AHP-TOSIS Based Approach for Supplier Selection: A Case Study

Aniruddha M Bavdhankar[1], Jayant S Karajagikar[2]
[1, 2] Department of Production Engineering and Industrial Management
[1, 2] College of Engineering Pune, India

Abstract- *To compete and grow in the global and networked economy the organizations must rely on the effective supply chain or networks. The optimal supply chain strategy plays an operational role in achieving economic, social and ecological performance. In the process of supply chain management, suppliers are the key element. Supplier selection is a process of determining the appropriate supplier who makes available the right quality of product and/or service at the right price, right time and in right quantities, is one of the critical activities in establishing an effective supply chain network. Appropriate suppliers reduce purchasing costs and lead time, increase customer satisfaction and competitive advantage. Supplier selection is the multi-criterion decision-making problem under the uncertain environment which includes both qualitative and quantitative factors. This problem may be solved by using various Multi-Criteria Decision-Making (MCDM) techniques. This paper provides the combined application of Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS) and Analytic Hierarchy Process (AHP) in an electronic device manufacturing company determining the best supplier with respect to selected criteria. The weights of respective criterion were calculated using AHP. Supplier evaluation and ranking was done using TOPSIS methodology. The contribution of this study is not only the application of the AHP-TOPSIS methodology for supplier selection problem, but also stating a comprehensive literature review of MCDM problems. This study can also be a guide for the methodology to be implemented to other multiple criteria decision making problems.*

Keywords- Supply Chain Management (SCM), Supplier selection, Multi-Criteria Decision-Making (MCDM), Analytic Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS).

I. INTRODUCTION

Increasing competencies in global markets enforce organizations to implement new strategies to achieve improvement in total cost structure, quality, efficiency, and production capability without increasing capital investment for top line growth. Therefore, suppliers play a key role in winning the corporate competencies, and because of this, selecting the appropriate supplies is a critical component of these new strategies.

Supplier selection, which includes multi criteria and multiple conflicting objectives, can be defined as the process of finding the right suppliers with the right quality at the right price, at the right time, and in the right quantities. It is noted that, manufacturers spend more than 60% of its total sales on purchased items [1]. In addition, their purchases of goods and services constitute up to 70% of product cost [2]. Therefore, selecting the right supplier significantly reduces purchasing costs, improves competitiveness in the market and enhances customer satisfaction [3]. Since this selection process mainly involves the evaluation of different criteria and various supplier attributes, it can be considered as a multiple criteria decision making (MCDM) problem [4]. Based on several criteria and alternatives to be considered, various decision making methods have been proposed to provide a solution to this problem [5].

Basically, there are two types of supplier selection problems [6]. In single sourcing type, one supplier can satisfy all the buyer's needs. In the multiple sourcing type, no supplier can satisfy all the buyer's requirements. Hence the management wants to split order quantities among different suppliers [7]. As a pioneer in the supplier selection problem, Dickson [8] identified 23 different criteria for selecting suppliers, including quality, delivery, performance history, warranties, price, technical capability, and financial position [9]. With a thorough literature survey, Weber, et al. [10] reviewed 74 different articles by classifying into three categories; linear weighting methods, mathematical programming models, and statistical approaches. Following Weber et al. [10], De Boer et al. [11], identified four stages for supplier selection including; definition of the problem, formulation of criteria, qualification, and final selection respectively [12].

According to one of the recent classifications made by Sanayei et al. [13], there are six classes. These are multi attribute decision making techniques (Analytic Hierarchy Process- AHP, Analytic Network Process- ANP, Technique for Order Preference by Similarity to Ideal Solution- TOPSIS),

mathematical programming (Linear Programming- LP, Goal Programming- GP or Mixed Integer Programming- MIP), probabilistic approaches, intelligent approaches (neural networks, expert systems), hybrid approaches (AHP-LP, ANP-MIP) and others.

In this paper, we have identified some effective criteria which affect the process of supplier selection. Based on Analytic Hierarchy Process (AHP), we have calculated the weights for each criterion and inputted those weights to the TOPSIS method to rank suppliers. The main advantages of using TOPSIS method are: -

1. It is simple to use.
2. It considers all types of criteria (quantitative and qualitative).
3. It is rational and understandable.
4. The computation processes are straight forward.
5. The concept permits the pursuit of best alternatives criterion depicted in a simple mathematical calculation.

Study in [14] has shown that over the years from 1966 to 2010, the selection criteria comprising of price, delivery, quality, and service is considered universal for most of the industries.

In real-world scenario, most problems have more than one decision criterion. So MCDM methods have been developed to solve complex problems. The aim in MCDM is to determine overall preferences among alternative options. According to the objective, MCDM methods can be used for outranking alternatives or final decision of choice.

The objective of present paper is to develop a methodology based on Technique for Order Preference by Similarity to Ideal Solution method (TOPSIS) for supplier evaluation considering some important criteria which affect the process of supplier selection, viz. product quality, service quality, delivery time and price credit terms etc. The weights for each criterion was calculated using Analytic Hierarchy Process (AHP) and then inputted these weights to TOPSIS to rank the suppliers.

This work is mapped as; the literature is reviewed as per the different criteria and methods used for the supplier selection problem in the second part. Part 3 explains the AHP-TOPSIS method in detail which is utilized to solve the supplier selection problem of an electronics device manufacturing firm elaborated as a case study in the fourth part. Part 5 presents the conclusion and directs for further steps of this study with the references following.

II. LITERATURE REVIEW

The objective of supplier selection is to identify suppliers with the highest potential for meeting an organization's needs consistently. Research results indicate that supplier selection process is one of the most significant variables, which has a direct impact on the performance of an organization. As the organization becomes more and more dependent on their suppliers, the direct and indirect consequences of poor decision making will become more critical. The nature of this decision is usually complex and unstructured. On the other hand, supplier selection decision making problem involves trade-offs among multiple criteria that involve both quantitative and qualitative factors, which may also be conflicting.

As mentioned previously there are comprehensive literature reviews performed before such as Dickson [8], Weber et al. [10], De Boer et al. [11] and Sanayei et al. [13]. However, in this part, at first, the literature will be reviewed according to the selection criteria and then the methodologies used for supplier selection problem will be explained mainly based on a previous study performed by Ayhan [14].

Many studies have been performed by using different criteria starting from the Dickson‟s 23 criteria [8]. When the methodologies used for solving supplier selection problem are reviewed, it is observed that, various multi criteria decision making methods are implemented, which can be grouped into three broad categories:

1) Value Measurement Models: AHP and multi attribute utility theory (MAUT) are the best known method in this group.
2) Goal, Aspiration, and Reference Models: Goal programming and TOPSIS are the most important methods that belong to the group.
3) Outranking Methods: ELECTRE and PROMETHEE are two main families of methods in this group.

AHP, which was first developed by Saaty [15], integrates experts‟ opinions and evaluation scores into a simple elementary hierarchy system by decomposing complicated problems from higher hierarchies to lower ones. Yahya and Kingsman [16] are one of the first known researchers to use AHP to determine priorities in selecting suppliers. Similarly Analytic Network Process (ANP) is also a multi attribute approach for decision making that allows the transformation of qualitative values to quantitative ones. Since AHP is a special case of ANP and it does not contain feedback loops among the factors, ANP is used to determine supplier selection for the longer terms.

For an Industry it is necessary to maintain the good coordination between management and supplier in terms of material quality, quantity, cost and time. The supplier selection for an Industry involves multiple criteria which show the important role in selection of suppliers. It allows the decision makers to rank the candidate alternative more efficiently and easily. P.Murali et al [17] use PROMETHEE and TOPSIS methods in solving a supplier selection problem and the results obtained are significantly important and can be use in framing the supplier selection strategies. P. Madke & M. Jaybhaye [18] use PUGH selection matrix and TOPSIS in selection of fuel level sensing technology for an Indian automobile manufacturer

III. ANALYTIC HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP) is a structured technique for helping people deal with complex decisions. Rather than prescribing a "correct" decision, the AHP helps people to determine one. An AHP hierarchy is a structured means of describing the problem at hand. It consists of an overall goal, a group of options or alternatives for reaching the goal, and a group of factors or criteria that relate the alternatives to the goal. In this paper, we have used the following steps of AHP to help us to measure the relative importance or the weighted values of several criteria.

- **Step 1**

List the overall goal, criteria which affects the selection and decision alternatives.

- **Step 2**

Develop a relative importance matrix.

- **Step 3**

Find a Geometric Mean, W or A2, A3, A4 matrix

- **Step 4**

Find λ(max), Consistency Index (CI), Random Index (RI) and Consistency Ratio (CR).

IV. TOPSIS METHOD

TOPSIS method was introduced for the first time by Yoon and Hwang and was appraised by surveyors and different operators. TOPSIS is a decision-making technique. It is a goal based approach for finding the alternative that is closest to the ideal solution. In this method, options are graded based on ideal solution similarity. If an option is more like an ideal solution, it has a higher grade. Ideal solution is a solution that is the best from any aspect that does not exist practically and we try to approximate it. Basically, for measuring similarity of a design (or option) to ideal level and non-ideal, we consider distance of that design from ideal and non-ideal solution.

General TOPSIS process with 7 steps is listed below: -.

Step 1

Form a decision matrix. The structure of the matrix can be expressed as follows:

$$D = \begin{Bmatrix} & X1 & X2 \ldots & Xj & .. & Xn \\ A1 & x11 & x12 \ldots & x1j & .. & x1n \\ A2 & x21 & x22 \ldots & x2j & .. & x2n \\ : & : & : & : & : & : \\ Ai & xi1 & xi2 \ldots & xij & .. & xin \\ : & : & : & : & : & : \\ Am & xm1 & xm2 \ldots & xmj & .. & xmn \end{Bmatrix}$$

where

Ai = ith alternative projects

Xij = the numerical outcome of the ith alternative projects with respect to jth criteria

Step 2

Normalize the decision matrix D by using the following formula:

$$r_{ij} = \frac{Xij}{\sqrt{\sum_{i=1}^{n} Xij^2}} \quad \ldots\ldots\ldots\ldots (1)$$

Step 3

Construct the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized value V_{ij} is calculated as:

$$V_{ij} = W_{ij} \times r_{ij} \quad \ldots\ldots (2)$$

Step 4

Determine the positive ideal solution and negative ideal solution.

$$A^* = \{(\max V_{ij} \mid j \epsilon J), (\min V_{ij} \mid j \epsilon J')\} \quad \ldots\ldots\ldots (3)$$

J = 1,2, 3…., n

where J is associated with the benefit criteria

A- = {(min V_{ij} | jϵJ), (max V_{ij} | jϵJ')} ……(4)

J' = 1,2, 3…., n

where J' is associated with the cost criteria.

Step 5

Calculate the separation measure.

The separation of each alternative from the positive ideal one is given by:

$$Sij^* = \sqrt{\sum_{j=1}^{n} (Vij - Vj^*)^2} \quad \text{……(5)}$$

where i = 1, 2…, m

Similarly, the separation of each alternative from the negative ideal one is given by:

$$Sij^- = \sqrt{\sum_{j=1}^{n} (Vij - Vj^-)^2} \quad \text{……(6)}$$

where i = 1, 2…, m

Step 6

Calculate the relative closeness to the ideal solution.

The relative closeness of Ai with respect to A* is defined as:

$Ci^* = Si^-/(Si^*+Si^-)$, $0 \leq Ci^* \leq 1$ ……(7)

where i = 1, 2…, m

The larger the Ci* value, the better the performance of the alternatives.

Step 7

Rank the preference order.

V. PROPOSED METHODOLOGY

The proposed methodology for supplier selection problem, composed of TOPSIS method, consists of three steps. These are:

1. Identify the criteria to be used in the model.
2. Weight the criteria by using AHP.
3. Evaluation of alternatives with TOPSIS and determination of the final rank.

In the first step, we try to recognize variables and effective criteria in supplier selection and the criteria which will be used in their evaluation is extracted. Thereafter, list of qualified suppliers is determined. In the second step, we assign weights to each criterion by using AHP. Finally, ranks are determined using TOPSIS method in the third step.

VI. CASE STUDY EXAMPLE, CALCULATION AND RESULTS

In this section, to implement the methodology, we have a practical numerical example. The management of an electronics goods manufacture wants to choose their best suppliers. Based on proposed methodology, 3 steps are applied for assessment and selection of suppliers. In this part, we deal with application of these steps. We are going to evaluate 8 suppliers as alternatives against Ability to meet specs & stands, Availability, competitive pricing, Convenience, Credit Days, Delivery time, Payment terms. Where, Ability to meet specs & stands, Availability, Convenience, Credit Days and Payment terms are benefit attributes and competitive pricing and Delivery time are non-benefit attributes. The following table 1.1 gives us a list of suppliers and their respective attributes.

All the calculations are performed in MS-EXCEL.

Performing different steps of AHP

1. Relative importance matrix:

The relative comparison for all attributes is done as shown in below

ALTERNATIVES	Ability to meet specs & stands	Availability	competitive pricing	Convenience	Credit Days	Delivery time	Payment terms
Ability to meet specs & stands	1.0000	6.0000	6.0000	6.0000	7.0000	5.0000	0.1667
Availability	0.1667	1.0000	0.5000	3.0000	2.0000	1.0000	0.1111
competitive pricing	0.1667	2.0000	1.0000	2.0000	2.0000	0.3333	0.2500
Convenience	0.1667	0.3333	0.5000	1.0000	3.0000	0.2500	0.1111
Credit Days	0.1429	0.5000	0.5000	0.3333	1.0000	0.3333	0.1111
Delivery time	0.2000	1.0000	3.0000	4.0000	3.0000	1.0000	0.1111
Payment terms	6.0000	9.0000	4.0000	9.0000	9.0000	9.0000	1.0000

Figure 1.

2. Finding Geometric Mean (GM), W, A3 & A4 matrix

GM	W (or A2)	A3	A4
2.7727	0.2430	1.9044	7.8383
0.6617	0.0580	0.4378	7.5497
0.7306	0.0640	0.5016	7.8352
0.4202	0.0368	0.2909	7.8984
0.3316	0.0291	0.2191	7.5418
0.9686	0.0849	0.6718	7.9149
5.5266	0.4843	4.0768	8.4185

Figure 2.

The weights for various attributes are as shown in above figure

3. Checking consistency of the relative comparison

RESULT	
COUNT =	7.0000
λ_{MAX} =	7.8567
C.I. =	0.1428
R.I. =	1.3200
C.R. =	0.1082

SIZE OF MATRIX	R.I.
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

NOTE: CR of 0.1 or less is considered as acceptable

Figure 3.

As the C.R. value for the attribute relative comparison for considered case is almost equal to 0.1 hence, the considered relative comparison is consistent and the weights for respective attributes are

Table 1.

I. ATTRIBUTE	II. WEIGHT
III. ABILITY TO MEET SPECS & STANDS	**IV.** 0.2430
V. AVAILABILITY	**VI.** 0.0580
VII. COMPETITIVE PRICING	**VIII.** 0.0640
IX. CONVENIENCE	**X.** 0.0368
XI. CREDIT DAYS	**XII.** 0.0291
XIII. DELIVERY TIME	**XIV.** 0.0849
XV. PAYMENT TERMS	**XVI.** 0.4843

Performing different steps of TOPSIS

1. Construct the decision matrix with all parameters (Beneficial or Non-Beneficial) for TOPSIS

Based on various functional requirements of purchase and quality departments with help of team members and with the experience of seniors following decision matrix was constructed

SUPPLIER	Ability to meet specs & stands	Availability	competitive pricing	Convenience	Credit Days	Delivery time	Payment terms
Saj Electronics Pvt.Ltd.	80	65	7	7	60	20	9
Prabha-Tech Enterprises	91	85	6	8	1	5	2
Pune Industrial Distributors Pvt.Ltd.	82	80	8	7	1	8	1
Element 14	95	95	3	9	30	7	3
Friends Industrial Suppliers	78	80	7	9	30	15	2
Pioneer Electro Devices	85	90	3	7	1	5	2
Rajiv Electronics	87	90	5	8	1	4	2
Yash Electronics	84	85	7	8	1	4	1
WEIGHTS >>	0.2430	0.0580	0.0640	0.0368	0.0291	0.0849	0.4843
BENEFICIAL OR NON BENEFICIAL	B	B	N	B	B	N	B

Figure 4.

2. Normalized and weighted normalized matrix

By using Eq. (1) and Eq. (2) normalize and weighted normalize matrix are calculated respectively and are as shown below

NORMALISED TABLE							
SUPPLIER	Ability to meet specs & stands	Availability	competative pricing	Convinience	Credit Days	Delivery time	Payment terms
Saj Electronics Pvt.Ltd.	0.331	0.273	0.411	0.313	0.816	0.698	0.866
Prabha-Tech Enterprises	0.377	0.357	0.352	0.357	0.014	0.175	0.192
Pune Industrial Distributors Pvt.Ltd.	0.339	0.336	0.470	0.313	0.014	0.279	0.096
Element 14	0.393	0.399	0.176	0.402	0.408	0.244	0.289
Friends Industrial Suppliers	0.323	0.336	0.411	0.402	0.408	0.524	0.192
Pioneer Electro Devices	0.352	0.378	0.176	0.313	0.014	0.175	0.192
Rajiv Electronics	0.360	0.378	0.294	0.357	0.014	0.140	0.192
Yash Electronics	0.348	0.357	0.411	0.357	0.014	0.140	0.096
WEIGHTED NORMALISED MATRIX							
Saj Electronics Pvt.Ltd.	0.080	0.016	0.026	0.012	0.024	0.059	0.419
Prabha-Tech Enterprises	0.092	0.021	0.023	0.013	0.000	0.015	0.093
Pune Industrial Distributors Pvt.Ltd.	0.082	0.019	0.030	0.012	0.000	0.024	0.047
Element 14	0.096	0.023	0.011	0.015	0.012	0.021	0.140
Friends Industrial Suppliers	0.078	0.019	0.026	0.015	0.012	0.044	0.093
Pioneer Electro Devices	0.085	0.022	0.011	0.012	0.000	0.015	0.093
Rajiv Electronics	0.087	0.022	0.019	0.013	0.000	0.012	0.093
Yash Electronics	0.084	0.021	0.026	0.013	0.000	0.012	0.047

Figure 5.

3. Calculate S* and S—

A* and A— values calculated using Eq. (3) & (4) while using Eq. (5) & (6) the values of S* & S—calculated and are as shown below

IDEAL SEPARATION MATRIX	S*	S-
Saj Electronics Pvt.Ltd.	0.0526	0.3735
Prabha-Tech Enterprises	0.3273	0.0663
Pune Industrial Distributors Pvt.Ltd.	0.3744	0.0360
Element 14	0.2800	0.1049
Friends Industrial Suppliers	0.3288	0.0506
Pioneer Electro Devices	0.3272	0.0677
Rajiv Electronics	0.3272	0.0683
Yash Electronics	0.3740	0.0482

Figure 6.

4. Find C* value and rank the suppliers.

Value of C* is calculated using Eq. (7). The ranking is done such that the supplier having highest C* value has rank "1" and the one with lowest C* value as last.

SUPPLIER	Ci*	RANK
Saj Electronics Pvt.Ltd.	0.877	1
Prabha-Tech Enterprises	0.169	5
Pune Industrial Distributors Pvt.Ltd.	0.088	8
Element 14	0.273	2
Friends Industrial Suppliers	0.133	6
Pioneer Electro Devices	0.172	4
Rajiv Electronics	0.173	3
Yash Electronics	0.114	7

Figure 7.

VI. CONCLUSION

In supply chains, co-ordination between a manufacturer and suppliers is typically a difficult and important link in the channel of distribution. This paper presents a multi-criteria decision making for evaluation of supplier by implementing TOPSIS method. This method is simple to understand and permits the pursuit of best alternatives criterion depicted in a simple mathematical calculation. Due to this, decision making for selection of suitable supplier is of special importance. Acquired results from numerical example determine that this model could be used for decision making optimization in supplier selection

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