

# Supplier Selection through AHP-VIKOR Integrated Methodology

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## Abstract

Supplier selection is one of the significant aspects of any supply chain. The incorrect decision on supplier selection affects not only the specific buyer but also the entire supply chain. The selection of good supplier may lead to reduce purchasing risk, maximize overall value to the purchaser and to establish reliable long-term relationships between buyers and suppliers. In fact, supplier selection is a multi-criteria decision making problem which includes both qualitative and quantitative factors. In this paper a methodology has been proposed by integrating Analytic Hierarchy Process (AHP) and Multi-criteria Optimization and Compromise Solution technique called VIKOR with a view to resolving the uncertainty while selecting the best one among various alternatives. A case study has been conducted in a manufacturing company to demonstrate the proposed methodology.

**Keywords** – Supplier selection, Multi-criteria decision making, AHP, VIKOR.

## I. INTRODUCTION

The supplier selection process has undergone significant changes in the past more than forty years (Thiruchelvam and Tookey, 2011). In the current competitive operating environment it is not possible to produce low cost, high quality products without the involvement of appropriate suppliers. Therefore, the decision on supplier selection plays an important role for the production and logistics management in many firms. As the suppliers have varied strengths and weaknesses, the purchase managers have to assess them carefully before ranking the suppliers. The supplier selection process would be simple if only one criterion was used in the decision making process. But in many situations, purchasers have to take account of a range of criteria in making their decisions (Yahya and Kingsman, 1999). The supplier selection is a multi-criteria decision making problem as it is influenced by multiple criteria. The performance criteria or attributes may be both qualitative as well as quantitative. In order to obtain solution for supplier selection problem, several decision models have been developed by the past researchers with the help of simple weighted techniques to advanced

mathematical programming methods. The linear weighting model, categorical model, weighted point model, total cost of ownership model, artificial neural network model and principal component analysis models are widely used to solve supplier selection problems with only quantitative information. It is observed from the literature that there has been little work in the area of application of multi-criteria decision making methods in solving the supplier selection problems (Chatterjee et al., 2011). In order to survive a company under heterogeneous unstable market conditions, the company has to adopt effective supplier selection methodology for identifying best supplier. The researchers are currently focusing on developing hybrid methodologies or integrated methodologies to provide effective solution for supplier selection problem. Pal et al., (2013) reviewed and analysed the literature thoroughly and addressed the issues of selection criteria and methods. They concluded that further attention is needed on the part of developing supplier selection methods by harmonizing the combination of qualitative and quantitative criteria. Nydic and Hill (1992) used analytic hierarchy process (AHP) to structure the supplier selection process. Tam and Tummala (2001) formulated AHP-based model and applied to a real case study to examine its feasibility in selecting a vendor for a telecommunications system. Handfield et al. (2002) integrated environment issues in their supplier assessment decisions with the help of AHP. Elanchezian et al.(2010) made an attempt to select the best vendor by using analytic network process (ANP) and technique for order preference by similarity to ideal solution (TOPSIS). Kilincci and Onal (2011) adopted fuzzy analytic hierarchy process based methodology to solve supplier selection problem in of a washing machine company in Turkey. Haldar et al.(2012) developed a hybrid MCDM model by using AHP-QFD methodology for resilient supplier selection. Durga Prasad et al.(2012)employed super efficiency and cross efficiency methods of Data Envelopment Analysis to establish suppliers' performance- efficiency score grid, which assists the purchases managers to select best supplier. Kassae et al. (2013) proposed an integrated hybrid MCDM model using Fuzzy ANP and Fuzzy TOPSIS to determine the weights of sub-criteria and attain ranking of the vendors. Asadabadi

(2014) developed a hybrid QFD-based approach to address supplier selection problem in product improvement process. Djordjevic et al. (2014) proposed a fuzzy MCDM approach by using fuzzy TOPSIS with a view to rank the artificial hip prosthesis suppliers. Siadat and Maleki (2015) adopted TOPSIS method to prioritize the suppliers from the view point of green supply chain criteria. In recent past, many researchers have used TOPSIS and VIKOR methods for decision making of supplier selection problem. Use of these two methods can help for best supplier selection on the basis of different criteria while considering their relative importance (Rajiv and Darshana, 2014). As VIKOR has much advantage over TOPSIS under group decision making environment (Liu, 2016), in the present work, an attempt has been made to apply VIKOR method for supplier selection. The Analytic Hierarchy Process (AHP) is employed for obtaining the priority structure of supplier selection attributes. The over view of AHP and VIKOR techniques are discussed briefly in the following paragraphs.

#### A. AHP

The AHP (Analytic Hierarchy Process) is a multi-criteria decision-making approach and was introduced by Saaty. The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria, and alternatives. The pertinent data are derived by using a set of pair-wise comparisons (Khan et al., 2014). The pair-wise comparisons are quantified by using a scale. Such a scale is a one-to-one mapping between the set of discrete linguistic choices available to the decision maker and a discrete set of numbers which represent the importance or weight of the previous linguistic choices. Saaty proposed a scale in which 9 as the upper limit and 1 as the lower limit and a unit difference between successive scale values. The values of the pair-wise comparisons in the AHP are determined according to the Saaty scale. According to Saaty scale, the available values for the pair-wise comparisons are members of the set: {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9} (Triantaphyllou and Mann, 1995). These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency. AHP aims at quantifying relative priorities for a given set of alternatives on a ratio scale, based on the judgment of the decision-maker, and stresses the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison of

alternatives in the decision-making process (Kamal, 2001).

#### B. VIKOR

The VIKOR (the Serbian name is 'VIšekriterijumsko KOmpromisno Rangiranje' which means multi-criteria optimization and compromise solution) method was mainly established by Zeleny and later advocated by Opricovic and Tzeng (Adhikary et al., 2015). This method helps to solve multi-criteria decision making problems with conflicting and non-commensurable criteria, assuming that a compromise can be acceptable for conflict resolution, when the decision maker wants a solution that is the closest to the ideal solution and farthest from the negative-ideal solution, and the alternatives can be evaluated with respect to all the established criteria. It focuses on ranking and selecting the best alternative from a set of alternatives with conflicting criteria, and on proposing the compromise solution (one or more). The compromise solution is a feasible solution, which is the closest to the ideal solution, and a compromise means an agreement established by mutual concessions made between the alternatives (Rao, 2007). In VIKOR method, the best alternative is preferred by maximizing utility group and minimizing regret group. This method calculates ratio of positive and negative ideal solution. In fact, both TOPSIS and VIKOR methods provide a ranking list. The highest ranked alternative by VIKOR is the closest to the ideal solution. However, the highest ranked alternative by TOPSIS is the best in terms of the ranking index, which does not mean that it is always the closest to the ideal solution. In addition to ranking the VIKOR method proposes a compromise solution with an advantage rate (Tzeng and Huang, 2011). Therefore, in the present work an integrated methodology is proposed by using AHP and VIKOR methods with a view to obtain solution for supplier selection problem.

## II. PROPOSED METHODOLOGY

In order to take wise decision on supplier selection, a methodology is proposed by combining Analytic Hierarchy Process (AHP) and VIKOR. The outline of the proposed methodology is shown in figure 1. In this methodology the priority structure of supplier selection attributes is obtained by using AHP. The weightages of the supplier selection attributes will be reflected in determining the VIKOR index for each supplier. On the basis of VIKOR indices it is easier for a decision maker to identify the best supplier. The step by step methodology is discussed below.

*Step 1:* Identification of supplier selection attributes

The process of selection of a supplier for any firm is started with the identification supplier selection attributes. The attributes for supplier selection are usually depends on the type of firm, product, purchasing capability etc. The top level executives

are generally involved in the identification of supplier selection attributes. There are a number of supplier selection attributes. But the most common attributes are quality, price, delivery, technical capability, performance history etc.

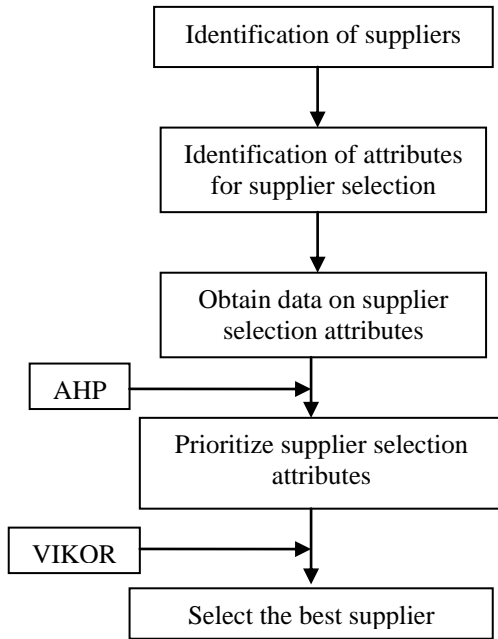


Fig. 1 Outline of the Proposed Methodology

**Step 2:** Obtain data on supplier selection attributes  
 The data pertaining to supplier attributes may be obtained through questionnaire survey. A questionnaire is developed by the purchase management of the company to obtain the response data on supplier selection attributes. The questionnaires are distributed to various suppliers of the company to obtain their responses.

**Step 3:** Determination of the priority structure of supplier selection attributes using AHP (Durga Prasad et al., 2011).

**Step 4:** Formulation of MCDM decision matrix:  
 The MCDM decision matrix has to be formed as shown below.

	$Cx_1$	$Cx_2$	$Cx_3$	·	·	$Cx_n$
$A_1$	$x_{11}$	$x_{12}$	$x_{13}$	·	·	$x_{1n}$
$A_2$	$x_{21}$	$x_{22}$	$x_{23}$	·	·	$x_{2n}$
$A_3$	$x_{31}$	$x_{32}$	$x_{33}$	·	·	$x_{3n}$
·	·	·	·	·	·	·
·	·	·	·	·	·	·
$A_m$	$x_{m1}$	$x_{m2}$	$x_{m3}$	·	·	$x_{mn}$

Where  $A_i$  = the  $i^{\text{th}}$  alternative ( $i = 1, 2, \dots, m$ )

$Cx_j$  = the  $j^{\text{th}}$  criterion ( $j = 1, 2, \dots, n$ )

$x_{ij}$  = individual performance of an alternative.

**Step 5:** Representation of normalized decision matrix  
 The normalized decision matrix can be expressed as follows:

$$F = [f_{ij}]_{m \times n}$$

$$\text{Where, } f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^n x_{ij}^2}}, \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n;$$

and  $x_{ij}$  is the performance of alternative  $A_j$  with respect to the  $j^{\text{th}}$  criterion.

**Step 6:** Determination of positive-ideal solution and negative-ideal solution

The positive ideal solution  $A^*$  and the negative ideal solution  $A^-$  are determined as follows:

$$A^* = \left\{ \left( \max f_{ij} \mid j \in J \right) \text{ or } \left( \min f_{ij} \mid j \in J \right) \mid i = 1, 2, \dots, m \right\}$$

$$= \{ f_1^*, f_1^*, \dots, f_j^*, \dots, f_n^* \}$$

$$A^- = \left\{ \left( \min f_{ij} \mid j \in J \right) \text{ or } \left( \max f_{ij} \mid j \in J \right) \mid i = 1, 2, \dots, m \right\}$$

$$= \{ f_1^-, f_1^-, \dots, f_j^-, \dots, f_n^- \}$$

**Step 7:** Calculation of Utility measure and Regret measure

The Utility measure ( $S_i$ ) and Regret measure ( $R_i$ ) for each alternative are computed using the following expressions

$$S_i = \sum_{j=1}^n w_j \times \left[ \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)} \right]$$

$$R_i = \max_j \left[ w_j \times \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)} \right]$$

Where  $w_j$  = weight of the  $j^{\text{th}}$  criterion.

**Step 8:** Computation of VIKOR index

The VIKOR index is calculated by using the following expression.

$$Q_i = v \left[ \frac{S_i - S^*}{S^- - S^*} \right] + (1-v) \left[ \frac{R_i - R^*}{R^- - R^*} \right]$$

Where,  $Q_i$  represents the  $i^{\text{th}}$  alternative VIKOR value,  $i = 1, 2, \dots, m$ ;  $S^* = \min_i(S_i)$ ,  $S^- = \max_i(S_i)$ ,

$$R^* = \min_i(R_i), \quad R^- = \max_i(R_i) \text{ and } v \text{ is the weight of}$$

the maximum group utility and its value is usually set to 0.5 (Kacker, 1985 and Opricovic, 1994).

**Step 9:** Rank the order of preference

The alternative which is having smallest VIKOR index value is the best solution.

### III. NUMERICAL ILLUSTRATION

In order to demonstrate the proposed methodology, a case study has been carried in hydraulic and pneumatic cylinders manufacturing company located in Visakhapatnam, Andhra Pradesh, India. At present the company has five suppliers for procuring necessary raw materials. The company is currently implementing bidding technique for the selection of supplier for procuring raw materials. In the current practice, the parameters such as quality,

lead time are not considered by the company. But, the company has to ensure that their products should meet the quality and specification standards for sustainability of the company in the competitive market environment. In order achieve this; the present study has been carried with a view to select the best supplier for the company to procure its raw materials. The response data on major supplier selection attributes namely quality, cost, warranty, capacity and delivery for the five suppliers of the industry are presented in table 1.

**Table1. The Response Data on Supplier Selection Attributes**

Supplier	Supplier selection attributes				
	Quality	Cost	Warranty	Capacity	Delivery
1	0.200	0.046	0.002	0.061	0.012
2	0.032	0.015	0.006	0.029	0.070
3	0.013	0.015	0.017	0.018	0.037
4	0.053	0.003	0.006	0.006	0.005
5	0.103	0.006	0.034	0.116	0.021

The pair-wise comparison matrix and the normalized pair-wise comparison matrix have been developed using AHP procedure (Venkata Subbaiah et al., 2011).

The table 2 shows the normalized pair-wise comparison matrix. The weightages for the supplier selection attributes is obtained by dividing each row sum of table 2 with the number of attributes. The priority structure of supplier selection attributes is presented in table 3. Saaty (1980) proposed consistency index (CI) and consistency ratio (CR) for checking the consistency of the pair-wise judgments. The CI and CR are defined as follows.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

and  $CR = \frac{CI}{RI}$

Where  $\lambda_{max}$  = maximum principal eigen value of the comparison matrix

and  $n$  = number of elements (order of the pair-wise comparison matrix)

The value of  $\lambda_{max}$  is obtained by first multiplying the pair-wise comparison matrix with the priority matrix. Then divide the first element of the resulting matrix by the first element of the priority matrix, the second element of the resulting matrix by the second element in the priority matrix, and so on. A single column matrix is obtained and the average of the elements of the matrix gives the value of  $\lambda_{max}$ . The RI in the above equation represents the average consistency index for numerous random entries of same-order reciprocal matrices (Saaty, 1980). In the present work, the value of CR is computed and is 0.09911, which is less than 0.10 and hence the AHP results were consistent (Chang et al., 2007).

**Table 2 Normalized Pair-Wise Comparison Matrix**

	Quality	Cost	Warranty	Capacity	Delivery
Quality	0.4044	0.5714	0.1667	0.5600	0.3429
Cost	0.1335	0.1905	0.3330	0.1600	0.3429
Warranty	0.2022	0.0476	0.0833	0.0400	0.0571
Capacity	0.0577	0.0952	0.1667	0.0800	0.0857
Delivery	0.2022	0.0952	0.2500	0.1600	0.1714

$$\frac{1}{5} \times \begin{bmatrix} 2.0454 \\ 1.1599 \\ 0.4302 \\ 0.4853 \\ 0.8788 \end{bmatrix} = \begin{bmatrix} 0.40908 \\ 0.23198 \\ 0.08604 \\ 0.09706 \\ 0.17576 \end{bmatrix}$$

**Table 3. Priority Structure of Supplier Selection Attributes**

Sl. No	Supplier selection attributes	Weightages ( $w_j$ )
1	Quality	0.40908
2	Cost	0.23198
3	Warranty	0.08604
4	Capacity	0.09706
5	Delivery	0.17576

On the basis of qualitative and quantitative data of five suppliers, normalized decision matrix is developed as discussed in step 5 of the section 2. The normalized decision matrix is obtained as given below.

$$X_i = \begin{bmatrix} 0.858 & 0.451 & 0.901 & 0.051 & 0.146 \\ 0.137 & 0.214 & 0.294 & 0.153 & 0.853 \\ 0.055 & 0.133 & 0.294 & 0.435 & 0.451 \\ 0.227 & 0.044 & 0.058 & 0.153 & 0.060 \\ 0.442 & 0.859 & 0.117 & 0.871 & 0.256 \end{bmatrix}$$

The positive ideal solution (PIS) and negative ideal solutions (NIS) are determined by considering the data under two approaches such as larger is better and smaller is better. For each

selection attribute the PIS ( $f_j^*$ ) and NIS ( $f_j^-$ ) are expressed as follows.

For Quality (Larger is Better):

$$f_j^* = 0.858 \text{ and } f_j^- = 0.055$$

For Cost (Smaller is Better):

$$f_j^* = 0.044 \text{ and } f_j^- = 0.859$$

For Warranty (Larger is Better):

$$f_j^* = 0.901 \text{ and } f_j^- = 0.058$$

For Capacity (Larger is Better):

$$f_j^* = 0.871 \text{ and } f_j^- = 0.051$$

For Delivery (Smaller is Better):

$$f_j^* = 0.060 \text{ and } f_j^- = 0.853$$

The utility measure ( $S_i$ ) and regret measure ( $R_i$ ) for all the supplier selection attributes have to be determined. As discussed in step 7 of the section 2, the values of ( $S_i$ ) and ( $R_i$ ) for quality are computed as follows.

$$S_{ij} = w_j \left[ \frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right]$$

For quality:  $w_j = 0.4097$ ;  $f_j^* = 0.858$ ;  $f_j^- = 0.055$

$$S_{11} = 0.40908 \times \frac{0.858 - 0.858}{0.858 - 0.055} = 0.00$$

$$S_{21} = 0.40908 \times \frac{0.858 - 0.137}{0.858 - 0.055} = 0.367$$

$$S_{31} = 0.40908 \times \frac{0.858 - 0.055}{0.858 - 0.055} = 0.409$$

$$S_{41} = 0.40908 \times \frac{0.858 - 0.227}{0.858 - 0.055} = 0.321$$

$$S_{51} = 0.40908 \times \frac{0.858 - 0.442}{0.858 - 0.055} = 0.212$$

In the same way utility measures for all other attributes with respect to all the suppliers are computed and are presented in utility matrix ( $S_{ij}$ ).

The utility measure ( $S_i$ ) and regret measure ( $R_i$ ) for all the suppliers are computed as discussed in the step 8 of section 2. The table 4 shows the values of utility measure and regret measure for all the five suppliers.

$$S_{ij} = \begin{bmatrix} 0.000 & 0.115 & 0.000 & 0.097 & 0.018 \\ 0.367 & 0.048 & 0.061 & 0.084 & 0.175 \\ 0.409 & 0.025 & 0.061 & 0.051 & 0.086 \\ 0.321 & 0.000 & 0.086 & 0.084 & 0.000 \\ 0.212 & 0.232 & 0.079 & 0.000 & 0.043 \end{bmatrix}$$

**Table 4 Utility Measure and Regret Measure Of The Suppliers**

Supplier	Utility measure ( $S_i$ )	Regret measure ( $R_i$ )
1	0.230	0.115
2	0.735	0.367
3	0.632	0.409
4	0.491	0.321
5	0.566	0.232

The VIKOR index for each supplier is computed as discussed in step 9 of section 2.

For supplier 1:

$$Q_1 = 0.5 \left[ \frac{0.230 - 0.230}{0.735 - 0.230} \right] + (1 - 0.5) \left[ \frac{0.115 - 0.115}{0.409 - 0.115} \right] = 0.00$$

For supplier 2:

$$Q_2 = 0.5 \left[ \frac{0.735 - 0.230}{0.735 - 0.230} \right] + (1 - 0.5) \left[ \frac{0.367 - 0.115}{0.409 - 0.115} \right] = 0.928$$

For supplier 3:

$$Q_3 = 0.5 \left[ \frac{0.632 - 0.230}{0.735 - 0.230} \right] + (1 - 0.5) \left[ \frac{0.409 - 0.115}{0.409 - 0.115} \right] = 0.898$$

For supplier 4:

$$Q_4 = 0.5 \left[ \frac{0.491 - 0.230}{0.735 - 0.230} \right] + (1 - 0.5) \left[ \frac{0.321 - 0.115}{0.409 - 0.115} \right] = 0.385$$

For supplier 5:

$$Q_5 = 0.5 \left[ \frac{0.566 - 0.230}{0.735 - 0.230} \right] + (1 - 0.5) \left[ \frac{0.232 - 0.115}{0.409 - 0.115} \right] = 0.532$$

The VIKOR indices for all the five suppliers are summarized in table 5.

**Table 5 VIKOR Indices for all the suppliers**

Supplier	1	2	3	4	5
VIKOR Index	0.0	0.928	0.898	0.385	0.532

It is observed from the table 5, the supplier 1 has lower value of VIKOR index. According to VIKOR method the alternative with the lower value of VIKOR index is the best alternative among the number of alternatives under consideration. Therefore, the supplier 1 is the best supplier for the manufacturing company considered in the present study.

#### IV. CONCLUSIONS

The ultimate objective of dealing with the supplier selection problem is to obtain a solution for selecting a best supplier. The best supplier may provide faster delivery, reduced cost along with the improved quality in order to increase competitive advantage in the market. In the present work, an integrated model of AHP-VIKOR for supplier selection has been developed and demonstrated the methodology through a case study conducted in

hydraulic and pneumatic cylinders manufacturing company. This integrated model is well suited to deal with multi-criteria decisions that involve both qualitative and quantitative factors. The proposed methodology can be applied for supplier selection in any manufacturing company.

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