requirements of the firm and the firm's strategy for effective evaluation. Balanced Scorecard is one of the techniques that helps translate the strategy into measures and action.

In recent times when firms have clear cut strategies for each functional area of a business, it is necessary to reconcile the goals of all the entities of the supply chain with the manufacturer's goals. Quantitative decision models for supplier selection need to be tailored according to a firm's strategy to ensure effective evaluation. The objective is not to select the overall best supplier, but to select the one whose performance best matches the company's requirements. Our work addresses this issue by using the Balanced Score Card as a basis for supplier evaluation. The firm's strategy is mapped and converted into performance measures using which the evaluation is made. Performance of the supplier in each functional area is considered separately and the supplier's are ranked area wise.

II. RELEVANT WORK

Some approaches that have been used in a crisp environment to model supplier selection are Analytical

Hierarchy Process (AHP) (Nydick and Hill 1992, Tam and Tummala 2001), Data envelopment analysis (Narasimhan et.al 2001, 2004), other MCDM approaches such as VIKOR(Opricovic and Tzeng 2004) , TOPSIS (Shyura and Shih 2006) and mathematical programming models such as linear programming, integer programming and goal programming. A comparative study of various vendor selection models based on a Total Cost of Ownership perspective found that mathematical programming models fare better than ranking models (Degraeve et. al 2000).

As supplier selection involves human judgments, crisp data is inadequate to model it. Human judgments are ambiguous and cannot be captured with values having definite boundaries. Fuzzy numbers are more suitable for representing such judgments. Bellman and Zadeh (1970) was one of the first papers to consider decision making in a fuzzy environment. Since then, supplier selection has been extensively analyzed in the fuzzy environment using Fuzzy Multi Criteria Decision Making approaches such as Fuzzy AHP, Fuzzy TOPSIS (Chen et al. 2006 Jahanshahloo et. al 2006), Fuzzy VIKOR and Fuzzy goal programming (Kumar et.al 2004).

An evaluation of five fuzzy decision approaches AHP, TOPSIS, Weighted Product Method (WPM), Weighted Sum Model (WSM) and Revised AHP found that fuzzy AHP and TOPSIS models are superior in capturing a human's appraisal in decision making problems (Triantaphyllou and Lin 1996). TOPSIS is a simple and effective MCDM approach used to rank alternatives based on the assessments' relative distance to the ideal solution. TOPSIS is most effective when accurate weights are obtained during evaluation (Olson 2004).

Chen et. al (2006) gives a comprehensive model for supplier selection based on fuzzy TOPSIS(Technique for Order Performance by Similarity to Ideal Solution). A group decision making approach has been considered and linguistic variables have been proposed to be used for the criteria weights and supplier assessment ratings. A numerical example with trapezoidal fuzzy numbers is presented and the final supplier ranking is based on the closeness coefficient values of each alternative. This work focuses more on the model development and supplier choice phase of the decision making process. Though the choice phase in supplier selection decision making is an important phase, preceding phases such as criteria formation and choice of method are vital to ensure effective decision making. The Criteria formation phase has not got much attention in literature (Boer et al. 2001) and most of the work in the area is focused only on the choice phase of supplier selection.

Also, evaluating suppliers based on a long list of criteria defeats the purpose of strategic supplier selection. It is hence, important to tailor the evaluation to a firm's strategy and develop the criteria for supplier selection based on the strategy. The Balanced Scorecard is a performance measurement and strategic management tool proposed by (Kaplan and Norton 1992, 1993, and 1996). The Balanced Score Card gives an overall perspective that looks at both operational and financial measures of performance. In this paper it is proposed to use the Balanced Score Card as a framework for the evaluation of suppliers and supplier selection.

III. METHODOLOGY

A Balanced Scorecard based fuzzy decision model for strategic sourcing

The proposed model considers supplier selection decision making in a fuzzy environment and has been built on the BSC as a framework. The first step is to develop a Balanced Scorecard for the firm. In a coordinated supply chain, more often than not, the whole supply chain has a single strategy. For firms that have been using the Balanced Score Card, the supply chain scorecard can directly be used for evaluating the suppliers. If there are major changes in the procurement strategy when compared to the overall supply chain strategy or when a BSC does not exist, then a scorecard for supplier selection is prepared.

The BSC helps translate the procurement and manufacturing strategy into performance measures which can be used to assess the supplier's performance. Hence, the BSC facilitates the criteria formation for the supplier evaluation ensuring that the criteria are in tune with the overall manufacturing strategy. After the criteria formation, a quantitative model for evaluation has been proposed using fuzzy TOPSIS. The model relies on human judgment to obtain the initial assessments and hence linguistic variables have been proposed to capture the evaluation effectively. Linguistic variables help represent human expressions that do not have well defined boundaries. These linguistic assessments are in-turn represented as triangular fuzzy numbers which can effectively capture the ambiguity inherent in the linguistic expressions.

The model considers decision making process where more than one decision maker participates in the decision making. Relative importance weights for the BSC perspectives and the performance measures are obtained from the decision makers. Each supplier's performance is assessed against the developed measures and is recorded. The recorded weights and ratings are converted

into triangular fuzzy numbers, aggregated into single assessments, normalized and weighted to obtain the final assessment values. "The TOPSIS method seeks to rank the alternatives in such a way that the alternative with the assessment value that is farthest from the negative ideal solution and closest to the positive ideal solution is ranked first."

The following are the main steps involved in the proposed model

- **S1**: Identifying the goal and the alternatives and developing the Balanced Score Card
- **S2**: Obtaining importance weights for the perspectives and measures and computing the combined importance weights
- **S3**: Obtaining the supplier assessments from the decision makers
- **S4**: Aggregating all decision makers' ratings into a single combined rating
- **S5**: Aggregating the final assessment perspective-wise
- **S6**: Obtaining the Weighted Normalized Assessment (WNA)
- **S7**: Calculating the deviation of the WNA from the ideal solution
- **S8**: Calculating the Closeness Coefficient and ranking the suppliers

The detailed step by step procedure involved in the selection and evaluation process of suppliers is presented in the flowchart Fig 1 given below. Each step has been explained in detail in the flowchart itself.

IV. IMPLEMENTATION

Application of the proposed methodology for an automobile manufacturing firm

An manufacturing firm intends to select a suitable supplier for the procurement for the coil components to their one of the assembly from among 2 potential suppliers S1 and S2. Two decision makers D_{M1} and D_{M2} are evaluating the suppliers on 20 evaluation measures. Hence d = 2; s= 2 and n = 20

Step1: Identifying the goal and the alternatives and developing the Balanced Score Card

The goal is to select the best seat supplier among two alternatives S1 and S2. They propose a Balanced Scorecard measurement system based on measures that have appeared most number of times in literature. The BSC presented below is taken from Sohn et. al 2003 and has been used to evaluate the alternatives in this example.

Step2: Obtaining importance weights for the perspectives and measures and computing the combined importance weights

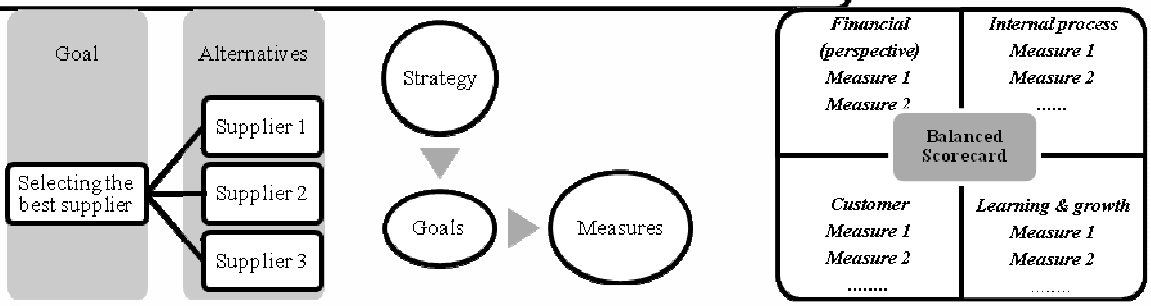
The relative importance weights for the perspectives- "Financial, position Customer, feedback processes and Learnings "are obtained from all the decision makers using the proposed linguistic scale presented in the flowchart. A 5-point Likert-based scale has been proposed to capture the criteria importance weights.

The linguistic assessment obatined, are in -turn represented as triangular fuzzy numbers as shown below. Table 1 gives the decision makers' importance weights for the BSC perspectives. In a Balanced Score Card, performance measures are developed for each perspective in order to monitor the performance in that perspective and propose necessary action. Each of these measures also have relative preference among the decision makers and hence they need to be recorded. The relative importance weights for the measures is shown in Table 2.

Step 2(i): Combining the importance weights of the perspectives with the measures for each perspective.

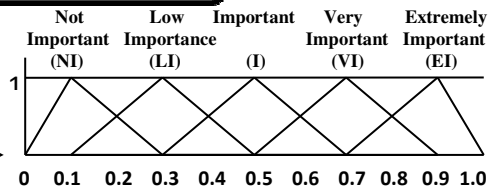
The final importance weights for each measure is obtained by multiplying the weights for the respective perspectives with the importance weights for the measures under that perspectve. For eg: DM1's importance weight for the Customer perpective is Very Important(VI). To incorporate this priority, all the measures under the perspective Customer get multiplied by the importance weight for customer i.e VI (0.5,0.7,0.9). Customer profitability a measure under the Customer perspective, which had an importance weight of I (0.3,0.5,0.7) from DM1 gets multiplied with VI(0.5,0.7,0.9) to obtain (0.15,0.35,0.63) as the combined importance weight. Table 3 gives the combined importance weights for all the measures.

1. Identifying the goal and the alternatives and developing the Balanced Score Card



2. Obtaining importance weights for the perspectives and measures and computing the combined importance weights

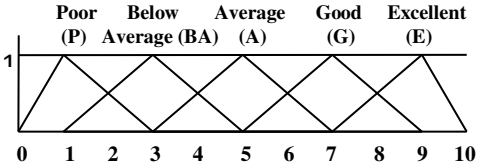
Importance weights for the BSC perspectives and the measures under them are obtained from decision makers as ***linguistic variables***
The linguistic assessment is then converted into a ***triangular fuzzy number***



'd' decision makers' fuzzy weights for each perspective is represented as $\bar{X}_d = \{ l_d, m_d, n_d \}$ and **'d'** decision makers' fuzzy weights for the measures under each perspective is represented as $\bar{Y}_d = \{ p_d , q_d , r_d \}$. The combined importance weights are obtained by multiplying the measure's importance weight with the main perspective's importance weight for that measure $W_d = \bar{X}_d \otimes \bar{Y}_d$

3. Obtaining the supplier assessments from the decision makers

Decision makers rate the suppliers on each measure using linguistic variables and the linguistic assessments are converted into triangular fuzzy numbers



The proposed linguistic scale for supplier assessment is shown above

'd' decision makers' linguistic ratings of 's' suppliers on 'n' measures are represented as $\{\bar{R}_{ijk}$ where i =1,2…d, j=1,2…s and k=1,2…n$\}$ then the corresponding fuzzy numbers can be represented as $\bar{R}_{ijk} = \{ a_{ijk} , b_{ijk} , c_{ijk} \}$

4. Aggregating all decision makers' ratings into a single combined rating

If Decision Maker 1's rating $\bar{R}_{1jk} = \{ a_{1jk}, b_{1jk}, c_{1jk}\}$

DM2- $\bar{R}_{2jk} = \{ a_{2jk}, b_{2jk}, c_{2jk}\}$

DMd - $\bar{R}_{djk} = \{ a_{djk}, b_{djk}, c_{djk}\}$

Then the aggregated fuzzy rating

$AR_{jk} = \{\bar{a}_{djk}, \bar{b}_{djk}, \bar{c}_{djk}\}$

where $\bar{a}_{djk} = \min \{ a_{djk} \}$;

$b = \frac{1}{d} \sum_1^d b_{djk}$;

$\bar{c}_{djk} = \max \{ c_{djk} \}$;

Now the aggregated ratings can be represented as

$$R = \begin{pmatrix} AR_{11}\, AR_{21} \ldots AR_{s1} \\ AR_{12}\, AR_{22} \ldots AR_{s2} \\ \ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots \\ AR_{1n}\, AR_{2n} \ldots AR_{sn} \end{pmatrix} \quad W = \begin{pmatrix} AW_1 \\ AW_2 \\ \ldots\ldots \\ \ldots\ldots \\ AW_n \end{pmatrix}$$

j=1,2…s and k=1,2…n. The same process is repeated for the criteria importance weights W_d to obtain $\mathbf{AW_k}$

5. Aggregating the final assessment perspectivewise

$$R = \begin{pmatrix} AR_{11}\ AR_{21}\ \ldots.\ AR_{s1} \\ AR_{12}\ AR_{22}\ \ldots.\ AR_{s2} \\ \ldots\ldots\ldots\ldots\ldots \\ \ldots\ldots\ldots\ldots\ldots \\ AR_{1n}\ AR_{2n}\ \ldots.\ AR_{sn} \end{pmatrix} W = \begin{pmatrix} AW_1 \\ AW_2 \\ \ldots\ldots \\ \ldots\ldots \\ AW_n \end{pmatrix} \longrightarrow R' = \begin{array}{c} \\ F \\ I \\ C \\ L \end{array} \begin{array}{c} \begin{array}{cccc} S_1 & S_2 & S_3 & S_n \end{array} \\ \begin{pmatrix} AR_{1F} & AR_{2F} & AR_{3F} & AR_{sF} \\ AR_{1I} & AR_{2I} & AR_{3I} & AR_{sI} \\ AR_{1c} & AR_{2c} & AR_{3c} & AR_{sc} \\ AR_{1L} & AR_{2L} & AR_{3L} & AR_{SL} \end{pmatrix} \end{array} W' = \begin{pmatrix} AW_F \\ AW_C \\ AW_I \\ AW_L \end{pmatrix}$$

The supplier ratings for the measures under each perspective are grouped back under the 4 BSC perspectives. The ratings against all measures under each main perspective are aggregated to get a single rating for each main perspective for every supplier. The method of aggregation is similar to the one shown in the previous step. F – Financial, I – Internal Processes, C - Customer, L – Learning& Growth.

6. Obtaining the Weighted Normalized Assessment (WNA)

$$R' = \begin{array}{c} \\ F \\ I \\ C \\ L \end{array} \begin{array}{c} \begin{array}{cccc} S_1 & S_2 & S_3 & S_n \end{array} \\ \begin{pmatrix} AR_{1F} & AR_{2F} & AR_{3F} & AR_{sF} \\ AR_{1I} & AR_{2I} & AR_{3I} & AR_{sI} \\ AR_{1c} & AR_{2c} & AR_{3c} & AR_{sc} \\ AR_{1L} & AR_{2L} & AR_{3L} & AR_{SL} \end{pmatrix} \end{array} W' = \begin{pmatrix} AW_F \\ AW_C \\ AW_I \\ AW_L \end{pmatrix} \longrightarrow WNA = \begin{array}{c} \\ F \\ I \\ C \\ L \end{array} \begin{pmatrix} \bar{A}_{11} & \bar{A}_{21} & \bar{A}_{31} & \bar{A}_{s1} \\ \bar{A}_{12} & \bar{A}_{22} & \bar{A}_{32} & \bar{A}_{s2} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ \bar{A}_{14} & \bar{A}_{24} & \bar{A}_{34} & \bar{A}_{s4} \end{pmatrix}$$

WNA = $\bar{A}_{ij} = N(.)\ W'$ for i =1,2…s ; j=1,2…n.

Normalize R' -> N [each value is divided by the max value in the matrix to get all values in the range 0-1]

where $\bar{A}_{ij} = \{ A_{ij1}, A_{ij2}, A_{ij3} \}$

7. Calculating the deviation of the WNA from the ideal solution

Initialize Fuzzy positive ideal solution (FPIS) = {1, 1, 1} and Fuzzy negative ideal solution (FNIS) = {0, 0, 0} (Maximum and minimum fuzzy values)

To compute the distance between the ideal solution and the assessment, we use the Euclidian distance between the ideal solution and the assessment. If $\tilde{x} = \{x_1, x_2, x_3\}$ is the FPIS or the FNIS and $\tilde{y} = \{y_1, y_2, y_3\}$ is the weighted normalized fuzzy assessment, then

Euclidian distance between $\tilde{x}$ and $\tilde{y}$ is given by $d_v(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}[(x_1 - y_1)^2 + (x_2 - y_2)^2 + (x_3 - y_3)^2]}$

8. Calculating the Closeness Coefficient and ranking the suppliers

Closeness Coefficient (CC) = $D_i^- / (D_i^+ + D_i^-)$ Where $D_i^+ = \sum_{j=1}^{n} d_v(\bar{A}ij, 1)$

and $D_i^- = \sum_{j=1}^{n} d_v(\bar{A}ij, 0)$ for i = 1,2…s.

Suppliers are ranked in descending order of their CC values perspective wise.

Fig 1: Methodology for BSC based decision model

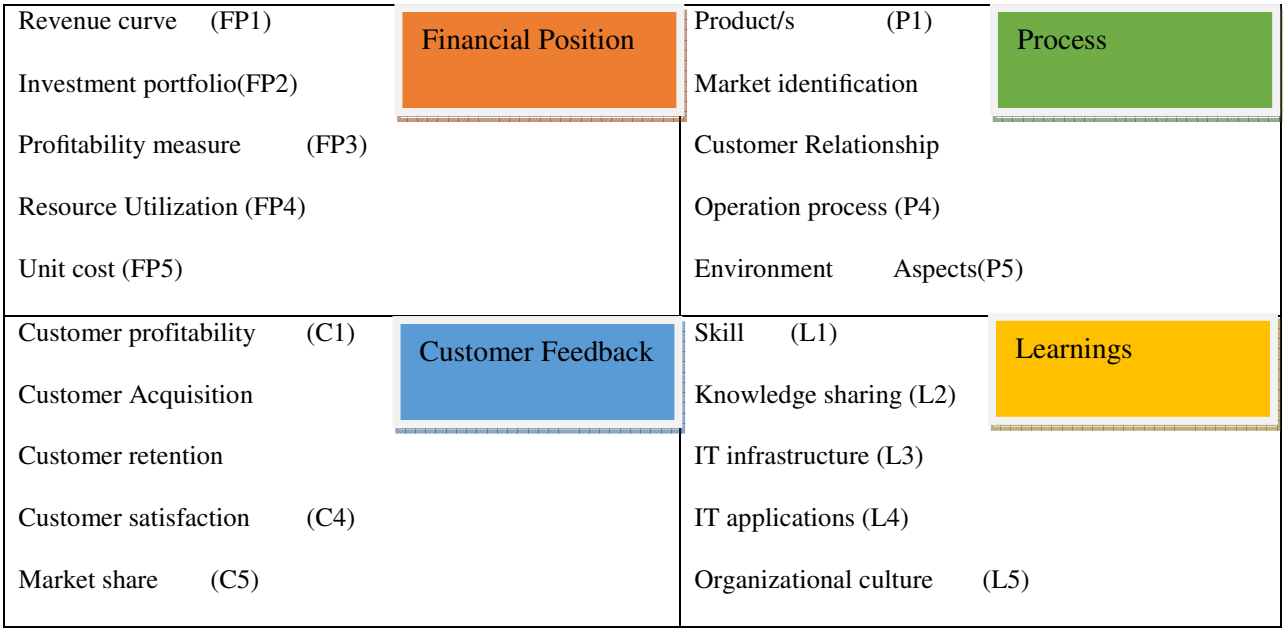


Fig 2: Balanced Scorecard

Linguistic assessment			**Corresponding triangular fuzzy numbers**					
Perspectives	**DM1**	**DM2**	Min	**DM1** Modal	Max	Min	**DM2** Modal	Max
			$\tilde{X}_1 = \{ l_1, m_1, n_1 \}$			$\tilde{X}_2 = \{ l_2, m_2, n_2 \}$		
Financial Position	I	VI	0.3	0.5	0.7	0.5	0.7	0.9
Processes	I	I	0.3	0.5	0.7	0.3	0.5	0.7
Customer feedback	VI	VI	0.5	0.7	0.9	0.5	0.7	0.9
Learnings	I	VI	0.3	0.5	0.7	0.5	0.7	0.9

Table1: Relative importance weights for the 4 BSC perspectives

Linguistic assessment			**Corresponding triangular fuzzy numbers**					
Perspective name	**Decision makers**		Min	**DM1** Modal	Max	Min	**DM2** Modal	Max
Financial Position	**DM1**	**DM2**	$\tilde{Y}_1 = \{ p_1, q_1, r_1 \}$			$\tilde{Y}_2 = \{ p_2, q_2, r_2 \}$		
Revenue curve	VI	I	0.5	0.7	0.9	0.3	0.5	0.7
Investment portfoloio	I	VI	0.3	0.5	0.7	0.5	0.7	0.9
Profitability measure	VI	VI	0.5	0.7	0.9	0.5	0.7	0.9
Resource Utilization	LI	I	0.1	0.3	0.5	0.3	0.5	0.7
Unit cost	I	LI	0.3	0.5	0.7	0.1	0.3	0.5
Internal processes								M
Product/s	VI	EI	0.5	0.7	0.9	0.7	0.9	1.0
Market identification	LI	I	0.1	0.3	0.5	0.3	0.5	0.7
Customer Relationship	VI	I	0.5	0.7	0.9	0.3	0.5	0.7
Operation process	VI	VI	0.5	0.7	0.9	0.5	0.7	0.9
Environment Aspects	LI	VI	0.1	0.3	0.5	0.5	0.7	0.9
Customer								
Customer profitability	I	I	0.3	0.5	0.7	0.3	0.5	0.7
Customer Acquisition	LI	I	0.1	0.3	0.5	0.3	0.5	0.7
Customer retention	VI	LI	0.5	0.7	0.9	0.1	0.3	0.5

Customer satisfaction	EI	VI	0.7	0.9	1.0	0.5	0.7	0.9
Market share	I	VI	0.3	0.5	0.7	0.5	0.7	0.9
Learning & growth								
Skill	I	I	0.3	0.5	0.7	0.3	0.5	0.7
Knowledge sharing	LI	I	0.1	0.3	0.5	0.3	0.5	0.7
IT infrastructure	VI	I	0.5	0.7	0.9	0.3	0.5	0.7
IT applications	I	VI	0.3	0.5	0.7	0.5	0.7	0.9
Organizational culture	I	VI	0.3	0.5	0.7	0.5	0.7	0.9

Table 2: Relative importance weights for the measures under each perspective

.**Perspective name**	**Combined importance weights**					
	DM1(W_1)			**DM2**(W_2)		
	Min	Modal	Max	Min	Modal	Max
Financial						
FP1	0.15	0.35	0.63	0.15	0.35	0.63
FP2	0.09	0.25	0.49	0.25	0.49	0.81
FP3	0.15	0.35	0.63	0.25	0.49	0.81
FP4	0.03	0.15	0.35	0.15	0.35	0.63
FP5	0.09	0.25	0.49	0.05	0.21	0.45
Processes						
P1	0.15	0.35	0.63	0.21	0.45	0.70
P2	0.03	0.15	0.35	0.09	0.25	0.49
P3	0.15	0.35	0.63	0.09	0.25	0.49
P4	0.15	0.35	0.63	0.15	0.35	0.63
P5	0.03	0.15	0.35	0.15	0.35	0.63
Customer Feedback						
C1	0.15	0.35	0.63	0.15	0.35	0.63
C2	0.05	0.21	0.45	0.15	0.35	0.63
C3	0.25	0.49	0.81	0.05	0.21	0.45
C4	0.35	0.63	0.90	0.25	0.49	0.81
C5	0.15	0.35	0.63	0.25	0.49	0.81
Learnings						
L1	0.09	0.25	0.49	0.15	0.35	0.63
L2	0.03	0.15	0.35	0.15	0.35	0.63
L3	0.15	0.35	0.63	0.15	0.35	0.63
L4	0.09	0.25	0.49	0.25	0.49	0.81
L5	0.09	0.25	0.49	0.25	0.49	0.81

Table3: Combined importance weights for the measures used for supplier evaluation

Step 3: Obtaining the supplier assessments from the decision makers

Each supplier's performance is evalauted against the measures developed in the BSC using the lingusitc scale proposed for the supplier ratings as shown in the flowchart. Here, only the top 2 measures under each perspective are selected for further assessment based on the modal values of the fuzzy number from both decision makers's ratings.

The supplier ratings for the top two measures under each perspective and the corressponding triangular fuzzy numbers are given in table 4.

Linguistic assessment			Corresponding triangular fuzzy numbers $\bar{R}_{ijk} = \{ a_{ijk}, b_{ijk}, c_{ijk} \}$					
Supplier 1 assessment								
Measure name	**Decision makers DM1**	**DM2**	Min	**DM1** Modal	Maxx	Min	**DM2** Modal	Maxx
Investment portfolio	G	E	5	7	9	7	9	10
Profitability measure	E	E	7	9	10	7	9	10
Product/s	G	A	5	7	9	3	5	7
Operation process	A	G	3	5	7	5	7	9
Customer satisfaction	E	G	7	9	10	5	7	9
Market share	G	A	5	7	9	3	5	7
IT applications	A	G	3	5	7	5	7	9
Organizational culture	A	G	3	5	7	5	7	9
Supplier 2 assessment								
Measure name	**Decision makers DM1**	**DM2**	Min	**DM1** Modal	Maxx	Min	**DM2** Modal	Maxx
Investment portfolio	G	A	5	7	9	3	5	7
Profitability measure	G	E	5	7	9	7	9	10
Product/s	A	G	3	5	7	5	7	9
Operation process	E	E	7	9	10	7	9	10
Customer satisfaction	A	G	3	5	7	5	7	9
Market share	A	A	3	5	7	3	5	7
IT applications	E	E	7	9	10	7	9	10
Organizational culture	G	A	5	7	9	3	5	7

Table 4: Supplier performance assessment for each measure

Step 4: Aggregating all decision makers' ratings into a single combined rating

Aggregation of the assessment is made as shown in the flowchart by combining all decision makers' ratings into a single rating. The aggregation ensures that a single fuzzy number can be used to represent all decision makers' ratings. The range of the aggregated fuzzy value is inclusive of the ranges of both the decision makers' ratings. Table 5 gives the aggregated assessment for the top two measures under each perspective.

Perspective Name	Measure name	Combined criteria weights (AW_k)			S1 rating (AR_{1k})			S2 rating (AR_{2k})		
		Min	Modal	Max	Min	Modal	Max	Min	Modal	Max
Financial	Investment portfolio	0.09	0.37	0.81	5	8	10	3	6	9
	Profitability measure	0.15	0.42	0.81	7	9	10	5	8	10
Internal Processes	Product/s	0.15	0.40	0.70	3	6	9	3	6	9
	Operation process	0.15	0.35	0.63	3	6	9	7	9	10
Customer	Customer satisfaction	0.25	0.56	0.90	5	8	10	3	6	9
	Market share	0.15	0.42	0.81	3	6	9	3	5	7
Learning& Growth	IT applications	0.09	0.37	0.81	3	6	9	7	9	10
	Organizational culture	0.09	0.37	0.81	3	6	9	3	6	9

Table 5: Aggregated criteria weights and supplier ratings from all decision makers

Step 5: Aggregating the final assessment perspective-wise

The previous step aggregates the assessments from more than one DM into a single assessment for all the measures. These measures each belong to four Balanced Scorecard perspectives i.e. Financial position, Customer feedback Processes and Learnings. In this step, the assessment is aggregated again to obtain a single assessment for each BSC perspective. For eg: measures

Investment and Profitability come under the Financial perspective. Hence the importance weights and supplier ratings for these measures are aggregated together to obtain a single inclusive weight and supplier rating for the Financial perspective. Table 6 gives the perspective-wise aggregated assessment

.

Perspective name	Perspective weights(W')			S1 assessment (R')			S2 assessment (R')		
	Min	Modal	Max	Min	Modal	Max	Min	Modal	Max
Financial Position	0.09	0.395	0.81	5	8.5	10	3	7	10
Processes	0.15	0.375	0.70	3	6	9	3	7.5	10
Customer feedback	0.15	0.490	0.90	3	7	10	3	5.5	9
Learnings	0.09	0.370	0.81	3	6	9	3	7.5	10

Table 6: Aggregated assessment perspective-wise.

Step 6: Obtaining the Weighted Normalized Assessment (WNA)

As different linguistic scales were used for representing the importance weights and the supplier ratings, the aggregated values are normalized so that all values lie in the range of 0 and 1.

The supplier ratings are multiplied with the respective importance weights for the perspectives to account for the difference in importance of the perspectives. Table 7 gives the weighted normalized assessment.

WNA						
Perspective	S1 assessment ($\bar{A}_{1j}$)			S2 assessment ($\bar{A}_{2j}$)		
	Min	Modal	Max	Min	Modal	Max
Financial Position	0.045	0.33575	0.81	0.027	0.2765	0.81
Processes	0.045	0.225	0.63	0.045	0.28125	0.7
Customer feedback	0.045	0.343	0.9	0.045	0.2695	0.81
Learnings	0.027	0.222	0.729	0.027	0.2775	0.81

Table 7: Weighted normalized supplier assessment

Step 7: Calculating the deviation of the WNA from the ideal solution

"As the fuzzy numbers are in the range 0-1, the Fuzzy Positive Ideal Solution (FPIS) is considered to be 1 and Fuzzy Negative Ideal Solution (FNIS) is considered to be 0. Deviation between two fuzzy numbers is calculated as the Euclidian distance

$$d_v(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}[(x_1 - y_1)^2 + (x_2 - y_2)^2 + (x_3 - y_3)^2]}$$

if $\tilde{x}$ and $\tilde{y}$ are two triangular fuzzy numbers. Table 8 gives the deviation of supplier 1 & 2's assessment from the FPIS and FNIS."

Perspective	S1 assessment deviation from FPIS D_1^+	S1 assessment deviation from FNIS D_1^-	S2 assessment deviation from FPIS D_2^+	S2 assessment deviation from FNIS D_2^-
Financial Position	0.680528	0.506903	0.708586	0.494396
Processes	0.741519	0.387105	0.711484	0.43632
Customer feedback	0.671733	0.556679	0.702793	0.493543
Learnings	0.736083	0.440248	0.701246	0.494582

Table 8: Deviation of assessment from the FPIS and FNIS

Step 8: Calculating the Closeness Coefficient and ranking the suppliers

The "Closeness Co-efficient (CC)" is found for each alternative using the formula shown in the flowchart and

the alternatives are ranked in the descending order of their CC values. A higher CC value shows that the supplier performance is inclined more towards the positive ideal solution.

Perspective	CC - S1	S1's rank	CC- S2	S2's rank
Financial Position	0.426891	1	0.410975	2
Processes	0.342988	2	0.380135	1
Customer feedback	0.45317	1	0.412546	2
Learnings	0.374255	2	0.411183	1

Table 9: Final CC values and corresponding ranks

Each supplier is ranked based on their performance area-wise. The ranking is based on the CC value. The supplier with higher Customer feedback for a particular perspective will get a higher rank. From the example, Supplier 1 ranks first in Financial and Customer perspectives and supplier 2 ranks first in Internal Processes and Learnings. The best supplier for the firm according to the firm's relative importance to each of these perspectives is chosen. For ex: If a firm places greater emphasis on financial performance and customer feedback, then supplier 1 is chosen as supplier 1 ranks better in these two areas.

Hence, a decision based on the performance of the alternative in each of the BSC perspectives can be made. This would be helpful in integrating the firm's strategy with the supplier's performance

V. CONCLUSION

The proposed model for strategic sourcing attempts at giving a functional area based evaluation of supplier performance. As the supplier has profound impact on the quality, delivery and cost of the final product, making the right choice is critical. The Balanced Scorecard is an effective tool to map the strategy and convert the strategy into performance measures which form the basis on which the performance is evaluated. Once the criteria formation has been completed, a quantitative framework for supplier selection based on fuzzy TOPSIS and linguistic variables allows us to easily translate human judgments into rankings, thus aiding in effective decision making. A balanced Scorecard based framework further helps us view the performance in all functional areas of a business separately so that a better and more informed decision can be made.

REFERENCES

Bellman, R. E., & Zadeh, L. A., Decision-making in a fuzzy environment. Management Science, 17(4), 141–164, 1970.

Boer, L.de., Labro, E., Morlacchi, P.,A review of methods supporting supplier selection. European Journal of Purchasing and Supply Management 7, 75–89, 2001.

Chen, C.T., Lin, C.T., Huang, S.F., A fuzzy approach for supplier evaluation and selection in supply chain management. International Journal of Production Economics, Vol. 102(6): 141-16, 2006.

Degraeve, Z., Labro, E., Roodhooft, F., Evaluation of Vendor Selection Models From a Total Cost of Ownership Perspective. European Journal of Operational Research, 125, 1, 34-58, 2000.

Dickson, G.W., An analysis of vendor selection systems and decisions. Journal of Purchasing and Supply Management, Vol. 2(1), pp 5-17, 1996.

Ganesan, S., Determinants of Long-Term Orientation in Buyer-Seller Relationships. Journal of Marketing Vol. 58, 1-19, 1994.

Haleem, A., Kumar,S., Parashar,N,. Analytical hierarchy process applied to vendor selection problem: Small scale, medium scale and large scale industries. Business Intelligence Journal 2(2), 355–362, 2009.

Jahanshahloo, G.R., Hosseinzadeh, L. F., and Izadikhah, M.,Extension of the TOPSIS method for decision-making problems with fuzzy data. Applied Mathematics and Computation 181, 1544–1551, 2006.

Kaplan, R.S., and Norton, D. P.,The Balanced Scorecard – Measures that Drive Performance. Harvard Business Review, Vol. 70, No. 1, pp. 71–79, 1992.

Kaplan, R.S., and Norton, D.P., Putting the balanced scorecard to work. Harvard Business Review 71/5 (September-October): 134-147, 1993.

Kaplan ,R.S., and Norton, D.P., Using the Balanced Scorecard as a Strategic Management System. Harvard Business Review 71 (1): 75 –85, 1996.

Kumar, M., Shankar, V.R., A fuzzy goal programming approach for vendor selection problem in a supply chain. Computer & Industrial Engineering 46 (1), 69–85, 2004.

Narasimhan, R., Talluri, S., Mendez, D., Supplier Evaluation and Rationalization via Data Envelopment Analysis: An Empirical Examination. Journal of Supply Chain Management, 37 (3), 28–37, 2001.

Nydick, R. L., Hill R. P., Using the Analytic Hierarchy Process to Structure the Supplier Selection procedure. International Journal of Purchasing and Materials Management; Spring; 28, 2; ABI/INFORM Global pg. 31, 1992.

Olson D. L., Comparison of weights in TOPSIS models. Mathematical and Computer Modeling, 40, (7) 21-727, 2004.

Opricovic S., Tzeng G.H., Compromise solution by MCDM methods:A comparative analysis of VIKOR and TOPSIS. European Journal of Operational Research 156, 445–455, 2004.

Ozdagoglu, A., Ozdagoglu, G.,. Comparison Of AHP and fuzzy AHP for the multi criteria decision making processes with linguistic evaluations. İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi Yıl: 6 Sayı:11Bahar /1 s. 65-85, 2007.

Shyura, HJ., Shih, HS., A hybrid MCDM model for strategic vendor selection. Mathematical and Computer Modelling, 44, 749-761, 2006.

Sohn, M. H., You, T., Lee, S. L., & Lee, H., Corporate strategies, environmental forces, and performance measures: A weighting decision support system using the k-nearest neighbor technique. Expert Systems with Applications, 25(3),279–292, 2003.

Talluri, S., & Narasimhan, R., A methodology for strategic sourcing. European Journal of Operational Research, vol. 154, no. 1, pp. 236-250, 2004.

Tam, M.C.Y., Tummala, V.M.R., An application of the AHP in vendor selection of a telecommunications system". OMEGA, Int. J.Manage. Sci. 29, 171–182, 2001.

Triantaphyllou, E., Lin, C.T., Development and evaluation of five multiattribute decision making methods. International Journal of Approximate Reasoning 14, 281–310, 1996.