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Multi-criteria decision making for supplier selection using AHP and TOPSIS method

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Abstract: *Supplier selection is one of the most critical issues to be dealt by manufacturing firms in today's competitive environment. It is a multi-criteria decision making problem which involves both qualitative and quantitative factors. In order to select the best supplier, it is important to make a trade-off between these tangible and intangible factors which conflict with each other. The purpose of this paper is to evaluate the suppliers in supply chain cycle using Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS). Factors such as product quality, facility, delivery time and price have been taken into consideration while evaluating the suppliers in this supplier selection process.*

Keywords: *Supplier Selection, AHP, Topsis*

I. INTRODUCTION

Supplier selection is one of the major tasks of the purchasing department which involves the acquisition of required materials and equipment for an organization. Generally, the decision of supplier selection depends upon a various number of criteria. Mainly, cost is the foremost criteria considered while choosing a supplier, others such as product quality of the material, delivery time and service quality of the supplier also play a vital role while selecting a suitable supplier. In today's competitive industrial scenario, it is also important to develop closeness and long-term relationships between purchasers and suppliers. A careful assessment of various suppliers with varied traits is required to rank different suppliers. The reduction in purchasing cost, decrease in supplying risk and improved product quality can be achieved by right supplier selection and determining the appropriate amount of orders to be ordered. Therefore, only the right supplier can contribute the advantages to the manufacturing organization. Supplier selection problem are basically of two types. Single sourcing, the supplier who can satisfy all the customer's requirements where the management needs to make only one decision to select the best supplier whereas no supplier can satisfy all the customer's demands is the multiple sourcing supplier selection problem. To choose the best supplier is not easy for decision maker who always satisfies the entire requirements of the buyers. Supplier selection is a multi-criteria decision making problem that includes both qualitative and quantitative factors, some of which conflict with each other. A multi-criteria decision making technique helps the decision-makers (DMs) to evaluate a set of alternatives. This paper provides a brief overview of AHP and implementation of steps used in TOPSIS method.

II. LITERATURE REVIEW

Parthiban et al. (2012) presented the factors affecting the supplier selection process using Analytic Hierarchy Process (AHP).The proposed model is applied to an automotive industry in south India to rank a group of 20 suppliers. Weber and Ellram (1993) developed the use of a multi-objective programming approach as a method for supplier selection in just in time (JIT) setting. Dweiri (2016) proposed a decision support model for supplier selection based on Analytic Hierarchy Process (AHP). Four main criteria are considered (price, quality, delivery and service) and the supplier is ranked according to their sub criteria. Boran et al. (2009) have illustrated the application of intuitionistic fuzzy TOPSIS method to select appropriate supplier in a group decision making environment. Tahriri (2008) discussed the different selection methods concerning supplier selection and listed the advantages and disadvantages these methods. Shahroudi and Maryam (2012) introduced a methodology to evaluate suppliers in supply chain cycle based on Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS) when decision makers set the target value of each criterion. Dalalah et al. (2011) presented a hybrid fuzzy multi-criteria group decision making model for evaluation of supplier against each alternative. The proposed model can be implemented and applied to different decision making problems. Ayhan (2013) introduced an application of the Fuzzy AHP methodology for supplier selection problem of a manufacturing company to determine the best supplier among 3 alternatives with respect to five criteria namely; Quality, Origin of the raw material, Cost, Delivery Time, and after Sales Services. Tahriri et al. (2008) proposed AHP model for evaluation and selection of suppliers. The proposed model can be applied to improve and assist decision making to resolve the supplier selection problem in choosing the optimal supplier combination. Adtiya et al. (2014) presented a (TOPSIS) method which deals with inaccurate, incomplete and imperfect information of expert judgment. Erdebilli and Saputro (2014) introduced fuzzy TOPSIS and Multi-Choice Goal Programming (MCGP) method for multi-criteria decision making problem under uncertain environments for supplier selection and also presented a hybrid method for supplier selection and allocation order.

III. TOPSIS METHOD

A Multi-Criteria Decision Making (MCDM) technique helps the decision makers (DMs) to evaluate the best alternatives. TOPSIS method is a most common technique of multi-Attribution Decision Making (MADM) models. "Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)" is a method of multi-criteria decision analysis and this method was introduced by Hwang and Yoon in 1981. TOPSIS logic is rational and understandable. It chooses the alternative which has the shortest geometric distance from the positive ideal solution and compares a set of alternatives by identifying weights for each criterion, normalizes the scores for each criterion and calculates the geometric distance between each alternative and the ideal alternative in order to give the best score for each criterion. TOPSIS method helps to choose the right suppliers with a various finite number of criteria.

TOPSIS method generally has the following steps:-

After forming an initial decision matrix, the stepwise procedure starts by normalizing the decision matrix.

Step 1

Construct normalized decision matrix using the following formula:

$$r_{ij} = x_{ij}/\sqrt{\sum_{i=1}^{n} x_{ij}}^{2}$$

Step 2

Calculate the weighted normalized decision matrix.

$$V_{ij} = W_{ij} r_{ij}$$

Step 3

Determine the positive ideal and negative ideal solution.

A*= {(max V_{ij}| j∈J), (min V_{ij}| j∈J

A- = {(min V_{ij} |j∈J), (max V_{ij}| j∈J)}

J= 1, 2, 3,…, n

Where J is associated with the cost criteria

Step 4

Calculate the separation measures for each alternative.

Separation of each alternative from the positive ideal is given by:

$$S_{i*=}\sqrt{\sum_{i=1}^{n}(v_{ij} - v_j *)^2}$$

where i= 1,2,…m

Similarly for negative ideal one is given by:

$$S_{i}^{-}{}_{-=}\sqrt{\sum_{i=1}^{n}(v_{ij} - v_j^{-})^2}$$

Step 5

Calculate the relative closeness to the ideal solution.

C*/S_i^-/ (S_i*+S_i^-) 0≤ C_i*≤ 1

where, i = 1,2,…,m

Step 6

Rank the preferred supplier

IV. SUPPLIER SELECTION WITH ANALYTIC HIERARCHY PROCESS (AHP)

Analytic Hierarchy Process was first introduced by Prof. Thomas L. Saaty (1980). It defines the ratio scale from paired comparison and allows some small inconsistency in judgment. Following are the steps involved in the AHP. AHP is the most common method used in supplier selection process because it allows decision makers to select the best suppliers based on the relative importance of the various criteria which suits the suppliers. It is relatively simple to use and ease to understand which incorporates qualitative and quantitative criteria. The steps involved in the AHP are as under:-

1. The hierarchy containing the decision goal, the alternatives, and the criteria for evaluating the alternatives.
2. Establish priorities among the elements of the hierarchy by making a series of judgments based on pairwise comparisons of the elements.
3. Check the consistency of the judgments.

4. Develop a normalized matrix.
5. Develop the priority vector.

Rank the preferred criteria

V. RESEARCH METHODOLOGY

The three phases of the methodology used are:

1. Identification of performance criterion.
2. Weights for the performance criteria by using AHP.
3. The evaluation of best alternatives criterion depicted in a simple mathematical calculation and the suppliers are ranked using TOPSIS method.

VI. NUMERICAL EXAMPLE

Ten suppliers (S1, S2, S3,..., S10) are evaluated as alternatives against four criteria that is, product quality (C1), facility (C2), delivery time (C3) and price (C4).

Table 1 Four criterions of the suppliers and their respective attributes are chosen from ten point scale are:

Product quality (C1)	Facility (C2)	Delivery time (C3)	Price (C4)
Good-6	Good-6	Fast-6	High-6
Very good-8	Very good-8	Very fast-8	Very high-8
Extremely good-9	Extremely good-9	Extremely fast-9	Extremely high-9

The following Table 2 gives the structure of a decision matrix for ten suppliers (mentioned earlier in the TOPSIS method) against 4 criteria which is rated by the ten point scale.

Table 2 showing the structure of a decision matrix

Suppliers	Product Quality(C1)	Facility (C2)	Delivery time (C3)	Price(C4)
S1	9	8	9	9
S2	6	8	8	8
S3	8	9	9	6
S4	9	6	8	8
S5	8	8	8	9
S6	9	9	9	6
S7	6	6	9	6
S8	6	8	6	8
S9	8	9	6	9
S10	9	9	6	9

After forming an initial decision matrix, the decision matrix values are to be normalized. Normalization is mainly used for elimination of the units of each criterion, so that all the criteria are dimensionless.

Table 3 showing the normalized decision matrix values

Suppliers	Product Quality(C1)	Facility (C2)	Delivery time (C3)	Price (C4)
S1	0.3554	0.3133	0.3602	0.3602
S2	0.2369	0.3133	0.3202	0.3202
S3	0.3202	0.3524	0.3602	0.2401
S4	0.3554	0.2349	0.3202	0.3202
S5	0.3159	0.3133	0.3202	0.3602
S6	0.3554	0.3524	0.3602	0.2401
S7	0.2369	0.2349	0.3602	0.2401
S8	0.2369	0.3133	0.2401	0.3202
S9	0.3159	0.3524	0.2401	0.3602
S10	0.3554	0.3524	0.2401	0.3602

Pairwise comparison and the subjective judgment are determined using AHP. The main function of pairwise comparison is to find out the relative importance of the criteria given by nine point scale.

Table 4 shows the numerical rating in the AHP method

Measurement Scale	Preference
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strongly importance
9	Extreme importance
2,4,6,8	Intermediate values between two adjacent judgments

The next step is to construct a 4 by 4 comparison matrix. The diagonal element of the matrix is always 1 and hence only the values for the upper triangular matrix is to be filled.

Table 5 for pair-wise comparison matrix

Supplier selection criteria	C1	C2	C3	C4
Quality (C1)	1	3	2	7
Facility (C2)	1/3	1	3	3
Delivery (C3)	1/2	1/3	1	5
Price (C4)	1/7	1/3	1/5	1

Therefore, the good performance on quality is very strongly preferred to the price, criteria of first row (with value 7) which is slightly preferred to the supplier having good delivery service. A supplier having good facility is moderately important than having good performance on price and the delivery service (shown by value 3). Having good performance on delivery is strongly important when compared to price (shown by value 5). After performing a pairwise comparison the next step is the computation of vector of priorities weights in terms of matrix in order to normalize each column to get sum is equal to 1. Thus, we divide the elements of that column by the total of the column and sum them up.

Table 6 Normalized matrixes of paired comparisons and calculation of priority weights.

Criteria for supplier selection	Quality (C1)	Facility (C2)	Delivery (C3)	Price (C4)	Row Total	Average
Quality (C1)	42/83	9/14	10/31	7/16	1.9089	0.4772
Facility (C2)	14/83	3/14	15/31	3/16	1.0543	0.2635
Delivery (C3)	21/83	1/14	5/31	5/16	0.7982	0.1945
Price (C4)	6/83	1/14	1/31	1/16	0.2384	0.0596
Total	1	1	1	1		

Thus the weighted values calculated using AHP are as follows:-

(i) Weighted value of product quality=0.4772
(ii) Weighted value of product facility =0.2635
(iii) Weighted value of delivery time =0.1945
(iv) Weighted value of price=0.0596

Table 7 showing the weighted normalized decision matrix

Supplier	Product Quality(C1)	Facility (C2)	Delivery time (C3)	Price (C4)
S1	0.1695	0.0825	0.0701	0.0214
S2	0.1131	0.0825	0.0622	0.0191
S3	0.1527	0.0928	0.0701	0.0143
S4	0.1695	0.0618	0.0622	0.0191
S5	0.1507	0.0825	0.0622	0.0214
S6	0.1695	0.0928	0.0701	0.0143
S7	0.1131	0.0618	0.0701	0.0143
S8	0.1131	0.0825	0.0466	0.0191
S9	0.1507	0.0928	0.0466	0.0214
S10	0.1695	0.0928	0.0466	0.0214

Table 8 shows the positive ideal solution and the negative ideal solution.

	C1	C2	C3	C4
A*	0.1695	0.0928	0.0701	0.0214
A^-	0.1131	0.0618	0.0466	0.0143

Table 9 shows the separation measures, relative closeness coefficient and the ranking order of different suppliers.

Suppliers	Si*	Si^-	Ci*	Rank
S1	0.0103	0.0649	0.8631	2
S2	0.1587	0.0263	0.1421	10
S3	0.0182	0.0555	0.7531	3
S4	0.0321	0.0587	0.6464	6
S5	0.0228	0.0462	0.6695	5
S6	0.0071	0.0685	0.9061	1
S7	0.0647	0.0235	0.2664	8
S8	0.0621	0.0212	0.2545	9
S9	0.0301	0.0492	0.6204	7
S10	0.0235	0.0647	0.7335	4

VII. CONCLUSION

An appropriate supplier selection plays a vital role in good performance of the organization in order to fulfill the customer requirements and to achieve their satisfaction in timely and cost effective manner. This study presents a multi-criteria group decision making problem for evaluation of different suppliers based on AHP and TOPSIS method. The TOPSIS method is simple to use and understandable, the computation processes are straightforward and the concept permits the pursuit of best alternatives criterion depicted in a simple mathematical calculation. AHP can measure the degree to which a manager's judgments are consistent. Ten suppliers are evaluated as alternatives against four criteria that is, product quality, facility, delivery time and price. The suppliers are ranked with respect to their main criteria using AHP pairwise comparison approach and the weights of the each criterion are determined and also the relative closeness coefficients were obtained using TOPSIS method. From the calculations done supplier S6 is ranked as best and appropriate supplier which has extremely good product quality, extremely good facility, extremely fast delivery and high price of the product followed by S1, S3 and so on, while S2 supplier appears to be the least suitable supplier. The approach using AHP and TOPSIS thus proves to be an efficient technique for supplier selection under multiple criteria.

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