Vendor Evaluation Using Multi Criteria Decision Making Technique

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ABSTRACT
A supply chain is a network of departments, which is involved in the manufacture of a product from the procurement of raw materials to the distribution of the final products to the customer. The term supply chain is already invoked effervescence among the managerial community. The purchasing function has gained importance in the supply chain management due to factors such as globalization, increased value addition in supply and accelerated technology change. A key and perhaps the most important process of the purchasing function is the efficient selection of suppliers, because it brings significant savings for the organization. In general, the supplier selection criteria most commonly used by the industries are quality, delivery and price. Also, depending on the corporate environment of the industries, the importance of the performance measure can vary. In this work a versatile technique namely multi criteria decision making (MCDM) technique which involves the analytical network process (ANP) and technique for order performance by similarity to idea solution (TOPSIS) method has been used to select the best vendor.

Analytical Network Process and TOPSIS method are powerful decision making processes which help people to set priorities on parameters that are to be considered by reducing complex decision to a series of one-to-one comparisons, thereby synthesizing the result

When any vendor for a particular item make changes for the parameters like price, quality etc to improve his performance or has improved abilities in managing supply chain by providing better delivery to his customer, the whole hierarchy process for arriving the ranking of vendors is to be performed again for finding out the best vendor. Now it is felt that a standard automated procedure which could perform the above processing task is essential. So, standard software was developed in a suitable platform such as VB, .NET and MS access that could meet the current requirement. This package can be executed several numbers of times with changing input parameters values thus serving the purpose.

1. INTRODUCTION
Traditionally organization have been divided into operative functions such as marketing, planning, purchasing, finance etc. supply chain is a strategy that integrates these functions creating a general plan for organization which satisfies the service policy, maintaining the lowest possible cost level due to the incredible competitive environment that they are exposed to. A supply chain is a network of departments, which is involved in the manufacturing of a product from the procurement of raw materials to the distribution of the final product to the customer.

The purchasing function has gained greater importance in the supply chain management due to factors such as globalization, increased value addition in supply, and accelerated technological change. Purchasing involves buying the raw materials, supplies and components for the organization. The activities associated with it include selecting and qualifying suppliers, rating supplier performance, negotiating contracts, comparing price, quality and service, sourcing goods and service, time purchases, selling terms of sale, evaluating the value received, predicting price, service and sometimes demand changes, specifying the form in which goods are to be received etc. A key and perhaps the most important process of the purchasing function is the efficient selection of suppliers, because it brings significant saving for the organization. The objective of the supplier selection process is to reduce risk and maximize the total value for the buyer, and it involves considering a series of strategic variables.

Some authors have identified several criteria for supplier selection, such as the net price, quality, delivery, historical supplier performance, capacity, communication systems; service an geographic location among others. These criteria are a key issue in the supplier assessment process since it measures the performance of the suppliers.

2. LITERATURE SURVEY
Satu Peltola et al(2002) emphasized the use of Analytical Hierarchy Process(AHP) and integrated Support System(GSS) method for improving the business performance in every sector. In this paper, the performance of buyer-supplier relationship will be enhanced by using a benchmarking method in aiding the identification and implementation of development actions required for reaching the world-class level. The benchmarking process will be led by two decision support systems namely AHP and GSS, to ensure valuable outcomes of the benchmarking with fewer resources

Jiann Liang Yang et al(2008) proposed an integrated fuzzy multiple criteria decision making(MCDM) techniques for solving vendor selection problem, Jiann utilize triangular fuzzy number to express the subjective preference of evaluators with respect to the considered criteria

Banar et al(2006) used analytical network process(ANP), one of the multi-criteria decision making (MCDM) tools to choose one of the four alternative landfill sites for the city of Eskisehir, Turkey. For this purpose super decision software has been used and benefit opportunity cost and risk(BOCR) analysis has been done to apply ANP.

Cevriye Gencer and Didem Gurpinar(2007) used Analytical Network Process(ANP) for selecting suppliers in an electronic industry . suppliers selection, which is the first step of the activities in the product realization process starting from the purchasing of raw material till the end of delivering the products, is evaluated as a critical factor for the companies desiring to be successful in today’s competitive condition. With the scope of this paper, suppliers selection was considered as a multi criteria decision problem.

Hsu Shih et al(2006) used an extension of TOPSIS(Technique for Order Performance by Similarity to Ideal Solution), a multi-attribute decision making(MADM) technique, to a group decision environment. TOPSIS is a practical and useful technique for ranking and selection of a number of externally determined alternatives through distant measures.

Ching Torng Lin et al(2006) developed a fuzzy agility index(FAI) based on agility providers using fuzzy logic. To achieve a competitive edge in the rapidly changing business environment, companies must align with suppliers and customers to streamline operation, as well as working together to achieve a level of agility beyond individual companies. To illustrate the efficacy of the method, the study also evaluates the supply chain agility of a Taiwanese company.

Desheng Wu et al(2008) considered three types of risk evaluation models within supply chain such as chance constrained programming(CCP), data envelopment analysis(DEA), and multi-objective programming(MOP) models. Various risks are modeled in the form of probability and simulation of specific probability distribution in risk-embedded attributed is conducted in these three types of risk evaluation models

Filip Roodhooft and Jozef Konings(1996) proposed an activity based costing approach for vendor selection and evaluation. This system allows us to compute total costs caused by a supplier in a firm’s production process, thereby increasing the objectivity in the selection process.

3. MEASURING SUPPLIER PERFORMANCE

Need for measuring supplier performance

Supplier performance has to be measured occasionally for the following reasons

1. To increase performance visibility
2. To uncover and remove hidden waste and cost drivers in the supply chain
3. To leverage the supply base
4. To align customer and supplier business practices
5. To mitigate risk
6. To improve supplier performance

THE DECISION MAKING TEAM

The decision making team comprises of the following members

1. Purchasing director
2. Purchasing manager
3. Quality manager
4. Product manager
5. Production manager

4. PROPOSED METHODOLOGY

4.1 Steps involved in the Proposed Model

The selection process has been modified to a five-step hybrid procedure, as follows

Step 1: Identification of necessary criteria for vendor selection
Step 2: Recognition of the independence between criteria
Step 3: Calculating the weights of criteria
Step 4: Evaluation of vendors
Step 5: Negotiation for the purchase

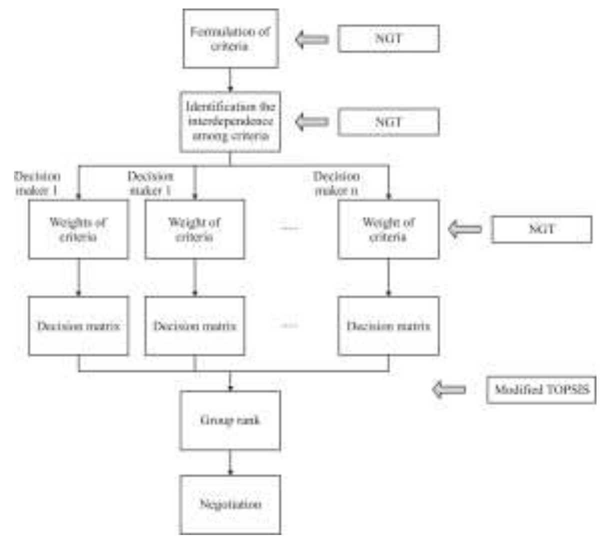

Figure 1: The proposed framework for vendor selection

4.2 Evaluation Criteria with Interdependence

In the vendor evaluation process, an objective, unbiased decision is very hard to reach given the numerous criteria that need to be carefully considered and examined. One formal group management technique for determining a set of evaluation criteria is NGT. This well-known process forces everyone to participate and no dominant person is allowed to come out and control the proceedings. In NGT, all ideas have equal stature and will be judged impartially by the group. In our problem, seven potential evaluation criteria are determined as follows

1. On-time delivery (Cl).
2. Product quality (C2).
3. Price/cost (C3).
4. Facility and technology (C4).
5. Responsiveness to customer needs (C5).
6. Professionalism of salesperson (C6).
7. Quality of relationship with vendor (C7).

To simplify the process and avoid any misunderstandings, the interaction between any two of these criteria is not considered in the first instance. These criteria may not include all of the decision factors in vendor selection. However, they are indeed meaningful measures and have been emphasized in many leading articles

Next, in order to reflect the interdependence property between the criteria, we need to identify the exact relationship in a network structure of ANP. Another NGT process is taken to construct the relationship based on the following two recognitions:

1. Price/cost may be influenced by the quality of products and the relationship with vendors.
2. Product quality may be influenced by facility and technology.

Figure 1.2 represents the relationship of interdependency. A single arrow implies a one-way relationship. For example, the arrow that leaves from C2 and feeds into C3 implies that the relationship of criterion C2 has an influence on criterion C3.

4.3 Determination of Weights to Criteria

To determine the relationship of the degree of interdependence, the ANP technique, which is an extension of AHP, is used to address the relative importance of the criteria. ANP is developed to generate priorities for decisions without making assumptions about a unidirectional hierarchy relationship between decision levels. To take the place of a linear top-to-bottom form of strict hierarchy, the ANP model provides a looser network structure and possibly represents any decision problem. The relative importance or strength of the impacts qn a given element is measured on a ratio scale, which is similar to AHP.

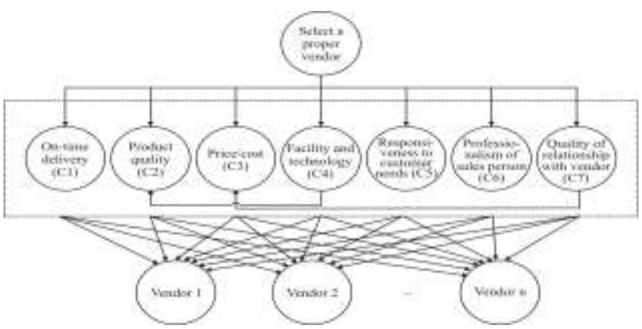

Figure 2: The interdependent relationship between the selected criteria

ACTIVITY: 1

Without assuming the interdependence between criteria, the decision makers or experts are asked to evaluate all proposed criteria pair-wise. They responded to questions such as "Which criteria should be emphasized more in a vendor, and how much more?" The responses were presented numerically and scaled on the basis of Saaty's 1- 9 scale, where 1 represents indifference between the two criteria and 9 represents extreme preference for one criterion over the compared criterion. Each pair of criteria is judged only once. A reciprocal value will be assigned automatically for the reverse comparison. Once the pair-wise comparisons are completed, the local priority vector w_x is computed as the unique solution of

$$Aw_1 = \lambda_{max} w_1.$$

Where $\lambda_{\mathbf{max}}$ is the largest eigen value of pair-wise comparison matrix A. All obtained vectors are further normalized to represent the local priority vector w_1.

ACTIVITY: 2

Next, the effects of the interdependence between the criteria are resolved. The group members will examine the impact of all criteria on each other by pair-wise comparisons too. To help smooth the comparison process, a couple of questions such as "Which criterion will influence criterion C3 more: C2 or C7? And how much more?" are answered. Various pair-wise comparison matrices are constructed for each criterion. These pair-wise comparison matrices are needed for identifying the relative impacts of criteria interdependent relationships. The normalized principal eigen vectors for these matrices are calculated and shown as column components in interdependence weight matrix B, where zeros are assigned to the eigenvector weights of the criteria with no interdependent relationship.

ACTIVITY: 3

Now the interdependence priorities .of the criteria can be obtained by synthesizing the results from the previous two steps as follows:

$$w_c = Bw_2^T \qquad \text{…. (1)}$$

Thus, the weights of the evaluation criteria can be determined

4.4 The Ranking and Selection Process

As large number of potential available vendors in the current marketing environment, a full ANP decision process becomes impractical in some cases. To avoid an unreasonably large number of pair-wise comparisons, we choose TOPSIS as the ranking technique because of its concept's ease of use. Also, ANP is adopted simply for the acquisition of the weights of criteria. First, a general TOPSIS process with six activities is listed below.

ACTIVITY: 1

Establish a decision matrix for the ranking.. The structure of the matrix can be expressed as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} F_1 & F_2 & \cdots & F_j & \cdots & F_n \end{array} \\ \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1j} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2j} & \cdots & f_{2n} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{i1} & f_{i2} & \cdots & f_{ij} & \cdots & f_{in} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mj} & \cdots & f_{mn} \end{bmatrix} \end{array}$$

where A_i denotes the alternatives i,j = 1,……m; F_j represents *j*th attribute or criterion, j=1,….., n related to ith alternative; and f_{ij} is a crisp value indicating the performance rating of each alternative A_i with respect to each criterion F_j.

ACTIVITY: 2

Calculate the normalized decision matrix R *(=[r_{ij}])*. The normalized value r_{ij} is calculated as shown in Eq. (2).

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{i=1}^{n} f_{ij}^2}} \qquad \text{…. (2)}$$

where j = 1,….., n; i =1,……., m.

ACTIVITY: 3

Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized value v_{ij} is calculated as shown in Eq. (3).

$$v_{ij} = w_j r_{ij}, \; j = 1,\ldots, n; \; i = 1,\ldots, m. \qquad \ldots (3)$$

where W_j represents the weight of the *j*th attribute or criterion.

ACTIVITY: 4

Determine the PIS and NIS, respectively:

$$v^+ = \{v_1^+ \ldots\ldots\ldots \ldots v_n^+\}$$
$$= \{(\max v_{ij} \mid j \in J), (\min v_{ij} \mid j \in J')\}$$
$$v^- = \{v_1^- \ldots\ldots\ldots \ldots v_n^-\}$$
$$= \{(\min v_{ij} \mid j \in J), (\max v_{ij} \mid j \in J')\}$$

where J is associated with the benefit criteria, and *j* is associated with the cost criteria.

ACTIVITY: 5

Calculate the separation measures, using the m-dimensional Euclidean distance. The separation measure D_i^+ of each alternative from the PIS is given in Eq. (4).

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}, \; i = 1\ldots\ldots m. \qquad \ldots (4)$$

Similarly, the separation measure D_i^- of each alternative from the NIS is as shown in Eq. (5).

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \; i = 1\ldots\ldots m. \qquad \ldots (5)$$

ACTIVITY: 6

Calculate the relative closeness to the idea solution and rank the alternatives in descending order. The relative closeness of the alternative A_i with respect to PIS V^+ can be expressed as:

$$\overline{C}_i = \frac{D_i^-}{D_i^+ + D_i^-}, \quad i = 1, \ldots\ldots, m \qquad \ldots (6)$$

Where the index value of $\overline{C}_i$ lies between 0 and 1. the larger the index value, the better the performance of the alternatives.

R+ = { r1+ …..r n+}

…(7)

$$D+ = \sqrt{\sum_{j=1}^{n} (r_{ij} - rj+)^2 wj}, \; i = 1\ldots\ldots m. \qquad \ldots (8)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (r_{ij} - r_j^-)^2 wj}, \; i = 1\ldots\ldots m.$$

$$\overline{C}_i = \frac{\overline{D}_i^-}{\overline{D}_i^+ + \overline{D}_i^-}, \quad i = 1, \ldots\ldots, m \qquad \ldots (9)$$

5. RESULTS AND DISCUSSION

For illustration purpose, an example of vendor selection is performed by the suggested hybrid approach. Let us consider that four vendors, Al, A2, A3, and A4 are involved for evaluation. A team of three is charged in this project. Seven criterias are considered for the selection (Step 1 and Step 2), and the other steps are summarized as follows:

Step 3: The decision makers will be asked to evaluate all criteria pair-wise without assuming the interdependence between them. The normalized eigen vector can be calculated as w_2 = (Cl, C2, C3, C4, C5, C6, C7) = (0.347, 0.247, 0.142, 0.035, 0.084, 0.043, 0.101) which represents the related local priority of these criteria. The degree of consistency of the pair-wise comparison is measured with the use of the consistency ratio (CR) index. It is considered logically consistent if CR is less than or equal to 0.1. The CR value for this case is 0.058, which is acceptable.

Step 4: The interdependence between the criteria is now considered. All decision makers or group members will examine the impact of all the criteria by pair-wise comparison. In total, there are seven comparison matrices generated by all members. The normalized eigenvector for these matrices developed by the first member is calculated and shown as seven columns in Table 2, where zeros are assigned to the eigenvector weights of the criteria with no interdependent relationship. The data in Table 2 imply the relative impact of part of the criteria on others. For example, the degree of relative impact of C2 for C3 is 0.236.

5.1 Pair-wise Comparison Matrix for Criteria

The pair-wise comparison matrix for different criterias is shown in Table 1.

Table 1 The pair-wise comparison matrix for criteria

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**Vector weights**
C_1	1	2	4	5	4	6	4	0.346
C_2	½	1	3	4	4	5	3	0.247
C_3	¼	1/3	1	1/3	2	1/5	1/2	0.142
C_4	¼	1/5	3	1	4	1/2	2	0.035
C_5	¼	1/4	1/2	1/4	1	1/4	1/3	0.084
C_6	1/6	1/5	5	2	4	1	3	0.043
C_7	¼	1/3	2	1/2	3	1/3	1	0.101

5.2 Degree of Relative Impact for Evaluation Criteria

Table 2 represents the degree of relative impact for evaluation criteria.

Table 2 Degree of relative impact for evaluation criteria

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**
C_1	1	0	0	0	0	0	0
C_2	0	0.866	0.236	0	0	0	0
C_3	0	0	0.606	0	0	0	0
C_4	0	0.134	0	1	0	0	0
C_5	0	0	0	0	1	0	0
C_6	0	0	0	0	0	1	0
C_7	0	0	0.158	0	0	0	1

The relative importance of the criteria considering interdependence can be obtained by synthesizing the results.

$$w_i = \begin{bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.866 & 0.236 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.606 & 0 & 0 & 0 & 0 \\ 0 & 0.134 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0.158 & 0 & 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 0.346 \\ 0.247 \\ 0.142 \\ 0.035 \\ 0.084 \\ 0.043 \\ 0.101 \end{bmatrix} = \begin{bmatrix} 0.346 \\ 0.247 \\ 0.086 \\ 0.068 \\ 0.084 \\ 0.043 \\ 0.123 \end{bmatrix}$$

According to the vector from decision maker 1, C1, C2, and C7 are three of the most important factors related to the evaluation process.

At the next level of the decision process, the decision makers will be asked to establish the decision matrix by comparing candidates under each criterion separately. The criteria are assumed to be benefit criteria and they were asked to give a set of crisp values within the range of 1 to 10 to represent the performance of each alternative with respect to each criterion. After the decision matrices are determined, we normalize these matrices via Eq. (2). Table 3 shows the result of decision maker

5.3 Normalized Decision Matrix

The normalized decision matrix of various vendors with respect to the criterias is shown below in Table 3.

Table 3 Degree of relative impact for evaluation criteria

	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**
A_1	0.552	0.396	0.431	0.453	0.462	0.629	0.375
A_2	0.552	0.594	0.323	0.543	0.577	0.449	0.375
A_3	0.442	0.495	0.647	0.543	0.577	0.449	0.600
A_4	0.442	0.495	0.539	0.453	0.346	0.449	0.600

Step 5: based on the PIS and N, the ranking activities will start. By Eq. (7), the PIS and NIS for decision maker 1 will be:

R^+= (0.552, 0.594, 0.647, 0.543, 0.577, 0.629, 0.600),

R^+= (0.442, 0.396, 0.323, 0.453, 0.346, 0.449, 0.375),

5.4 Separation distances of the Group

Table 4 shows the separation distances calculated by the three decision makers based on the performance of vendors for the chosen criterias.

Table 4 Separation distances of the group

	DM#1		DM#2		DM#3		Aggregated separation distances	
	D_i^+	D_i^-	D_i^+	D_i^-	D_i^+	D_i^-	$\overline{D}_i^+$	$\overline{D}_i^-$
A_1	0.151	0.064	0.208	0.080	0.236	0.017	0.195	0.044
A_2	0.146	0.120	0.185	0.11	0.141	0.165	0.157	0.131
A_3	0.089	0.165	0.126	0.234	0.025	0.222	0.066	0.205
A_4	0.120	0.119	0.197	0.133	0.160	0.103	0.156	0.118

Note: DM - decision maker.

5.5 Final Rank of the Vendor Selection Problem

Table 5 shows the closeness coefficient of various vendors which is calculated by TOPSIS method. It ranges between 0 and 1.

Table 5.5 Final rank of the vendor selection problem

Rank	**Alternative**	**Closeness coefficient**
1	**A_3**	**0.758**
2	**A_2**	**0.457**
3	**A_4**	**0.430**
4	**A_1**	**0.185**

Using the criteria weights (Wc) obtained from step 1-3 and Eq. (8), the weighted Euclidean distances, between A_t and R^+, and between Ai and R , can be calculated immediately. Table 4 represents the separation distances developed by all three members. Next, to derive group priorities, the group's aggregated separation distances are generated by its geometric mean. The last two columns of Table 4 show the results. Finally, the relative closeness to the idea solution of each alternative can be calculated using Eq. (9). The final results can be seen in Table 5. According to the closeness coefficient, the ranking order of the four candidates is A_3, A_2, A_4 and A_1. Obviously, the best selection is candidate A_3.

6. SOFTWARE DEVELOPMENT

In order to execute several number of times with changing input parameters, software to calculate vendor rating is being developed during the phase II using VB.NET and MS Access Query Language

7. CONCLUSION

Developing a robust, easy-to-deploy method of evaluating suppliers is a-critical business competency. The methodology should be sound and the approach practical. Gathering data for the sake of data will not produce the return on investment in supplier evaluation. Most importantly, companies need to use the results as a means to foster communications and a starting point for supplier development and performance improvement. This, in turn, will help companies to reap the financial and competitive rewards of high performing key suppliers. In this project an attempt has been made to select the best vendor by using Multi Criteria Decision Making technique which uses Analytical Network process (ANP) and TOPSIS method. Analytical Network Process mainly avoids arbitrary assignments of weights for the factors depending on the decision maker, and relative pair wise comparison still makes the process more feasible and more accurate vendor rating can be obtained when compared to any other method. A software program has been developed during phase II by using VB.NET and Ms Access by considering various factors such as quality, price, on-time delivery, responsiveness, etc. as input to evaluate the best vendor as an output. In this process time, manpower requirement is very less as it is based on a software and no technical knowledge is required to operate this which can be done by a simple data entry operator.

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