Comparative Study of Supplier Selection by using Analytical Hierarchy Process in Supply Chain Management

Engineering

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ABSTRACT *The success of any manufacturing organization is largely depends on suitable selection of its supplier as it ensures organizations to meet its customer demand within due time. Supplier selection process essentially depends on some important factor such as quality, cost, serviceability, capacity and compliance (CC) and supplier portfolio (SP). All these factors are selected on the basis of their influence on the firm performance and customer satisfaction. So there is a need to develop an approach which integrates all these important factors with their respected weightage. It is a multi-objective problem which is solved with the help of comparative study of supplier selection by using an analytical hierarchy process (AHP) in supply chain management. This paper undertakes a case study on solving the supplier selection process problem in a production firm which requires multiple parts of the final product and the supplier changes time to time because of their dynamic nature.*

INTRODUCTION

In today's highly competitive and dynamic environment, optimization of supply chain to meet the increasing customer's demand is an important task for manufacturing organizations, within due time keeping the desired quality level in minimum cost. According to Enyinda, Chris I. (2010) [2], selection of competent suppliers is an important issue for purchasing and supply chain management. In the current paradigm of lean production, there have been many manufacturing organizational and managerial modifications in vendor-rating systems as given by Riccardo and Valeria (2003) [8].The traditional approaches for supplier selection were based solely on price but with the advent of time, need for more dynamic and comprehensive approach was felt. Essentially, supplier selection is a decision process. As proposed by Francisco, Lauro and Luiz (2014) [4], these decisions are based on evaluation of suppliers on multiple quantitative as well as qualitative criteria. However, Remica and Ainesh (2015) [7] proposed that uncertainty in demand, vendor's capacity, lead time and quality makes selection of suppliers more challenging for a firm whereas Nilesh R, S. P. Singh and D. K. Banwet (2014) [5] concluded that supplier selection is dynamic in nature as business of any organization is a continuous process. When considering a multi-period horizon, number of suppliers could be changed in each period, depending upon the organization's requirement (or demand) due to the fluctuations in alternative suppliers and number of criteria, Analytical Hierarchy Model and Fuzzy Logic were incorporated with supplier selection process. The decision based on Analytical Hierarchy has been best explained by Thomas L. Saaty (1990) [10] who presented a mathematical model using pairwise comparison ratio matrix. Nydick and Ronald (1992) [9] then used this model for supplier selection considering quality, service, delivery and cost as the prime factors responsible for supplier selection. However, in today's scenario, for efficient selection of supplier, the buyer must consider supplier's portfolio in terms of its awareness towards standards and certifications and its level of being responsible and friendly towards environment and their employees, as an important factor. A review by Wan Lung Ng [11] discussed an efficient and comprehensive model for multiple criteria supplier selection problem. Francisco, Lauro and Luiz (2014) [4] used a Hybrid model combining Fuzzy AHP and Fuzzy TOPSIS to select suppliers more effectively.

In this paper, a large number of criteria for supplier selection process are combined into some specific number of factors viz. Quality, Cost, Serviceability, Capacity & Compliance and Supplier's Portfolio. The combination of these criteria requires a great

analysis over the effect of them on the supplier selection. All these factors have their own importance and this is presented with the help of their weightage which improves the overall selection process. All these factors are represented as Indices and integration of analytical hierarchy with these factors makes an efficient model to suggest the best supplier for the firm in a very less time.

NOTATION

n_i = number of products in a sample

r_i = number of rejected products

N = number of required product

U_s = unit cost by s^{th} supplier   {s=1, 2, 3…}

T_s = transportation cost of sth supplier {s=1, 2, 3…}

METHODOLOGY ADOPTED

The research methodology which is applied here starts with the selection of variables and end with supplier selection. Taking the literature review and case study into account, results in 9 variables such as quality, cost, delivery, service rate, manufacturing capacity, annual turnover, flexibility, green purchasing and ISO certification. These variables are then grouped into 5 criteria through index analysis.
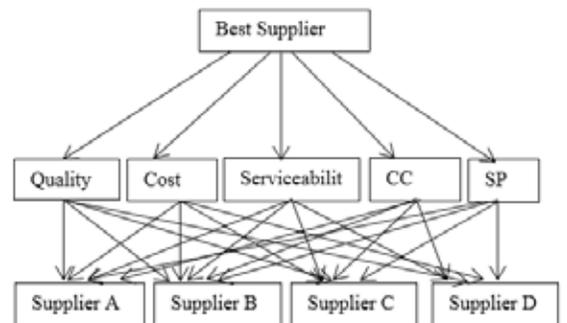

Figure 1: Analytical Hierarchical Model for Supplier Selection

The process of supplier selection comprises of criteria formula-

tion and qualification of potential suppliers. This will lead to the ultimate selection of one or two main suppliers. Here, an analytical hierarchical process (AHP) is used which includes different criteria for best supplier selection and relative importance of each supplier on the basis of different criteria. This analytical hierarchical model is shown in the Figure 1. Number of criteria can be varied according to the researcher's preference and liking and number of suppliers can be varied depending upon the product requirement

These indices are described in the following section.

a) Quality
40% weightage is given to this criterion for supplier selection process and it is calculated as

$$\text{Quality index} = \frac{10 - r_i}{10} \qquad (1)$$

b) Cost
Weightage of this index is taken as 25%. It is calculated as:

$$\text{Cost index} = \frac{(N \times U_s) + T_s}{\sum_{s=1}^{S}[(N \times U_s) + T_s]} \qquad (2)$$

c) Serviceability
Weightage of this index is taken as 15%. It is calculated with the help of two ratings i.e. time taken for delivery (R1) and time taken for repair/replacement/service (R2) are merged to give ranking for serviceability of the supplier.

$$SI = \frac{R_{1_s} + R_{2_s}}{\sum_{s=1}^{S}[R_{1_s} + R_{2_s}]} \qquad (3)$$

d) Capacity and Compliance
Higher the manufacturing capacity of the firm, higher will be its CC Index. Similarly, higher the annual turnover and flexibility, more rating will be allotted to the supplier. The weightage of this index in supplier selection is given as 12%.

e) Supplier Portfolio
A firm with more advanced and number of certificates of quality and standards followed in manufacturing will be given a higher ranking. This index holds a weightage of 8% in supplier selection analysis.

ILLUSTRATIVE EXAMPLE
To demonstrate the adopted methodology all the required data is collected. Firstly, the product is selected, i.e. Blow out coil for electro-pneumatic contactor. After that, the number of available suppliers for the same product is checked. Four suppliers were found in the nearby locations, termed as A, B, C & D. The ratings of each supplier based on different criteria are calculated separately as described in the following section.

TABLE-1
RATINGS FOR QUALITY INDEX

	Supplier A	Supplier B	Supplier C	Supplier D
	100	100	100	100
	4	1	3	5
Q	0.6	0.9	0.7	0.5

TABLE-2
RATINGS FOR COST INDEX

	Supplier A	Supplier B	Supplier C	Supplier D
	200	255	260	270
	2,000	15,000	55,000	32,000
C	0.188	0.742	0.286	0.738

TABLE-3
RATINGS FOR SERVICEABILITY INDEX

	Supplier A	Supplier B	Supplier C	Supplier D
	4	4	2	3
	2	4	3	1
S	0.26	0.35	0.22	0.17

CC Index rating and Portfolio Index rating along with the ratings shown in Tables 1, 2 & 3 are collectively shown in Table 4 for each supplier, depending on which the relative ranking of each supplier and consequently the final rankings of suppliers are calculated.

TABLE-4
RATINGS OF ALL CRITERIA FOR EACH SUPPLIER

	Supplier A	Supplier B	Supplier C	Supplier D
QI	0.6	0.9	0.7	0.5
CI	0.188	0.742	0.286	0.738
SI	0.26	0.35	0.22	0.17
CCI	0.60	0.80	0.95	1
SPI	0.50	0.75	0.80	1

Depending upon the weightage given to all the criteria, the importance of each criterion with respect to another is calculated and a matrix is constructed.

$$R = \begin{bmatrix} 0.5 & 0.62 & 0.73 & 0.77 & 0.83 \\ 0.39 & 0.5 & 0.63 & 0.68 & 0.76 \\ 0.27 & 0.38 & 0.5 & 0.56 & 0.65 \\ 0.23 & 0.44 & 0.5 & 0.5 & 0.6 \\ 0.17 & 0.24 & 0.35 & 0.40 & 0.5 \end{bmatrix} \qquad (4)$$

Each row of the previous matrix is summed up to get an element of a vector termed as "priority vector". Now, each element of this vector is divided by the sum of all elements in this vector to get a normalized rating of priority. This will be our required vector which shows the importance of each criterion.

$$R' = \begin{bmatrix} 0.275 \\ 0.236 \\ 0.188 \\ 0.167 \\ 0.133 \end{bmatrix} \qquad (5)$$

The relative rating for each supplier is calculated by dividing rating of one supplier to the rating of another supplier. This way, a matrix is constructed for each criterion as given in the following section.

Quality Index

$$M_1 = \begin{bmatrix} 1 & 0.67 & 0.86 & 1.2 \\ 1.5 & 1 & 1.29 & 1.8 \\ 1.17 & 0.78 & 1 & 1.4 \\ 0.83 & 0.55 & 0.71 & 1 \end{bmatrix} \quad (6)$$

Cost Index

$$M_2 = \begin{bmatrix} 1 & 0.25 & 0.66 & 0.26 \\ 3.9 & 1 & 2.59 & 1.00 \\ 1.52 & 1.38 & 1 & 0.387 \\ 3.93 & 0.99 & 2.58 & 1 \end{bmatrix} \quad (7)$$

Serviceability index

$$M_3 = \begin{bmatrix} 1 & 0.74 & 0.18 & 1.53 \\ 1.35 & 1 & 1.59 & 2.06 \\ 0.85 & 0.63 & 1 & 1.29 \\ 0.65 & 0.49 & 0.73 & 1 \end{bmatrix} \quad (8)$$

CC Index

$$M_4 = \begin{bmatrix} 1 & 0.75 & 0.63 & 0.60 \\ 1.33 & 1 & 0.84 & 0.80 \\ 1.58 & 1.19 & 1 & 0.95 \\ 1.67 & 1.25 & 1.05 & 1 \end{bmatrix} \quad (9)$$

SP Index

$$M_5 = \begin{bmatrix} 1 & 0.67 & 0.63 & 0.50 \\ 1.50 & 1 & 0.94 & 0.75 \\ 1.60 & 1.06 & 1 & 0.80 \\ 2 & 1.33 & 1.25 & 1 \end{bmatrix} \quad (10)$$

Each row of the previous matrix is summed up to get an element of a vector termed as "ranking vector". Now each element of this vector is divided by the sum of all elements in this vector to get a normalized ranking of supplier.

$$M_1' = \begin{bmatrix} 0.22 \\ 0.33 \\ 0.26 \\ 0.18 \end{bmatrix}, M_2' = \begin{bmatrix} 0.10 \\ 0.38 \\ 0.15 \\ 0.39 \end{bmatrix}, M_3' = \begin{bmatrix} 0.23 \\ 0.39 \\ 0.18 \\ 0.19 \end{bmatrix},$$

$$M_4' = \begin{bmatrix} 0.18 \\ 0.23 \\ 0.30 \\ 0.29 \end{bmatrix}, M_5' = \begin{bmatrix} 0.15 \\ 0.23 \\ 0.24 \\ 0.36 \end{bmatrix}$$

The final ranking of each supplier is calculated by summing up the multiplications of normalized ranking of supplier with normalized priority ranking of each criterion.

TABLE-5
FINAL RANKINGS

S. No.	Supplier	Ranking	Ranking %
1	A	0.33	47%
2	B	0.14	20%
3	C	0.15	21%
4	D	0.08	12%

RESULT

With respect to overall rating scores of alternative suppliers, supplier A (47%) is most preferred, followed by supplier C (21%), supplier B (20%), supplier D (12%), Essentially, supplier A is judged to be overall best.

It is found that this supplier is also preferred by the firm but the approach of their selection is very complex and time consuming. They also take a large number of factors, but this approach creates a new interest because of simplicity and ease of its application. It has various advantages over previously adopted approaches due to the inclusion of weightage of factors and a combined structure of selection criteria. It shows better results in terms of clear depiction of the best supplier.
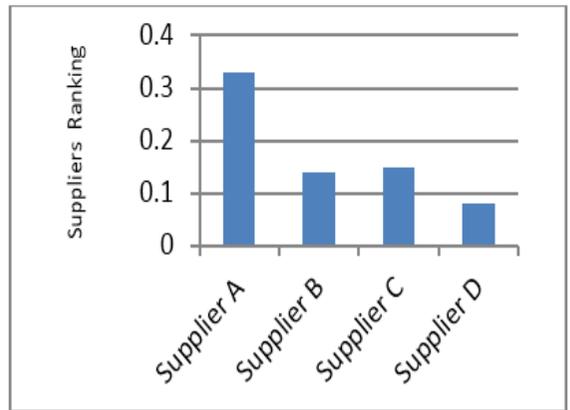

Figure 2: suppliers ranking

CONCLUSION AND FUTURE WORK

This paper presents a new methodology for decision making system in the supplier selection process. Starting from the combination of main criteria and integration with AHP, all suppliers are ranked to suggest the best supplier. AHP is a widely used decision-making process which is further modified with the help of efficient involvement of all influencing factors. Both factors, qualitative as well as quantitative are considered here. Literature has supported the determination of the supplier selection criterion to create an effective combination. The value acquired from supplier's personal evaluation of the factors evaluated in the hierarchy. Subsequently, the comparison matrix is calculated with pair-wise comparison matrix to obtain their ranks. Better rank shows the best supplier.

It is the initial phase of this integration, which requires more calculation in the future, it can be reduced with the help of software involvement and inclusion of programming could also be an advanced version of this methodology which will be able to provide factors values with more efficiency. Introduction of new factors can modify this method with respect to time.

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