Global Journal of researches in engineering
Industrial engineering
Volume 12 Issue 1 Version 1.0 February 2012
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 Print ISSN:0975-5861

Supplier Selection Using MCDM Method in TV Manufacturing Organization

By Ajit Pal Singh
Adama Science & Technology University

Abstract - The aim of this study was to provide an analytical tool to evaluate and select the best supplier(s)/vendor(s) in fuzzy environment for Television (TV) manufacturing organization. A hierarchy through which decision makers can bring about a comparison among the suppliers was worked out and software for the same was developed. The methodology for selection was based upon multiple criteria decision making/multiple attribute decision making (MCDM/MADM) method using technique for order preference by similarity to ideal solution (TOPSIS). MCDM approach and application of TOPSIS proved to be a powerful technique for rapid, performance evaluation, comparative assessment and selection of supplier(s). Biasness in decision making process was avoided using weights for DM's based on their proficiency in the problem under consideration. The suppliers were evaluated and selected on the basis of criteria/attributes (quality, delivery, price, and suggestion acceptance) and weights were assigned (0.5, 0.3, 0.1, and 0.1) to them. The ranking/selection order of ten suppliers (alternatives) was determined as C4, C5, C10, C7, C2, C6, C1, C8, C9, and C3. Although the study concentrates on TV manufacturing organization, however the methodology can be adopted by any organization if the criteria and alternatives are clearly defined. Results have provided valuable suggestions to suppliers on how to improve each criterion so that they could bridge the gap between actual and aspired performance values in the future. The decision-aiding software was implemented in C language to automate the supplier(s) selection process.

Keywords : supplier(s) selection, decision matrix, MCDM, MADM, TOPSIS, purchasing.

GJRE-G Classification: FOR Code: 091599

SUPPLIER SELECTION USING MCDM METHOD IN TV MANUFACTURING ORGANIZATION

Strictly as per the compliance and regulations of:

Supplier Selection Using MCDM Method in TV Manufacturing Organization

Ajit Pal Singh

Abstract - The aim of this study was to provide an analytical tool to evaluate and select the best supplier(s)/vendor(s) in fuzzy environment for Television (TV) manufacturing organization. A hierarchy through which decision makers can bring about a comparison among the suppliers was worked out and software for the same was developed. The methodology for selection was based upon multiple criteria decision making/multiple attribute decision making (MCDM/MADM) method using technique for order preference by similarity to ideal solution (TOPSIS). MCDM approach and application of TOPSIS proved to be a powerful technique for rapid, performance evaluation, comparative assessment and selection of supplier(s). Biasness in decision making process was avoided using weights for DM's based on their proficiency in the problem under consideration. The suppliers were evaluated and selected on the basis of criteria/attributes (quality, delivery, price, and suggestion acceptance) and weights were assigned (0.5, 0.3, 0.1, and 0.1) to them. The ranking/selection order of ten suppliers (alternatives) was determined as C4, C5, C10, C7, C2, C6, C1, C8, C9, and C3. Although the study concentrates on TV manufacturing organization, however the methodology can be adopted by any organization if the criteria and alternatives are clearly defined. Results have provided valuable suggestions to suppliers on how to improve each criterion so that they could bridge the gap between actual and aspired performance values in the future. The decision-aiding software was implemented in C language to automate the supplier(s) selection process.

Keywords : supplier(s) selection, decision matrix, MCDM, MADM, TOPSIS, purchasing.

I. Introduction

In today's highly competitive environment, it is impossible for an organization to successfully produce low-cost, high-quality products without help/involvement of suppliers. Supplier selection or its evaluation is a common problem for acquiring the necessary raw materials (semi-finished/finished materials) to support the outputs of organizations. Supplier evaluation and selection involve decisions that are critical to the profitability, growth and survival of manufacturing organizations in the increasingly competitive global scenario. Such decisions are often complex, because they require the identification consideration and analysis of many tangible factors.

The decision problem involves tradeoffs between multiple criteria that are often qualitative. In recent years, many methods have gained considerable acceptance for judging different proposals [1, 2, 3].

Author : Mechanical & Vehicle Engineering Department, School of Engineering & Information Technologies, Adama Science & Technology University, P.O. Box 5008, Adama, Ethiopia, Africa.
E-mail : singh_ajit_pal@hotmail.com, Telephone: +251-921512436

II. General Methods of Supplier Selection

Most commonly used methodologies for solving the supplier selection problem are as follows:

- **Total cost approach:** In the total cost approach, the quoted price of each vendor was taken as the starting point and then each constraint being considered as replaced by a cost factor and the business was awarded to the vendor with the lowest unit total cost [12, 17, 25].
- **Multiple attribute utility theory (MAUT):** MAUT is a vendor selection technique most useful in dealing with international vendor selection, as it is capable of handling multiple conflicting attributes inherent in international vendor selection [14, 19, 21].
- **Multi-objective programming:** It is an additional flexibility of multi-objective approach which allows a varying number of vendors into the solution and provides suggested volume allocation by vendor. However, the process of obtaining solution through this method is complex [7, 10, 20].
- **Total cost of ownership (TCO):** TCO is a methodology and philosophy. It looks beyond the price of purchase to include many other purchase-related costs. The TCO models are further classified by usage such as vendor selection and vendor evaluation [6, 9, 15].
- **Analytic hierarchy process (AHP):** It is considered to be a good approach and can be used in a multifactor decision-making environment, especially when subjective and/or qualitative considerations have to be incorporated. It also provides a structured approach or to determines the scores and weights for the different criteria to be used in decision making [5, 11, 13, 16].

Different mathematical, statistical and game theoretical models have been proposed to solve the vendor/supplier selection problem. De Boer et al. (2001), Weber et al. (1991) and many others (see Tahriri, 2008) have reviewed the methodology of supplier/vendor selection.

Weber et al. (1991) had provided a comprehensive review of the criteria that academicians and purchasing managers feel important in the vendor selection decision. Several factors affect a supplier's

Global Journal of Researches in Engineering (G) Volume XII Issue I Version I February 2012

performance, for example, Stamm & Golhar (1991), and Ellram (1990) had identified, 13 and 18 criteria for supplier selection respectively, however, price, quality, lead-time, technical service and delivery reliability have been considered as the five primary criteria used in the supplier selection problem.

On the other hand Dickson (1966) had identified 23 different criteria in vendor selection process and quality was given an extreme importance.

Present studies, presents a real-life problem from a developing–country. Since MCDM (Hwang & Yoon, 1981) provides an effective framework for supplier comparison based on the evaluation of multiple conflict criteria, therefore, MCDM method in supplier selection has been applied in this paper, which provides decision maker's with a method to systematically analyze the effects of policy decisions on the relevant criteria in supplier selection decisions.

The objective of the study was therefore, (i) to integrate multidimensional issues in an MCDM framework that may help decision makers to develop clear insights and make intelligent decisions, (ii) to assess supplier performance for suitability of approved suppliers.

The procedure covers all the approved suppliers who were supplying raw material and semi-finished/finished components to the manufacturing company except for foreign suppliers/contractors.

The responsibility for implementing the supplier selection procedure lied mainly with Head-Product Planning. Suppliers rating system was evolved in such a way that it was a continuous process. A rating was done on six months supplies by the supplier(s) by considering various aspects, such as quality, delivery, price, and suggestion acceptance.

III. Formulation of MCDM Supplier Selection Model

In most large organizations supplier selection process is done empirically. In this paper, we deal with the problem of supplier selection where buyers order quantities from different suppliers in a multiple sourcing network. The supplier selection, which inherently involves conflicting criteria, has not been dealt with as a multi attribute problem frequently.

In the present study, on supplier selection problem, quality, delivery (time), price, and suggestion acceptance as the four attributes/objectives functions were selected.

The MCDM problem was solved using the multiple attribute decision making (MADM)-technique for order preference by similarity to ideal solution (TOPSIS) technique.

MCDM refers to making decisions in the presence of multiple, usually conflicting, criteria. Problems for multiple criteria decision making are common occurrences in everyday life. The problems of MCDM are widely diverse and share the following common characteristics:

- Each problem has multiple objectives/attributes. A decision maker must generate relevant objectives/attributes for each problem setting.
- Multiple criteria usually conflict with each other.
- Each objective/attribute has a different unit of measurement.

Solutions to these problems are either to design the best alternative or to select the best one among the specified finite alternatives. The problems of MCDM can be broadly classified into two categories viz., Multiple attribute decision making (MADM), and Multiple objective decision making (MODM) [27, 28]. In actual practice this classification is well fitted in two facets of the problem solving viz., MADM is for selection (evaluation) and MODM for design.

The distinguishing feature of the MADM is that there are usually a limited number of predetermined alternatives. The alternatives have associated with them a level of the achievement of the attributes (which may not necessarily be quantifiable) based on which the final decision is to be made. The final selection of the alternative is made with the help of inter- and intra-attribute comparisons. The comparisons may involve explicit or implicit tradeoff.

IV. Formulation of MCDM Supplier Selection Model

Consider a manufacturing organization has 'm' suppliers for evaluation and selection. However, owing to operational and resource constraints, it is unable to consider all 'm' suppliers simultaneously.

Hence, the management is faced with a decision problem. As discussed earlier, MCDM philosophy is broadly classified into two categories: MADM and MODM.

There are three features of MADM method: should have a set of quantifiable objectives; should possess a set of well-defined constraints; and should have a process to obtain some trade off information between the stated and unstated objectives.

The methodology of TOPSIS is a MADM process, which is expressed in matrix form. TOPSIS method evaluates the decision matrix 'D' of a $m \times n$ matrix which contain 'm' number of alternatives associated with 'n' number of criteria (or attributes).

The element x_{ij} of the 'D' matrix indicates the value alternative $i(A_i)$ for the criteria. The structure of a 'D' matrix is shown in Fig. 1.

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \cdots \\ A_i \\ \cdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & \cdots & C_j & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{ij} & \cdots & x_n \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{in} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix} \end{array}$$

Fig.1 : Structure of 'D' matrix.

where: A_i = the i^{th} alternative considered, x_{ij} = the numerical outcome of the i^{th} alternative with respect to the j^{th} criterion

Different researchers have employed MCDM methodology and its various techniques for supplier's selection process [1, 2, 24]. The technique of TOPSIS (of MADM) hitherto, has not been employed for supplier selection as this mainly refers to a selection process where objectives/attributes are conflicts. However, in the present study TOPSIS has been employed for supplier selection process as quality, delivery, price, and suggestion acceptance criteria were also in a sort of conflict in nature. In the present studies suppliers have been ranked/selected according to the weights of the criteria given by the decision maker's of the organization.

a) The TOPSIS model

TOPSIS is a method for cardinal preference to attributes. Hwang and Yoon (1981) developed this technique based upon the concept that the chosen alternative should have the shortest Euclidean distance from the ideal solution and farthest from the negative-ideal solution.

Assuming that each attribute takes the monotonically increasing (or, decreasing) utility; then it is easy to locate the 'ideal' solution which is composed of all best attribute values attainable, and the 'negative-ideal' solution composed of all worst attribute values attainable. One approach is to take an alternative which has the (weighted) minimum Euclidean distance to the ideal solution in a geometrical sense [27]. Dasarathy (1976) used this similarity measure in clustering multidimensional data arrays. This method is simple and yields an indisputable preference order of solution.

b) Algorithm for TOPSIS model

The general structure of the MCDM model is that of a heuristically evolved procedure that can provide support to decision makers. The steps are described below.

Step 1: List the set of suppliers to be evaluated and selected by the organization. Identify all the intrinsic and extrinsic factors that may influence the organization while it is evaluating the suppliers. Generate a matrix 'D' having size $m \times n$. This is known as decision matrix.

Step 2: Obtain the information from the decision maker's or users on the relative importance of criteria. Assign weights to each of the criteria given by the decision maker's, is then accommodated to the decision matrix. It is usually given by a set of (preference) weights, which is normalized to sum 1. In case of n criteria, a set of weights is

$$w = (w_1, w_2, \ldots\ldots, w_j, \ldots\ldots, w_n) \qquad (1)$$

$$\sum_{j=1}^{n} w_j = 1 \qquad (2)$$

Step 3: Construct the normalized decision matrix: Normalization may be essential to facilitate the computational problems inherent to the presence of different units in decision matrix. The advantage of normalization is that all the criteria are measured in dimensionless units so that inter-attribute comparison is possible.

The normalization procedure does not lead to equal minimum and maximum values for all attributes, so straightforward comparison is therefore difficult. An element r_{ij} of the normalized decision matrix R can be calculated as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}}, \quad R = \begin{bmatrix} r_{11} & r_{12} & r_{ij} & r_{1n} \\ r_{21} & r_{22} & r_{ij} & r_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & r_{mj} & r_{mn} \end{bmatrix} \qquad (3)$$

where: $i = 1,2,\ldots\ldots,m; \ j = 1,2,\ldots\ldots,n$

So that all criteria's have the same unit length of vector.

Step 4: Construct the weighted normalized decision matrix: This matrix 'V' can be calculated by multiplying each column of the matrix R with its associated weight w_j.

Therefore, the weighted normalized decision matrix V is equal to RW:

$$V = \begin{bmatrix} v_{11} & v_{12} & v_{ij} & v_{1n} \\ v_{i1} & v_{i2} & v_{ij} & v_{in} \\ \cdots & \cdots & \cdots & \cdots \\ v_{m1} & v_{m2} & v_{mj} & v_{mn} \end{bmatrix}$$

$$V = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & w_j r_{ij} & w_n r_{1n} \\ w_1 r_{i1} & w_2 r_{i2} & w_j r_{ij} & w_n r_{in} \\ \cdots & \cdots & \cdots & \cdots \\ w_1 r_{m1} & w_2 r_{m2} & w_j r_{mj} & w_n r_{mn} \end{bmatrix} \qquad (4)$$

Global Journal of Researches in Engineering (G) Volume XII Issue I Version I February 2012

where:

$$W = \begin{bmatrix} w_1 & & & 0 \\ & w_2 & & \\ & & \cdots & \\ 0 & & & w_n \end{bmatrix}$$

Step 5: Determine ideal and negative-ideal solutions from step 4: Let the two artificial alternatives and be defined as:

Ideal solution,

$$A^+ = (\max_i v_{ij} \,|\, j \in J), (\min_i v_{ij} \,|\, j \in J') | i = 1,2,......,m$$
$$= \{v_1^+, v_2^+, ..., v_j^+, ..., v_n^+\} \quad (5)$$

Negative-ideal solution,

$$A^- = \{(\min_i v_{ij} \,|\, j \in J), (\max_i v_{ij} \,|\, j \in J') | i = 1,2,......,m\}$$
$$= \{v_1^-, v_2^-, ..., v_j^-, ..., v_n^-\} \quad (6)$$

where:

$$J = \{j = 1,2,....., n \,|\, j \text{ associated with benefit criteria}\}$$

and

$$J' = \{j = 1,2,....., n \,|\, j \text{ associated with cost criteria}\}$$

The ideal solution is a hypothetical solution for which all attribute values correspond to the maximum attribute values (most preferable alternative). The negative-ideal solution is a hypothetical solution for which all attribute values correspond to the minimum attribute values (least preferable alternative).

Step 6: Calculate the separation measure: Calculate S_{i^+} and S_{i^-} (where $i = 1$ to m) from ideal and negative-ideal solutions (step 5), respectively. Separation measure is nothing but the n-dimensional Euclidean distance. The separation of each alternative for ideal and negative-ideal solution can be measured by Euclidean distance:

$$S_{i^+} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^+\right)^2} \quad i = 1,2,......,m \quad (7)$$

$$S_{i^-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^-\right)^2} \quad i = 1,2,......,m \quad (8)$$

where: S_{i^+} and S_{i^-} are the separation measures of 'i^{th}' alternative from A^+ and A^-, respectively.

Step 7: Calculate the relative closeness to the ideal solution: Determine the relative closeness of A_i with respect to A^+ (ideal solution). This can be measured by the relation:

$$C_{i^+} = S_{i-} \div (S_{i+} + S_{i-}) \;, 0 \langle C_{i^+} \langle 1, \quad i = 1,2,.....,m \quad (9)$$

The S_{i^+} and S_{i^-} values are obtained from step 7. It is clear that $C_{i^+} = 1$ if $A_i = A^+$ and $C_{i^+} = 0$ if $A_i = A^-$. An alternative A_i is closer to A^+ as C_{i^+} approaches to 1.

Step 8: Rank the preference order: Rank the alternatives according to the descending order of C_{i^+}.

c) Criteria employed in evaluation and selection (rating) of suppliers

The suppliers were evaluated based on the following criteria:

(a) *Quality:* A six monthly statement of rejections was generated by computerized system for the rejections during the supplies of the last six months which gave the percentage of rejections for the received material. Head-Quality Assurance allocated marks in the quality column of suppliers rating format.

Quality rating (Quality verification) was done on the basis of inspection stages: Incoming inspection and Inprocess inspection stages.

- Incoming inspection: It is based on quantity delivered versus quantity accepted for a given consignment, it was calculated as follows:

$$q = (Q_1 + 0.8Q_2 + 0.5Q_3)100 \div Q$$

where:

q = quality rating for a particular month,

Q_1 = Quantity accepted,

Q_2 = Quantity accepted under deviation,

Q_3 = Quantity accepted after rework,

Q = Total quantity received.

$$C_1 = (q_1 + q_2 + q_3 + ... + q_N) \div N$$

then, $$QR = Sum(C) \div N$$

where: C = Consignment and N = Number of consignments received in a month.

- Inprocess inspection: In this category, quality rating was determined based on the feedback from assembly shop after the materials have been used up. Information on shop rejection on account of manufacturing defects was provided by the shop to electronic data processing (EDP) every month. To calculate the quality rating the same formula as given above (see Incoming inspection) was applied. where: q = Quality rating for a particular month, Q_1 = Quantity used without problems, Q_2 = Quantity used under deviation, Q_3 = Quantity used after rework in shop, Q = Total quantity used in the month, N = Number of the months. Rating for quality was limited to 0.5 weights given by decision maker's.

(b) *Delivery:* A quarterly statement on receipts was generated for each material supplied by the suppliers during the period and was compared with the

Global Journal of Researches in Engineering (G) Volume XII Issue I Version I February 2012

delivery schedule given to the suppliers at the start of the quarter. Based on this statement, Head-Planning and Purchase allocated marks in the delivery column of supplier rating format, which were intimated to EDP. Delivery rating was calculated based on scheduled delivery versus actual delivery. In case, purchase required to be postponed or preponed for delivery of consignment from the date specified in purchase order, a request approved by Head-Planning and Purchase was sent to EDP and the amended delivery schedule was taken into consideration for calculating delivery rating. Weights allocated for delivery rating were 0.3 and calculated as follows:

A=If delivery was on the scheduled date or within a week prior to the schedule-0.3

B=If delivery schedule was not met and supplies were delayed, the ratings were as per Table 1.

Table 1 : Delivery rating points.

	Day	Week				
Delays by	1	1	2	3	4	$\rangle$ 4
Points	0.25	0.2	0.15	0.1	0.05	0
Early delivery by	-	-	2	3	4	$\rangle$ 4
Points	-	-	0.25	0.2	0.15	0.1

(c) *Price:* Every six months a comparative statement of each supplier price with the rates of other suppliers was prepared or in case of a single source, comparison with organization norms were made by purchase and planning department and given to its Head who inturn allocated marks in price column in the supplier rating format and sent it to EDP.

Price rating (PR) was calculated based on the ratio of the quoted price over standard price. Until a standard price was worked out, the lowest price quoted was used as a substitute. The maximum price rating was 0.1 weights and calculated as follows:

$$PR = (S\tan dard\ \Pr ice)10 \div Quoted\ \Pr ice$$

EDP systems worked out the progress to accommodate all these inputs in order to implement the supplier rating system.

(d) *Suggestion acceptance:* To overcome the rejection and improve the quality, various suggestions were given to suppliers by quality assurance/planning and purchase department and a check was kept on implementation of those suggestions and marks were allocated to a particular supplier in the supplier rating format.

Suggestion acceptance was calculated on the basis of suggestions made during supplier's visits, their implementation in the future supplies or in infrastructure changes suggested were checked during future visits. Weights allocated for suggestion acceptance were 0.1.

(e) *Periodicity:* Suppliers rating system was evolved in such a way that it was a continuous on going exercise. It was possible at any point of time to get a rating for any suppliers, based on previous six months performance. The ratings were formally communicated to respective suppliers twice a year (in the month of April and October).

V. Illustrative Example of Supplier Selection in TV Manufacturing Organization

In this section, an empirical example of supplier selection decision was used to demonstrate that the MCDM (MADM-TOPSIS) is an appropriate model for supplier selection in a TV manufacturing organization.

Step 1: A supplier selection problem consists of five basic elements: alternatives (suppliers), criteria, outcomes, preferences and information (see Table 2).

Table 2 : Decision matrix for supplier selection.

S_j	C_i			
	C_1	C_2	C_3	C_4
	$w_1 = 0.5$	$w_2 = 0.3$	$w_3 = 0.1$	$w_4 = 0.1$
S_1	48	28	7	8
S_2	49	26	7	7
S_3	33	26	7	8
S_4	48	25	7	7
S_5	46	25	7	8
S_6	47	25	8	8
S_7	47	25	7	8
S_8	47	27	8	7
S_9	39	27	7	8
S_{10}	46	22	6	5

where: S_j :Suppliers/Alternatives, C_i: Criteria/ Attributes, C_1: Quality, C_2: Delivery, C_3: Price, C_4: Suggestion acceptance.

Note that S_j: the set of m suppliers/ alternatives we will choose from to make our decision, $j = 1,\ldots,m$; C_i : the set of criteria with which we need to make a good decision, i ; $=1,\ldots$, n , w_j : the weights a decision maker place on each criterion; f_{ij} : the performance scores of each choice, measured in terms of the criteria. Note that the five elements can evolve over time as situations change. Thus the dynamic change of the ''information'' represented by the evolution of the elements above will be treated in the decision process.

The multiple criteria decision issue focuses mainly on the identification of the evaluation criteria and on the determination of the preference structure (i.e., weights) [4, 26].

Global Journal of Researches in Engineering (G) Volume XII Issue I Version I February 2012

Ten suppliers have been evaluated and the main criteria for evaluation and selection that were used are quality, delivery, price and suggestion acceptance. The weights are assigned by decision maker's for each criterion was 0.5, 0.3, 0.1, and 0.1 respectively. (Note: that all criteria's except C_3 are the benefit criteria).

The decision matrix 'D' (see Table 2) was generated for further problem solving. Other criteria which could be added if necessary, together with a suggestion that a computer may be used to simplify calculations. Performance score (f_{ij}) regarding the quality, delivery, price and suggestion acceptance for different suppliers were required to solve the problem. For which, decision matrix was obtained which is shown in Table 2.

Step 2: The weights a decision maker placed on each criterion was as follows. As per Eqs. (1) and (2):

$$w = (0.5, 0.3, 0.1, \text{ and } 0.1) \text{ and } \sum_{j=1}^{4} w_j = 1$$

Step 3: Calculation of the normalized decision matrix. The decision matrix values were provided by the organization and on this basis further calculations for supplier selection were made. As per Table 2 and Eq. (3):

$$R = \begin{bmatrix} 0.3354 & 0.3518 & 0.3108 & 0.3392 \\ 0.3424 & 0.3267 & 0.3108 & 0.2968 \\ 0.2306 & 0.3267 & 0.3108 & 0.3392 \\ 0.3354 & 0.3141 & 0.3108 & 0.2968 \\ 0.3214 & 0.3141 & 0.3108 & 0.3392 \\ 0.3284 & 0.3141 & 0.3552 & 0.3392 \\ 0.3284 & 0.3141 & 0.3108 & 0.3392 \\ 0.3284 & 0.3392 & 0.3552 & 0.2968 \\ 0.2725 & 0.2764 & 0.3108 & 0.3392 \\ 0.3214 & 0.2764 & 0.2664 & 0.2120 \end{bmatrix}$$

$$R = \begin{bmatrix} 0.1677 & 0.1055 & 0.03108 & 0.03392 \\ 0.1712 & 0.0980 & 0.03108 & 0.02968 \\ 0.1153 & 0.0980 & 0.03108 & 0.03392 \\ 0.1677 & 0.0942 & 0.03108 & 0.02968 \\ 0.1607 & 0.0942 & 0.03108 & 0.03392 \\ 0.1642 & 0.0942 & 0.03552 & 0.03392 \\ 0.1642 & 0.0942 & 0.03108 & 0.03392 \\ 0.1642 & 0.10176 & 0.03552 & 0.02968 \\ 0.1362 & 0.08292 & 0.03108 & 0.03392 \\ 0.1607 & 0.08292 & 0.02664 & 0.02120 \end{bmatrix}$$

Step 4: Calculation of the weighted normalized decision matrix 'V': As per eq. (4),

$$V = \begin{bmatrix} 0.1677 & 0.1055 & 0.0310 & 0.0339 \\ 0.1712 & 0.0980 & 0.0310 & 0.0296 \\ 0.1153 & 0.0980 & 0.0310 & 0.0339 \\ 0.1677 & 0.0942 & 0.0310 & 0.0296 \\ 0.1607 & 0.0942 & 0.0310 & 0.0339 \\ 0.1642 & 0.0942 & 0.0355 & 0.0339 \\ 0.1642 & 0.0942 & 0.0310 & 0.0339 \\ 0.1642 & 0.1017 & 0.0355 & 0.0296 \\ 0.1362 & 0.0829 & 0.0310 & 0.0339 \\ 0.1607 & 0.0829 & 0.0266 & 0.0212 \end{bmatrix}$$

Step 5: Determination of ideal and negative-ideal solutions from step 4, as per Eqs. (5) and (6):

$$A^{+} = 0.1712, 0.0829, 0.0266, 0.0339 \text{ and}$$
$$A^{-} = 0.1153, 0.1055, 0.0355, 0.0212$$

Step 6: Calculation of separation measure S_i^{+} and S_i^{-} as per Eqs. (7) and (8):

$$S_{1^+} = \sqrt{\begin{matrix}(0.1677-0.1712)^2 + (0.1055-0.0829)^2 + \\ (0.0310-0.0266)^2 + (0.0339-0.0339)^2\end{matrix}}$$

$$S_{1^+} = 0.0232$$

$$S_{2^+} = \sqrt{\begin{matrix}(0.1712-0.1712)^2 + (0.0980-0.0829)^2 + \\ (0.0310-0.0266)^2 + (0.0296-0.0339)^2\end{matrix}}$$

$$S_{2^+} = 0.0163$$

$$S_{3^+} = \sqrt{\begin{matrix}(0.1153-0.1712)^2 + (0.0980-0.0829)^2 + \\ (0.0310-0.0266)^2 + (0.0339-0.0339)^2\end{matrix}}$$

$$S_{3^+} = 0.0580$$

$$S_{4^+} = \sqrt{\begin{matrix}(0.1677-0.1712)^2 + (0.0942-0.0829)^2 + \\ (0.0310-0.0266)^2 + (0.0296-0.0339)^2\end{matrix}}$$

$$S_{4^+} = 0.0133$$

$$S_{5^+} = \sqrt{\begin{matrix}(0.1607-0.1712)^2 + (0.0942-0.0829)^2 + \\ (0.0310-0.0266)^2 + (0.0339-0.0339)^2\end{matrix}}$$

$$S_{5^+} = 0.0126$$

$$S_{6^+} = \sqrt{\begin{matrix}(0.1642-0.1712)^2 + (0.0942-0.0829)^2 + \\ (0.0355-0.0266)^2 + (0.0339-0.0339)^2\end{matrix}}$$

$$S_{6^+} = 0.0159$$

$$S_{7^+} = \sqrt{(0.1642-0.1712)^2 + (0.0942-0.0829)^2 + (0.0310-0.0266)^2 + (0.0339-0.0339)^2}$$
$$S_{7^+} = 0.0140$$
$$S_{8^+} = \sqrt{(0.1642-0.1712)^2 + (0.1017-0.0829)^2 + (0.0355-0.0266)^2 + (0.0296-0.0339)^2}$$
$$S_{8^+} = 0.0223$$
$$S_{9^+} = \sqrt{(0.1362-0.1712)^2 + (0.0829-0.0829)^2 + (0.0310-0.0266)^2 + (0.0339-0.0339)^2}$$
$$S_{9^+} = 0.0352$$
$$S_{10}^+ = \sqrt{(0.1607-0.1712)^2 + (0.0829-0.0829)^2 + (0.0310-0.0266)^2 + (0.0212-0.0339)^2}$$
$$S_{10^+} = 0.0138$$
$$S_{1^-} = \sqrt{(0.1677-0.1153)^2 + (0.1055-0.1055)^2 + (0.0310-0.0355)^2 + (0.0339-0.0212)^2}$$
$$S_{1^-} = 0.0541$$
$$S_{2^-} = \sqrt{(0.1712-0.1153)^2 + (0.0980-0.1055)^2 + (0.0310-0.0355)^2 + (0.0296-0.0212)^2}$$
$$S_{2^-} = 0.0572$$
$$S_{3^-} = \sqrt{(0.1153-0.1153)^2 + (0.0980-0.1055)^2 + (0.0310-0.0355)^2 + (0.0339-0.0212)^2}$$
$$S_{3^-} = 0.0154$$
$$S_{4^-} = \sqrt{(0.1677-0.1153)^2 + (0.0942-0.1055)^2 + (0.0310-0.0355)^2 + (0.0296-0.0212)^2}$$
$$S_{4^-} = 0.0544$$
$$S_{5^-} = \sqrt{(0.1607-0.1153)^2 + (0.0942-0.1055)^2 + (0.0310-0.0355)^2 + (0.0339-0.0212)^2}$$
$$S_{5^-} = 0.0486$$
$$S_{6^-} = \sqrt{(0.1642-0.1153)^2 + (0.0942-0.1055)^2 + (0.0355-0.0355)^2 + (0.0339-0.0212)^2}$$
$$S_{6^-} = 0.0517$$
$$S_{7^-} = \sqrt{(0.1642-0.1153)^2 + (0.0942-0.1055)^2 + (0.0310-0.0355)^2 + (0.0339-0.0212)^2}$$
$$S_{7^-} = 0.0519$$
$$S_{8^-} = \sqrt{(0.1642-0.1153)^2 + (0.1017-0.1055)^2 + (0.0355-0.0355)^2 + (0.0296-0.0212)^2}$$
$$S_{8^-} = 0.0497$$
$$S_{9^-} = \sqrt{(0.1362-0.1153)^2 + (0.0829-0.1055)^2 + (0.0310-0.0355)^2 + (0.0339-0.0212)^2}$$
$$S_{9^-} = 0.0336$$
$$S_{10^-} = \sqrt{(0.1607-0.1153)^2 + (0.0829-0.1055)^2 + (0.0266-0.0355)^2 + (0.0212+0.0212)^2}$$
$$S_{10^-} = 0.0514$$

Step 7: Calculation of relative closeness to ideal solution as per Eq. (9). The S_{i^+} and S_{i^-} values were obtained from step 6.

$$C_{1^+} = \frac{0.0541}{0.0232+0.0541} = 0.6998; \quad C_{2^+} = \frac{0.0572}{0.0163+0.0572} = 0.7782$$
$$C_{3^+} = \frac{0.0154}{0.0580+0.0154} = 0.2098; \quad C_{4^+} = \frac{0.0544}{0.0133+0.0544} = 0.8035$$
$$C_{5^+} = \frac{0.0486}{0.0126+0.0486} = 0.7941; \quad C_{6^+} = \frac{0.0517}{0.0159+0.0517} = 0.7647$$
$$C_{7^+} = \frac{0.0519}{0.0140+0.0519} = 0.7875; \quad C_{8^+} = \frac{0.0497}{0.0223+0.0497} = 0.6902$$
$$C_{9^+} = \frac{0.0336}{0.0352+0.0336} = 0.4883; \quad C_{10^+} = \frac{0.0514}{0.0138+0.0514} = 0.7883$$

Step 8: Suppliers (alternatives) were evaluated/ selected (ranked) according to the descending order of C_{i^+}, the preference order is C_4, C_5, C_{10}, C_7, C_2, C_6, C_1, C_8, C_9, C_3 and decision maker's/management can take decision accordingly.

VI. Results

An interactive computer code was generated in C language that runs under the Microsoft Disc Operating System using a Turbo compiler. This program enables the user to rank the various suppliers (alternatives) depending upon their 'relative closeness to ideal solutions' values. The computer code generates first a decision matrix (D) after seeking data for various alternatives from user. Again, it obtains information (weights) for the relative importance of each criterion. Then it calculates the values of the ideal, A^+ and negative ideal solutions A^-, respectively for finding out the separation measures as well as the 'relative closeness to ideal solutions', C_{i^+} where i =1 to 10. The final ranking is thus obtained (by computational and software) and is shown in Table 3.

Table 3 : Final ranking (selection) of the supplier(s).

Rank	Supplier (S_j)	C_{i^+} value	Rank	Supplier (S_j)	C_{i^+} value
1	S_4	0.8035	6	S_6	0.7647
2	S_5	0.7941	7	S_1	0.6998
3	S_{10}	0.7863	8	S_8	0.6902
4	S_7	0.7875	9	S_9	0.4883
5	S_2	0.7782	10	S_3	0.2098

VII. Conclusion

The MCDM (MADM-TOPSIS) model has been described in this paper and applied to a real-life organization. It has helped the organization as follows:

- A systematic and structured approach that focuses on relevant evaluation criteria has made the organization decision makers quantify their subjective perceptions.
- The modeling approach has helped the organization to collate and clarify systematically various types of information.
- The procedure has been used to replace the biased judgments of decision makers.
- The selection of suppliers and the determination of appropriate order quantities to be placed with them are important decisions for many organizations. Such decisions may greatly affect a firm's ability to compete in the market as they frequently account for large portion of a product's production cost and may involve long-term contracts.
- Supplier selection decisions also affect the ability of the organization to effectively implement production strategies, e.g., although price is important, however, delivery reliability and product quality take on increased importance in just-in-time manufacturing systems.
- The approach allows the purchasing manager to generate non-inferior purchasing options and systematically analyze the inherent tradeoffs among the relevant criteria. This is particularly an important feature in that it allows organizations to analyze potential impacts of strategic options.
- The number and specific forms of the objectives were determined in consultation with the purchasing manager. The inclusion of more objectives though would pose no theoretical problems; however, it would increase computational time (i.e., an increased number of non-inferior solutions to be generated) and increased complexity of the output (i.e., more solutions and more tradeoffs to be analyzed) might create implementation problems. The practical implications of these potential problems are another area for future research.
- Organization can provided valuable suggestions to suppliers on how to improve each criterion so that they could bridge the gap between actual and aspired performance values in the future.
- Study carried out in the TV manufacturing organization prove the practical feasibility of the model TOPSIS for the suppliers ranking/selection problem.
- Finally, the model TOPSIS has been used, as a conscious exercise, within the manufacturing organization to make a choice between suppliers on the basis of very relevant criteria, so that capital can be committed to feasible, as well as profitable ventures.

Acknowledgements

I am grateful to Prof. Arun Kanda, Department of Mechanical Engineering, Indian Institute of Technology Delhi, New Delhi, India for his kind help under whose supervision this work was carried out. The author also wishes to express his gratitude to Mr. S.K. Das, General Manager and Mr. K.P. Preman, Manager (Quality Assurance) of ABC Limited (Television Manufacturing Plant), India for providing relevant data.

References Références Referencias

1. Sreekumar and S.S. Mahapatra, S.S. (April 2009). A fuzzy multi-criteria decision making approach for supplier selection in supply chain management. African Journal of Business Management, 3(4), 168-177.
2. Tahriri, F., Osman, M.R., Ali, A. & Yusuff, R.M. (2008). A review of supplier selection methods in manufacturing industries. Suranaree Journal Science Technology, 15(3), 201-208.
3. Vahdani, B., Zandieh, M. & Alem-Tabriz, A. (2008). Supplier selection by balancing and ranking method. Journal of Applied Sciences, 8(19), 3467-3472.
4. Tsiporkova, E. & Boeva, V. (2006). Multi-step ranking of alternatives in a multi-criteria and multi-expert decision making environment. Information Sciences, 176(18), 2673-2697.
5. Kahraman, C., Cebeci, U. & Ulukan, Z. (2003). Multi-criteria supplier selection using fuzzy AHP. Logistics Information Management, 16(6), 382-394.
6. Bhutta, K.S. & Huq, F. (2002). Supplier selection: A comparison of the total cost of ownership and analytical hierarchy process approaches. Supply Chain Management–An International Journal, 7(3), 126-135.

7. Kumar, M., Vrat, P. & Shankar, R. (2002). A multi-objective interval programming approach for supplier selection problem in a supply chain. Proceedings of the International Conference on E-Manufacturing: An Emerging Need for 21st Century World Class Enterprises, Bhopal, India: IEI, 17-19.
8. De Boer, L., Labro, E. & Morlacchi, P. (2001). A review of methods supporting supplier selection. European Journal of Purchasing and Supply Management, 7, 75-89.
9. Degraeve, Z. & Roodhooft, F. (1999). Effectively selecting suppliers using total cost of ownership. Journal of Supply Chain Management, 35(1), 5-10.
10. Karpak, K. & Kasuganti, R.R. (1999), "An application of visual interactive goal programming: A case in supplier selection decisions. Journal of Multi-Criterion Decision Making, 8, 93-105.
11. Ghodsypour, S.H. & O'Brien, C. (1998). A decision support system for supplier selection using an integrated analytical hierarchy process and linear programming. International Journal Production Economics, 56-57.
12. Harding, M.L. (1998). How to calculate total purchase cost. Hospital Material Management Quarterly, 19(4), 9-13.
13. Ghodsypour, S.H. & O'Brien, C. (1997). An integrated method using the analytical hierarchy process with goal programming for multiple sourcing with discounted prices. Proceedings of the 14th International Conference on Production Research, Osaka, Japan.
14. Min, H. (1994). International supplier selection: A multi-attribute utility approach. International Journal of Physical Distribution and Logistics Management, 24(5), 24-33.
15. Ellram, L.M. (1993). Total cost of ownership: elements and implementation. International Journal of Purchasing and Materials Management, 29(2), 3-11.
16. Mohantry, R.P. & Deshmukh, S.G. (1993). Use of analytic hierarchic process for evaluating sources of supply. International Journal of Physical Distribution and Logistics Management, 23(3), 22-28.
17. Porter, A.M. (1993). Tying down total cost. Purchasing, 21, 38-43.
18. Stamm, C.L. & Golhar, D.Y. (1993). JIT purchasing: Attribute classification and literature review. Production Planning and Control, 4, 273-282.
19. Von, N. & Webber, M. (1993). The effects of attribute ranges on weights in multi-attribute utility measurements. Management Science, 39(8), 937-943.
20. Weber, C.A. & Current, J.R. (1993). Theory and methodology: A multi-objective approach to vendor selection. European Journal Operational Research, 68, 173-184.
21. Bard, J.F. (1992). A comparison of AHP process with multi-attribute utility theory: A case study. IIE Transaction, 24(5), 111-121.
22. Weber, C.A., Current, J.R. & Benton, W.C. (1991). Vendor selection criteria and methods. European Journal of Operational Research, 50, 1-17.
23. Ellram, L.M. (1990). The supplier selection decision in strategic partnerships. Journal of Purchasing and Materials Management, 26, 8-14.
24. Weber, C.A. (1990). A decision support system using multi-criteria techniques for vendor selection. Ph.D. Dissertation, College of Business, The Ohio State University, Columbus, OH.
25. Monckza, R.M. & Trecha, S.J. (1988). Cost-based supplier performance evaluation. Journal of Purchasing and Materials Management, 24(1), 2-7.
26. Hwang, C.L. & Yoon, K. (1981). Multiple attribute decision making, methods and applications, A state-of-the-art survey, Lecture notes in economics and mathematical systems (Managing Editors: Beckmann, M. and Kunzi, H.P.) Springer-Verlag, Berlin/Heidelberg/New York.
27. Hwang, C.L. & Masud, A.S.M. (1979). Multiple objective decision making-methods and applications: A state-of-art survey, (in Collaboration with Paidy, S.R. and Yoon, K.), Springer-Verlag, Berlin/Heidelberg/New York.
28. Cohon, J.L. (1978). Multiobjective programming and planning, Academic Press, New York.
29. Dasarathy, B.V. (1976). SMART: Similarity measure anchored ranking technique for the analysis of multidimensional data analysis. IEEE Transition on Systems, Man, and Cybernetics, 6(10), 708-711.
30. Dickson, G.W. (1966). An analysis of vendor selection systems and decisions. Journal of Purchasing, 2, 5-17.