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Integrated Multi-Criteria Decision-Making Methods for Selection of Supply Chain Partner for Supply Chain Management

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Abstract: In today's competitive business world, it is extremely important for decision makers to have access to decision support tools in order to make quick, right and accurate decisions. One of these decision-making areas is supplier or service provider selection. Supplier selection is a multi – criteria decision making process that deals with the optimization of conflicting objectives such as quality, services, cost, and delivery time. Although numbers of multiple criteria decisions making (MCDM) methods are available for solving MCDM problem, it's observed that in most of these methods the ranking results are very sensitive. This work proposes a multi-criteria decision making (MCDM) based framework that is used to evaluate supplier selection by using an entropy weight method (EWM) for calculation of weightage of each criterion, once the weightage is calculated the EWM is combined with Proximity Indexed Value (PIV) Method for calculating the supplier rank. Finally, the ranking performance of PIV method is compared with other MCDM Methods for same set of alternative and criterions. A numerical example along with graphical illustrations is considered and comparison analysis is provided to test the feasibility of the proposed method. In the illustrative example a manufacturing firm is looking for select most suitable supplier for supply among the ten-supplier based on four different criteria such as Price/Cost, Service, Quality and Delivery, in which Price/Cost is non-beneficial and the attributes pertaining to other criteria are beneficial one.

Keywords: EWM, MCDM, PIV, Supplier Selection, Supply Chain Management.

I. INTRODUCTION

As supplier selection and evaluation is the basic exercise of purchase department of any organization or we can say that supplier selection is the one of the most important link of supply chain management. It's very important for purchase manager/department to select suitable supplier without selection of proper one its very impossible for organization to sustain the product or service quality based on the benchmarks. For selecting the best among the group of suppliers there are many methods. Multi-criteria decision making (MCDM) techniques are used for making appropriate solution for complex problem deals with different criterions and alternatives. Basically, MCDM works with priorities of the criterions related to the problem objectives, with the help of the defined mathematic algorithmic for each and every MCDM techniques. After applying the algorithmic the results help the decision makers to establish judgments.

II. PROPOSED INTEGRATED METHOD

Supplier selection methods are the various approaches to find the most suitable supplier for business purposes. There are many selection methods are discussed by many researchers. It is observed there is a rapid increase in works aggregating sustainability by using variety of MCDM. All MCDM methods have certain strengths and weaknesses and have been designed to deal with different types of problems. From among various distinct methods, TOPSIS has been successfully adopted in a wide range of different applications in industrial and other sectors [1]. The technique is known for its various advantages that include simple computation, logical and rational procedure and incorporation of attributes relative weights [2]. Moreover, the number of steps remains the same regardless of the number of attributes [3]. But the major flaw in this method, like AHP, is occurrence of rank reversal. Rank reversal is a phenomenon where the alternatives' order of preference is altered when new alternative/s is/are added, or an existing alternative/s is/are deleted from a decision problem. The phenomenon of rank reversal was first observed in AHP by Belton and Gear [4] in 1980 and was later found to exist in almost all the MCDM models due to the mutual correlations between the relevant and irrelevant alternatives, as a consequence of normalization [5][6]. The MCDM techniques are powerful tools which are used for evaluation and selection related problems. In this chapter a new integrated model were discussed and compared for supplier selection based on different criterion and alternates. In the present study, weights of the criteria were calculated by Entropy Weight Method and then the performance rankings of the different alternatives by Proximity Indexed Value (PIV) Method.

A. Entropy Weight Method

The concept of information entropy was first introduced by Claude E. Shannon. Nowadays, it has been widely used in engineering, economy, finance etc. Information entropy is the measurement of the disorder degree of a system. It can measure the amount of useful information with the data provided. When the difference of the value among the evaluating objects on the same indicator is high, while the entropy is small, it illustrates that this indicator provides more useful information, and the weight of this indicator should be set correspondingly high. On the other hand, if the difference is smaller and the entropy is higher, the relative weight would be smaller. Hence, the entropy theory is an objective way for weight determination. [7][8]

The entropy by Shannon, can be used to ascertain the disorder degree and its utility in system information. The smaller the entropy value is, the smaller the disorder degree of the system is. The index's weight is determined by the amount of information based on Entropy Weight Method, which is one of objective fixed weight methods. [9]

Entropy Weight Method includes following 5 steps: [10][11]

- 1) *Step 1:* Construction of a decision matrix (X). A set of alternatives (A= {A_i, i = 1, 2, ..., n}) is to be compared to with respect to a set of criteria (C= {C_j, j =1, 2, ..., m}). Therefore, an n*m performance matrix (the decision matrix; X) can be obtained as:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{1}$$

Where x_{ij} is a crisp value indicating the performance rating of each alternative A_i with regard to each criterion C_j.

- 2) *Step 2:* To ascertain objective weights by the entropy measure, the decision matrix in Eq. (1) needs to be normalized for each criterion C_j (j= 1,2,....m)

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^n x_{ij}} \tag{2}$$

The Normalized decision matrix is obtained as a result of the process

$$P = \begin{bmatrix} p_{11} & p_{12} & \dots & p_{1m} \\ p_{21} & p_{22} & \dots & p_{2m} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ p_{m1} & p_{m2} & \dots & p_{mn} \end{bmatrix} \tag{3}$$

- 3) *Step 3:* Calculate the entropy measure of every index using the following equation:

$$e_j = -k \sum_{i=1}^m p_{ij} \cdot \ln p_{ij} \tag{4}$$

where $k = \frac{1}{\ln(n)}$ is a constant which guarantees $0 < e_j < 1$

- 4) *Step 4:* The degree of divergence (d_j) of the average intrinsic information contained by each criterion C_j (j = 1, 2, ..., m) can be calculated as

$$d_j = 1 - e_j \tag{5}$$

- 5) *Step 5:* The objective weight for each criterion C_j (j = 1, 2, ..., m) is thus given by

$$w_j = \frac{1 - e_j}{\sum_{j=1}^m 1 - e_j} \tag{6}$$

B. Proximity Indexed Value (PIV) Method

The method proposed in this paper has been developed by Mufazzal and Muzakkir [12] which can be used by the decision makers for solving varieties of MCDM problems including the selection of the most suitable E-learning websites. This method involves the following simple steps:

Step 1: Identify the available alternatives A_i ($i = 1, 2, \dots, m$) and decision criteria C_j ($j = 1, 2, \dots, n$) involved in the decision problem.

Step 2: Formulate the decision matrix Y by arranging alternatives in rows and criteria in columns as given in Eq. (7)

$$Y = \begin{bmatrix} Y_{11} & Y_{12} & \dots & Y_{1n} \\ Y_{21} & Y_{22} & \dots & Y_{2n} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ Y_{m1} & Y_{m2} & \dots & Y_{mn} \end{bmatrix} \tag{7}$$

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

where Y_{ij} represents i th alternative performance value on j th criterion, m is the number of alternatives and n is the number of criteria.

Step 3: Determine the normalised decision matrix using Eq. (8)

$$R_i = \frac{Y_i}{\sqrt{\sum_{j=1}^n Y_{ij}^2}} \tag{8}$$

where Y_i is the actual decision value of the i th alternative.

Step 4: Determine the weighted normalised decision matrix using Eq. (9)

$$v_i = w_j * R_i \tag{9}$$

where w_j is the weight of the j th criterion.

Step 5: Evaluate the Weighted Proximity Index (WPI), u_i using Eq. (10)

$$u_i = v_{max} - v_i \text{ (For beneficial attributes)} \tag{10}$$

$$u_i = v_i - v_{min} \text{ (For non-beneficial attributes)}$$

Step 6: Determine the Overall Proximity Value, d_i using Eq. (11)

$$d_i = \sum_{j=1}^n u_i \tag{11}$$

Step 7: Rank the alternatives based on d_i values. The alternative with least value of d_i represents minimum deviation from the best and therefore, it is ranked first, followed by alternatives with increasing d_i .

III. ILLUSTRATIVE EXAMPLE

This example is taken from [13] where an Original Equipment Manufacturing (OEM) company wants to choose their best vendor for supply. In selection of a vendor various criterions are to taken into account, among the number of suppliers. In this case of computation procedure and applicability of the proposed method, considering five suppliers and four criterions based on which most suitable supplier required to identified. The four criterions are Quality, Price/Cost, Delivery and Service among which Price/Cost is non-beneficial and the attributes pertaining to other criteria are beneficial, which is shown in Table 1.

Table I
Decision Matrix for Alternatives

	Quality	Price/Cost	Delivery	Service
Supplier 1	7	6	9	9
Supplier 2	7	7	7	9
Supplier 3	9	8	7	9
Supplier 4	5	4	9	7
Supplier 5	5	3	7	7

Weights of the criteria calculated by using EWM are shown in Table 2. Since our main objective is to demonstrate the applicability of the PIV method, not to calculate the criteria weights therefore, we used the criteria weights obtained by [13] for ranking the alternatives using PIV method.

Table II
Criterion Weights [13]

Criterion	Quality	Price/Cost	Delivery	Service
Weights	0.2594	0.587	0.0794	0.0742

Normalised decision matrix, as shown in Table 3, was obtained using Eq. (8).

Table III
Normalised Decision Matrix

Alternatives	Quality	Price/Cost	Delivery	Service
A1	0.4626	0.4549	0.5120	0.4874
A2	0.4626	0.5307	0.3982	0.4874
A3	0.5947	0.6065	0.3982	0.4874
A4	0.3304	0.3032	0.5120	0.3791
A5	0.3304	0.2274	0.3982	0.3791

Using criteria weights (Table 2), weighted normalised decision matrix was obtained using Eq. (9) and it is shown in Table 4.

Table IV
Weighted Normalised Decision Matrix

Alternatives	Quality	Price/Cost	Delivery	Service
Supplier 1	0.1200	0.2670	0.0407	0.0362
Supplier 2	0.1200	0.3115	0.0316	0.0362
Supplier 3	0.1543	0.3560	0.0316	0.0362
Supplier 4	0.0857	0.1780	0.0407	0.0281
Supplier 5	0.0857	0.1335	0.0316	0.0281

The weighted proximity index (u_i), the overall proximity value (d_i) of all the alternatives were calculated using Equations. (10) and (11), respectively, as shown in Table 5. Based on the values of d_i , the ranking of alternatives was done in such a way that the alternative with the least value of the d_i is ranked first followed by the alternatives with increased values of d_i . The ranking of alternatives is also shown in Table 5.

Table V
Weighted Proximity Index, Overall Proximity Index & Ranking Results

Alternatives	Quality	Price/Cost	Delivery	Service	d_i	Rank
Supplier 1	0.0343	0.1335	0.0000	0.0000	0.1678	3
Supplier 2	0.0343	0.1780	0.0090	0.0000	0.2213	4
Supplier 3	0.0000	0.2225	0.0090	0.0000	0.2315	5
Supplier 4	0.0000	0.0445	0.0000	0.0000	0.0445	2
Supplier 5	0.0000	0.0000	0.0000	0.0000	0.0000	1

IV. RESULT & DISCUSSION

The weighted proximity index (u_i), the overall proximity value (d_i) of all the alternatives were calculated using Equations (10) and (11) respectively as shown in Table 5. Based on the values of d_i , the ranking of alternatives was done in such a way that the alternative with the least value of the d_i is ranked first followed by the alternatives with increased values of d_i . So, according to the obtained result supplier 5 is the most suitable supplier for the further business with manufacturing firm and reveals the ranking order of supplier selection as supplier 5 > supplier 4 > supplier 1 > supplier 2 > supplier 3.

A. Comparison with ARAS Method

Supplier selection is a very important process and activity for any manufacturing firm, it can be said that supplier selection is one activity in which huge brain storming and trial are carried out. This MCDM problem help the selector to take most suitable decision regarding the vendor selection process, Hence the supplier selection procedure and, above all, the selection of an adequate method is significant, especially from the aspect of the final result. In this paper, an illustrative example was successfully conducted aimed at indicating that multi-criteria decision making can be successfully applied for the supplier selection. In this section PIV method is compared with ARAS method used for supplier selection [13].

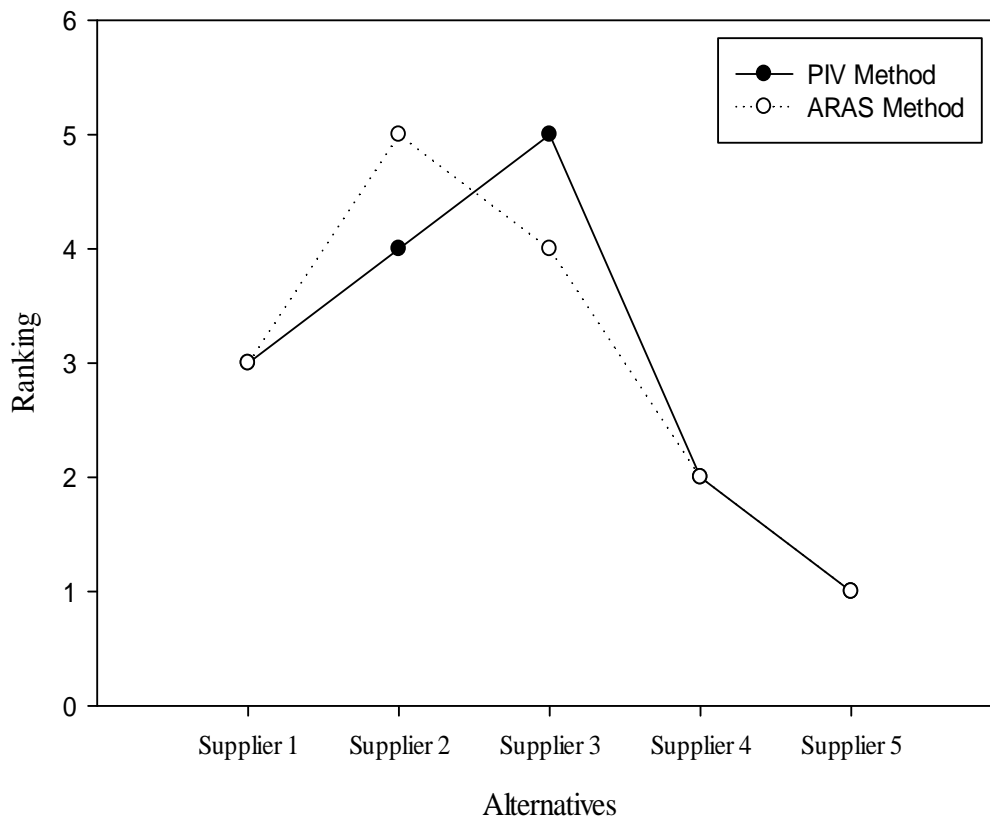


Fig. 1 Comparison of PIV Method with ARAS Method

From the Figure 1, it is shown that the ranking comparison of Proximity Indexed Value (PIV) Method with Additive Ratio Assessment (ARAS) Method is identified that supplier 5, supplier 4 and supplier 1 for both Methods respectively for the manufacturing firm, but when the data analysis studied further then only, we are able to understand the difference in the both methods, its showed that there were significant differences in the results and high amount of uncertainty for other suppliers.

In supply chain management, co-ordination between a company and its supplier plays a vital role in determining the success of the company. This paper presents a multi-criteria decision making for evaluation of suppliers by implemented the integration of EWM and PIV method.

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