MULTI-CRITERIA DECISION MAKING APPROACH FOR VENDOR SELECTION

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Certificate of Approval

This is to certify that the thesis entitled **MULTI-CRITERIA DECISION MAKING APPROACH FOR VENDOR SELECTION** submitted by ***Sri Utkarsh Yadav*** has been carried out under my supervision in partial fulfillment of the requirements for the Degree of ***Bachelor of Technology (B. Tech.)*** in ***Mechanical Engineering*** at National Institute of Technology, NIT Rourkela, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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Abstract

In the present study an efficient Multi-Criteria Decision Making (MCDM) approach has been proposed for quality evaluation and performance appraisal in vendor selection. Vendor selection is a Multi-Criteria Decision Making (MCDM) problem influenced by multiple performance criteria/attributes. These criteria attributes may be both qualitative as well as quantitative. Qualitative criteria estimates are generally based on previous experience and expert opinion on a suitable conversion scale (Likert Scale). This conversion is based on human judgment; therefore, predicted result may not be accurate always because the method doesn't explore real data. These are analyzed using AHP, QFD, Fuzzy techniques etc. reported in literature. In solution of MCDM problems there should be a common trend is to convert quantitative criteria values into an equivalent single performance index called Multi-attribute Performance Index (MPI). Benchmarking and selection of the best alternative can be made in accordance with the MPI values of all the alternatives. In this context, present study highlights application of VIKOR method adapted from MCDM for utilizing quantitative real performance estimate scores. Detail methodology of VIKOR method has been illustrated in this reporting through a case study.

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1. Introduction

The vendor selection process can be a very complicated and emotional undertaking if you don't know how to approach it from the very start. Here are five steps to help you select the right vendor for your business. This guide will show you how to analyze your business requirements, search for prospective vendors, lead the team in selecting the winning vendor and provide you with insight on contract negotiations and avoiding negotiation mistakes.

Analyze the Business Requirements

Before you begin to gather data or perform interviews, assemble a team of people who have a vested interest in this particular vendor selection process. The first task that the vendor selection team needs accomplish is to define, in writing, the product, material or service that you are searching for a vendor. Next define the technical and business requirements. Also, define the vendor requirements. Finally, publish your document to the areas relevant to this vendor selection process and seek their input. Have the team analyze the comments and create a final document. In summary:

1. Assemble an Evaluation Team
2. Define the Product, Material or Service
3. Define the Technical and Business Requirements
4. Define the Vendor Requirements
5. Publish a Requirements Document for Approval

Vendor Search

Now that you have agreement on the business and vendor requirements, the team now must start to search for possible vendors that will be able to deliver the material, product or service. The larger the scope of the vendor selection process the more vendors you should put on the table. Of course, not all vendors will meet your minimum requirements and the team will have to decide which vendors you will seek more information from. Next write a Request for Information (RFI) and send it to the selected vendors. Finally, evaluate their responses and select a small number of vendors that will make the "Short List" and move on to the next round. In summary:

1. Compile a List of Possible Vendors
2. Select Vendors to Request More Information From
3. Write a Request for Information (RFI)
4. Evaluate Responses and Create a "Short List" of Vendors

Request for Proposal (RFP) and Request for Quotation (RFQ)

The business requirements are defined and you have a short list of vendors that you want to evaluate. It is now time to write a *Request for Proposal* or *Request for Quotation*. Which ever format you decide, your RFP or RFQ should contain the following sections:

1. Submission Details
2. Introduction and Executive Summary

3. Business Overview & Background
4. Detailed Specifications
5. Assumptions & Constraints

Proposal Evaluation and Vendor Selection

The main objective of this phase is to minimize human emotion and political positioning in order to arrive at a decision that is in the best interest of the company. Be thorough in your investigation, seek input from all stakeholders and use the following methodology to lead the team to a unified vendor selection decision:

1. Preliminary Review of All Vendor Proposals
2. Record Business Requirements and Vendor Requirements
3. Assign Importance Value for Each Requirement
4. Assign a Performance Value for Each Requirement
5. Calculate a Total Performance Score
6. Select a the Winning Vendor

Contract Negotiation Strategies

The final stage in the vendor selection process is developing a contract negotiation strategy. Remember, you want to "partner" with your vendor and not "take them to the cleaners." Review your objectives for your contract negotiation and plan for the negotiations be covering the following items:

1. List Rank Your Priorities Along With Alternatives
2. Know the Difference Between What You Need and What You Want
3. Know Your Bottom Line So You Know When to Walk Away
4. Define Any Time Constraints and Benchmarks
5. Assess Potential Liabilities and Risks
6. Confidentiality, non-compete, dispute resolution, changes in requirements
7. Do the Same for Your Vendor (i.e. Walk a Mile in Their Shoes)

Contract Negotiation Mistakes

The smallest mistake can kill an otherwise productive contract negotiation process. Avoid these ten contract negotiation mistakes and avoid jeopardizing an otherwise productive contract negotiation process.

2. Prior State of Art

In today's competitive manufacturing world selection of an appropriate vendor has become a great concern for various enterprises. Quality and performance appraisal of candidate vendors are indeed required to select the best one before a mass production of a new product is targeted. In most of the cases this selection procedure is based on their previous performance records which finally determine who will get the opportunity for supply contract [Datta et al. (2010)].

Roodhooft and Konings (1996) proposed an Activity Based Costing approach for vendor selection and evaluation. This system allowed us to compute total costs caused by a supplier in a firm's production process, thereby increasing the objectivity in the selection process. The authors showed that for vendor evaluation purposes the difference between the budgeted and actual total vendor score can be decomposed in a purchaser effect, a supplier effect and a combined effect. An Activity Based Costing approach with a case study was illustrated in this paper. Charles et al. (1998) described three approaches for the selection and negotiation with vendors who were not selected. Furthermore, it described how in certain situations two multi-criteria analysis tools, multi-objective programming and data envelopment analysis, could be used together for this selection and negotiation process. The author described non-cooperative vendor negotiation strategies where the selection of one vendor results in another being left out of the solution. Ding et al. (2003) presented a simulation-optimization approach using genetic algorithm to the supplier selection problem. The problem consists in selecting a portfolio of suppliers from a set of pre-selected candidates. The proposed approach used discrete-event simulation for performance evaluation of a supplier portfolio and a genetic algorithm for optimum portfolio identification based on performance indices estimated by the simulation. Numerical results on a real-life case study were presented. Chih-Hung Tsai et al. (2003) applied the Grey relational analysis in the Grey theory (Deng, 1982) to establish a complete and accurate evaluation model for selecting vendors. This methodology significantly reduced the purchasing cost and increased the production efficiency and overall competitiveness. Kumar et al. (2004) applied a fuzzy goal programming approach for solving the vendor selection problem with multiple objectives, in which some of the parameters are fuzzy in nature. A vendor selection problem was formulated as a fuzzy mixed integer goal programming vendor selection problem that includes three primary goals: minimizing the net cost, minimizing the net rejections, and minimizing the net late deliveries subject to realistic constraints regarding buyer's demand, vendors' capacity, vendors' quota flexibility, purchase value of items, budget allocation to individual vendor, etc. Heung-Suk Hwang et al. (2005) proposed a supplier selection analysis model considering both by AHP method and integration method of analysis results. The proposed first analysis model using AHP which was a three-step decision analysis model which converts the qualitative factors of suppliers transferred into the quantitative measure reliability. Then, the integration model integrates the results of multi-analysis and selects the best supplier. The authors also developed a computer program for both the AHP model and for integration model. Bayazita and Karpakb (2005) reported that supplier selection is one of the most crucial activities performed by the organizations because of its strategic importance. A supplier selection problem is a multi-objective problem involving both quantitative and qualitative criteria. Over the years a number of quantitative approaches have been applied to supplier selection problems. Although the Analytic Hierarchy Process (AHP) has previously been implemented in supplier selection problems, in this paper for the first time a comprehensive application of AHP for a real-world case is presented along with sensitivity analysis to choose the best supplier. We proposed an AHP model to choose the best supplier and place the order quantities among them for a construction company. Sonmez (2006) reported the findings of a wide ranging literature review of supplier selection practices and models. Chen and Chen (2006) applied the process incapability index to develop an evaluation model that assesses the quality performance of suppliers. The model simplifies the evaluation of suppliers, facilitates their effective selection, and provides insights into the process situation of suppliers who may enter into a long-term partnership with a company. Kubat and Yuce (2006) suggested integrating Analytic Hierarchy Process (AHP), Fuzzy AHP and Genetic Algorithm (GA) to determine best suppliers. Fuzzy set was utilized linguistic factor to organize criteria and sub criteria weight, with pair wise compare with fuzzy AHP; it was recommended to be utilized to organize all factors and which assigned weighting for related factor. Finally, a hypothetical supplier selection problem was solved by proposed (GA) algorithm. Xiao et al. (2006) proposed a new approach for online supplier selection, based on state of the art literature and existing industry practices. One important aspect of developing collaborations was to locate and select suitable partners, especially for OEMs (Original Equipment Manufacturers) who often need to initiate collaborations with their suppliers. This resulted in a desire for effective and efficient supplier selection. With the development of information technologies, especially internet technologies, OEMs could now source and select suppliers on the internet, on an international scale. Chandra Mouli KVV et al. (2006) proposed a methodology for selection of vendors and quantities to be ordered based on transportation cost criteria. Particle swarm optimization (PSO) technique was used in constrained handling to arrive an optimal solution. A case study of an automobile components manufacturing company was presented to illustrate the methodology. Gencer and Gürpinar (2007) considered supplier selection as a multi criteria decision problem. A model aiming the usage of analytic network process (ANP) in supplier selection was developed owning to the evaluation of the relations between supplier selection criteria in a feedback systematic in an electronic company. Tahriri et al. (2008) highlighted different selection methods concerning supplier selection. The advantages and disadvantages of selection methods, especially the Analytic Hierarchy Process (AHP) were illustrated and compared in their work. Ketata et al. (2008) proposed a new approach based on the integration of the fuzzy logic with the classical multi-criteria methods on the one hand and taking into account the concept of supplier reliability for resolving a supplier selection and evaluation problem on the other hand. The first approach called “Method with Constraints” (MC) consists of combination of the “Fuzzy Analytical Hierarchy Process” (FAHP) with the “Goal Programming” (GP) methods. This method reflects the idea of supplier reliability and at the same time the quantitative and qualitative factors. Considering the fuzzy constraints, the authors proposed the second approach called “Method with Fuzzy Constraint” (MCF) which consists of combination of the FAHP with the “Fuzzy Goal Programming” (FGP) methods. Omid Jadidi et al. (2008) proposed a method based on TOPSIS concepts in grey theory to deal with the problem of selecting suppliers. The method calculates the weighted connection between each of the alternatives sequence and the positive and negative referential sequence to compare the ranking of grey numbers and select the most desirable supplier. The authors demonstrated that the method was a good means of evaluation, and it was also more optimal than the two methods. Taghavifard and Mirheydari (2008) suggested an algorithm for the evaluation and selection of suppliers. At the beginning, all the needed materials and services used by the organization were identified and categorized with regard to their nature by ABC method. Afterwards, in order to reduce risk factors and maximize the organization's profit, purchase strategies were determined. Then, appropriate criteria were identified for primary evaluation of suppliers applying to the organization. The output of this stage was a list of suppliers qualified by the organization to participate in its tenders. Subsequently, considering a material in particular, appropriate criteria on the ordering of the mentioned material were determined, taking into account the particular materials' specifications as well as the organization's needs. Finally, for the purpose of validation and verification of the proposed model, it was applied to Mobarakeh Steel Company (MSC), the qualified suppliers of this Company are ranked by the means of a Hierarchical Fuzzy TOPSIS method. The obtained results show that the proposed algorithm is quite effective, efficient and easy to apply.

Many of the methodologies reported in literature rely on subjective or qualitative data based on human judgment which may prone to be incorrect. In this evaluation process, both quantitative and qualitative performance parameters are converted into numeric score using some appropriate scale (Likert Scale). The numeric scores of each criteria multiplied by individual priority weight are added together to compute an overall performance index. However, this method doesn’t consider exact values of quantitative performance indices; which may lead to misleading result. To overcome this shortcoming, in the present reporting VIKOR based Multi-Criteria Decision Making (MCDM) approach has been proposed to utilize exact numeric values of quantitative parameters (quality and performance indices). Detailed methodology of the aforesaid approach has been illustrated in this reporting through a case study.

3. VIKOR Method

The MCDM method is very popular technique widely applied for determining the best solution among several alternatives having multiple attributes or alternatives. A MCDM problem can be represented by a decision matrix as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ . \\ . \\ . \\ . \\ A_m \end{array} \begin{bmatrix} \underline{Cx_1} & \underline{Cx_2} & . & . & . & . & \underline{Cx_n} \\ x_{11} & x_{12} & . & . & . & . & x_{1n} \\ x_{21} & x_{22} & . & . & . & . & x_{2n} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ x_{m1} & x_{m2} & . & . & . & . & x_{mn} \end{bmatrix} \tag{1}$$

Here, A_i represents ith alternative, $i = 1, 2, ..., m$; Cx_j represents the jth criterion, $j = 1, 2, ..., n$; and x_{ij} is the individual performance of an alternative. The procedures for evaluating the best solution to an MCDM problem include computing the utilities of alternatives and ranking these alternatives. The alternative solution with the highest utility is considered to be the optimal solution.

The following steps are involved in VIKOR method [Opricovic, S. and Tzeng, G.-H., 2007]:

Step 1: Representation of normalized decision matrix

The normalized decision matrix can be expressed as follows:

$$F = \left[f_{ij} \right]_{m \times n} \tag{2}$$

Here, $f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$, $i = 1, 2, ..., m$; and x_{ij} is the performance of alternative A_i with respect to the jth criterion.

Step 2: Determination of ideal and negative-ideal solutions:

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

$$A^* = \left\{ (\max f_{ij} \middle| j \in J) \, or \, (\min f_{ij} \middle| j \in J^{'}), i = 1, 2, ..., m \right\} = \left\{ f_1^*, f_2^*, ...f_j^*, ...f_n^* \right\} \tag{3}$$

$$A^- = \left\{ (\min f_{ij} \middle| j \in J) \, or \, (\max f_{ij} \middle| j \in J^{'}), i = 1, 2, ..., m \right\} = \left\{ f_1^-, f_2^-, ...f_j^-, ...f_n^- \right\} \tag{4}$$

where, $J = \left\{ j = 1, 2, ..., n \middle| f_{ij}, if \; desired \; response \; is \; l \arg e \right\}$

$J^{'} = \left\{ j = 1, 2, ..., n \middle| f_{ij}, if \; desired \; response \; is \; small \right\}$

Step 3: Calculation of utility measure and regret measure

The utility measure and the regret measure for each alternative are given as

$$S_i = \sum_{j=1}^{n} w_j \frac{\left(f_j^* - f_{ij} \right)}{\left(f_j^* - f_j^- \right)} \tag{5}$$

$$R_i = \underset{j}{Max}\left[w_j \frac{\left(f_j^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \right] \tag{6}$$

where, S_i and R_i, represent the utility measure and the regret measure, respectively, and w_j is the weight of the jth criterion.

Step 4: Computation of VIKOR index

The VIKOR index can be expressed as follows:

$$Q_i = \upsilon\left[\frac{S_i - S^*}{S^- - S^*}\right] + \left(1-\upsilon\right)\left[\frac{R_i - R^*}{R^- - R^*}\right] \tag{7}$$

where, Q_i, represents the ith alternative VIKOR value, $i = 1, 2, ..., m$;

$S^* = \underset{i}{Min}\,(S_i)$;

$S^- = \underset{i}{Max}\,(S_i)$; $R^* = \underset{i}{Min}\,(R_i)$; $R^- = \underset{i}{Max}\,(R_i)$ and υ is the weight of the maximum group utility (usually it is to be set to 0.5). The alternative having smallest VIKOR value is determined to be the best solution.

4. Procedure Adopted in VIKOR method for MCDM

Step 1: Estimation of quality loss

Taguchi defined quality loss estimates for responses using Lower-the-better (LB) and Higher-the-better (HB) criterion are given bellow.

(a) For a Lower-the-Better (LB) attribute:

$$L_{ij} = k_1 \times \frac{1}{r}\sum_{k=1}^{r} y_{ijk}^2 \tag{8}$$

(b) For a Higher-the-Better (LB) attribute:

$$L_{ij} = k_2 \times \frac{1}{r}\sum_{k=1}^{r}\frac{1}{y_{ijk}^2} \quad (9)$$

Here, L_{ij} is the quality loss associated with the jth attribute in the ith experimental run; y_{ijk} is the observed kth repetition datum for the jth attribute in the ith experimental run; r is the number of repetitions for each experimental run. k_1, k_2 are quality loss coefficients, $i = 1, 2, ..., m$; $j = 1, 2, ..., n$; $k = 1, 2, ..., r$.

Step 2: Calculation of normalized quality loss (NQL) for individual attributes in each experimental run. The NQL can be obtained as follows:

$$f_{ij} = \frac{L_{ij}}{\sqrt{\sum_{i=1}^{m} L_{ij}^2}}, \; i = 1, 2, ..., m; \; j = 1, 2, ..., n. \quad (10)$$

Here f_{ij} represents the NQL of the jth attribute in the ith experimental run.

Step 3: Evaluation of ideal and negative-ideal solutions.

A smaller NQL is preferred, so the ideal and negative-ideal solutions which represent the minimum and maximum NQL of all experimental runs are as follows:

$$A^* = \left\{ \min f_{ij} \middle| i = 1, 2, ..., m \right\} = \left\{ f_1^*, f_2^*, ..., f_j^*, ..., f_n^* \right\} \quad (11)$$

$$A^- = \left\{ \max f_{ij} \middle| i = 1, 2, ..., m \right\} = \left\{ f_1^-, f_2^-, ..., f_j^-, ..., f_n^- \right\} \quad (12)$$

Step 4: Calculation of the utility and regret measures for each response in each experimental run using equation (5) and (6) respectively.

Step 5: Calculation of VIKOR index of the ith experimental run. Substituting S_i and R_i into equation (7) yields the VIKOR index of the ith experimental run as follows. A smaller VIKOR index produces better multi-response performance.

Step 6: Determination of optimal parametric combination

The multi-attribute quality scores for each alternative can be determined from the VIKOR index obtained in step 5. The best one is finally determined, in view of the fact that a smaller VIKOR value indicates a better quality.

5. Results of VIKOR Method: An Example

As a case study, the vendor selection problem in procuring silencer of vehicle in an automotive industry in eastern part of India has been explored. Table 1 represents multiple attributes to be taken under consideration while selecting an appropriate vendor. The industry has its own requirements which have been assumed as target. The targeted values of each criterion correspond to the elements of reference data series for comparison. The target is to minimize cost, achieve high insertion loss and less volume, less weight, less number of components associated with the silencer.

Quality loss estimates for individual attributes have been calculated using equations (8 and 9). For cost, volume, weight and number of components, LB (Lower-the-Better) criteria and for insertion loss HB (Higher-the-Better) criteria have been selected. Normalized quality loss estimates (NQL) have been determined using equation (10) and shown in Table 2. Table 3 represents utility measure of individual attributes (criterion). Individual attribute weights have been used as 0.20 (equal priority weight). Utility and regret measure for each alternative have been tabulated in Table 4. VIKOR INDEX of each alternative (candidate vendor) has been presented in Table 5. The appropriate alternative indicates smallest VIKOR INDEX. From Table 5 the individual candidate vendors can be ranked according to their VIKOR INDEX.

6. Conclusion

In the present study, application feasibility of a MCDM approach: VIKOR method has been highlighted to solve multi-criteria decision making problems through a case study of vendor selection. The study demonstrates the effectiveness of the said MCDM techniques in solving such a vendor selection problem.

Table 1: Attributes for Silencer of a Vehicle: Vendor Selection Criteria

Sl. No.	Attributes C_i	Alternative Vendors				
		A	B	C	D	E
1	Cost (Rs.)	1800	400	1000	1200	1400
2	Insertion Loss (dB)	12	7	9	8	10
3	Volume (CC)	44000	9000	30000	37000	40000
4	Weight (Kg)	20	5	10	12	16
5	No. of Components	10	6	7	8	9

Table 2: Normalized quality loss estimates (NQL)

Vendors	Cost	Insertion Loss	Volume	Weight	Components
A	0.8266	0.2240	0.6454	0.7892	0.6408
B	0.0408	0.6582	0.0270	0.0493	0.2307
C	0.2551	0.3982	0.3000	0.1973	0.3140
D	0.3674	0.5040	0.4564	0.2841	0.4101
E	0.5000	0.3225	0.5334	0.5051	0.5190

The ideal and negative-ideal solutions which represent the minimum and maximum NQL of all alternatives are as follows:

$$A^{*} = \left\{\min f_{ij} \middle| i = 1,2,3,4,5\right\} = \left\{f_1^{*}, f_2^{*}, f_3^{*}, f_4^{*}, f_5^{*}\right\} = \left\{0.0408, 0.2240, 0.0270, 0.0493, 0.2307\right\}$$

$$A^{-} = \left\{\max f_{ij} \middle| i = 1,2,3,4,5\right\} = \left\{f_1^{-}, f_2^{-}, f_3^{-}, f_4^{-}, f_5^{-}\right\} = \left\{0.8266, 0.6582, 0.6454, 0.7892, 0.6408\right\}$$

Table 3: Utility measures of individual criteria attribute

Vendors	Cost	Insertion Loss	Volume	Weight	Components
A	0.2000	0.0000	0.2000	0.2000	0.2000
B	0.0000	0.2000	0.0000	0.0000	0.0000
C	0.0545	0.0802	0.0883	0.0400	0.0406
D	0.0831	0.1290	0.1389	0.0635	0.0875
E	0.1169	0.0454	0.1638	0.1232	0.1406

Table 4: Utility measures (S_i) and regret measures (R_i) of alternatives

Vendors	S_i	R_i
A	0.4545	0.2000
B	0.4546	0.2000
C	0.5909	0.0883
D	0.4267	0.1389
E	0.4687	0.1638

Table 8: VIKOR index of individual alternatives

Vendors	VIKOR INDEX	Ranking
A	0.5879	2
B	0.5882	1
C	0.5190	3
D	0.2265	5
E	0.4707	4

#Vendor B is to be selected

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8. Communication

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