The Integration of Fuzzy Analytic Hierarchy Process and VIKOR for Supplier Selection

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***Abstract*— Supplier selection is one of the Multi-Criteria Decision Making problems since it involves many suppliers with different criteria that often conflict with each other. This paper shows the integration of Fuzzy Analytical Hierarchy Process (FAHP) and VIKOR methods in selecting the best supplier in a selected automotive spare part manufacturing company. FAHP is used to calculate the important weights of the evaluation criteria and the overall performance for ranking of suppliers is then determined by VIKOR. Results show that there is no supplier with the same performance value from the FAHP-VIKOR analysis as compared to normal practice in that particular company which eventually can help the decision maker to select the supplier.**

Keywords*—Fuzzy Analytical Hierarchy Process; Fuzzy Weight, Ranking; Supplier Selection; VIKOR.*

1. Introduction

Selecting the best supplier is one of the vital decisions for any firm especially for those in manufacturing industries in order to achieve an efficient supply chain and attain the company goal. Ref. [1] discussed how high performing companies put a lot of attention on selecting their suppliers. In order for these companies to maintain their performance, it is essential for them to choose the best suppliers that are able to offer quality spare parts or raw materials with good price and at the right time [2]. Furthermore, high quality raw materials supplied at the right time would help the companies to produce high quality end products. Hence, in ensuring a continuous smooth supply chain, while reducing operational costs and risks in meeting customers' expectancy, the performance of the suppliers should be evaluated consistently.

Supplier selection is a multi-criteria decision making problem which involves many criteria. Choosing correct criteria can be considered as heart of the supplier evaluation process. Dickson [4] is the first person who considered the supplier selection criteria. His twenty-three criteria has become a main reference for evaluating supplier's performance. Since that many researchers have revised and provided the most significant criteria for supplier selection [4-6]

This paper aims to illustrate how two multi-criteria methods, FHAP [7] and VIKOR [8] were integrated in analyzing performances of suppliers of automotive spare parts for a manufacturing company in Penang, Malaysia. This paper is organized as follows. The following section provides the development of the integrated model of FHAP-VIKOR. It is followed by sections that discuss on the conducted case study, conclusions.

2. Supplier Selection Model Development

In selecting the best supplier that complies with the company goal, experts of the company, in particular the purchasing managers need to identify the criteria and the sub-criteria. Then, FAHP is used to evaluate the importance weights of criteria, sub-criteria and alternatives. FAHP uses pairwise comparison along with expert judgements based a nine point scale of linguistic terms. Center of gravity defuzzification method is used to convert fuzzy important weights to their corresponding crisp important weights. To effectively compare the relative importance weights, the defuzzification values priorities are normalized. Finally, VIKOR is implemented to rank overall performance of suppliers. Figure 1 provides supplier selection framework that used in this study.

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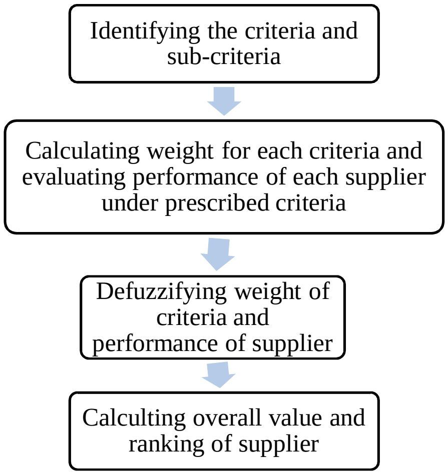

Figure 1. Supplier selection framework using FAHP-VIKOR

2.2 Fuzzy Analytic Hierarchy Process

The traditional AHP [9-10] is basically a method to compare qualities of entities in a pairwise manner based on a nine scale with the linguistic terms as given in Table 1. In line with the development of fuzzy theory by Zadeh [11], Laarhoven and Pedrycz [7] had converted the crisp AHP to FAHP by introducing the fuzzy scale as in Table 1.

The use of these fuzzy scale seems to be appropriate since in the context of quality of supplies, the evaluators may found difficulties to give exact evaluations that are represented as real numbers as in the traditional AHP method. Details procedures of FAHP are given in the following steps.

Step 1: Establish fuzzy pair wise comparison matrices of each criteria

An Expert assigns linguistic term represented by triangular fuzzy number to the pairwise comparisons among all criteria. A 9-point scale of linguistic term with its corresponding Triangular Fuzzy Number is shown in Table 1.

The fuzzy pairwise comparison matrices $\tilde{A}=[a_{ij}]$ describes the importance of criterion Ci with respect to criterion Ci as follows,

$$\tilde{A}=\begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{1} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{21} & \tilde{1} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & \tilde{1} \end{bmatrix} \quad (1)$$

Table 1. Linguistic term and the corresponding triangular fuzzy number

Fuzzy Numbers	**Linguistic term**	**Triangular Fuzzy Scale**
$\tilde{1}$	Equal Importance	(1,1,2)
$\tilde{2}$	Least Important	(1,2,3)
$\tilde{3}$	Weak Importance	(2,3,4)
$\tilde{4}$	Less Strong Importance	(3,4,5)
$\tilde{5}$	Strong Importance	(4,5,6)
$\tilde{6}$	More Strong Importance	(5,6,7)
$\tilde{7}$	Very Strong Importance	(6,7,8)
$\tilde{8}$	Extremely Importance	(7,8,9)
$\tilde{9}$	Very Extremely Importance	(8,9,9)

Step 2: Calculate the fuzzy importance weights

The fuzzy relative important weights of criterion C_i are calculated using geometric mean method [12] given by

$$\tilde{w}_i = \tilde{r}_i \times (\tilde{r}_1 + \tilde{r}_2 + \cdots + \tilde{r}_n)^{-1} \quad (2)$$

where $\tilde{r}_i = (\tilde{a}_{i1} \times \tilde{a}_{i2} \times \ldots \times \tilde{a}_{in})^{\frac{1}{n}}$.

Step 3: Defuzzify importance weight

The relative weight of all criteria are defuzzified using Center of Gravity [13].

$$dw_i = \frac{(u_i - l_i) + (m_i - l_i)}{3} + l_i \quad (3)$$

Step 4: Normalized importance weight

Defuzzified priority values are normalized using

$$w_i = \frac{dW_i}{\sum_i^n dW_i} \quad (4)$$

2.3 VIKOR Method

After calculating the relative important weights, overall performance values are ranked by VIKOR using the following procedures:

Step 1: Finding the positive ideal solution and negative ideal solution for all the criterion function; *i*=1,2,…,*n*

$$f_i^+ = \max_j f_{ij} \quad (5)$$

$$f_i^- = \min_j f_{ij} \quad (6)$$

where f_{ij} = the performance rating value of the j^{th} supplier with respect to i^{th} subcriteria, *i*= 1,…*n* , *j*=1,…,*m*

Step 2: *Computing the S_j values and R_j values for j=1,2,…,m*

$$S_j = \sum_{i=1}^{n} w_i (f_i^+ - f_{ij})/(f_i^+ - f_i^-) \quad (7)$$

$$R_j = \max_i [w_i (f_i^+ - f_{ij})/(f_i^+ - f_i^-)] \quad (8)$$

where w_i = the weight of criteria (expressing their relative performance)

Step 3: *Computing the Q_j values for j=1,2,…,m*

$$Q_j = v\left[\frac{S_j - S^*}{S^- - S^*}\right] + (1-v)\left[\frac{R_j - R^*}{R^- - R^*}\right] \quad (9)$$

where $S^* : \min_j S_j$ $S^- : \max_j S_j$

$R^* : \min_j R_j$ $R^- : \max_j R_j$

v: weight of the strategy of the majority of criteria ("the maximum group utility"), here *v*=0.5.

Step 4: *Ranking the alternatives, sorting by the values S, R and Q in decreasing order.*

Step 5: *Proposing a compromise solution*

The alternative (a´) which is ranked the best by the measure Q (minimum) if the following two conditions are satisfied:

C1. "Acceptable Advantage"

$Q(a'') - Q(a') \geq \frac{1}{J-1}$

where: (a'') is the alternative with second position in the ranking list by Q

C2. "Acceptable Stability in decision making": The alternative (a') must also be the best ranked by S or/and R. This compromise solution is stable within a decision making process, which could be the strategy of maximum group utility (when v > 0.5 is needed), or "by consensus" v about 0.5($v \sim 0.5$)), or "with veto" *v* < 0.5).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

- Alternatives (a') and (a'') if only the condition C2 is not satisfied, or
- Alternatives (a'),(a'')..., (a^M) if the condition C1 is not satisfied; (a^M) is determined by the relation $Q(a^M) - Q(a') < \frac{1}{J-1}$ for maximum M (the positions of these alternatives are "in closeness").

The best alternative ranked by Q, is the one with the minimum value of Q.

3. Case Study

An automotive spare part manufacturing company was selected to demonstrate the feasibility of the FAHP-VIKOR model. To produce quality spare parts that fulfilled the customer requirement and meet the company goal, the company has to select thoroughly its eighteen suppliers. Thus, in selecting the best suppliers, the Purchasing and Quality Assurance's manager has established five criteria and sixteen sub-criteria. In practice, the company used the simplest method, a weight point system to select the suppliers based on the criteria identified. However, some suppliers were ranked the same positions which made the decision difficult.

Normalized important weight of criteria and sub-criteria using all four steps in FAHP are given in Table 2. The performance of the suppliers for Quality's sub-criteria is presented in Table 3.

Table 2. Importance weight of criteria, sub-criteria

Criteria	Weight	Sub-Criteria	Weight
Quality	0.6129	Q1 Q2 Q3 Q4	0.2528 0.1752 0.1304 0.0546
Delivery	0.1115	D1 D2 D3	0.0575 0.0062 0.0478
Cost	0.1400	C1 C2	0.1040 0.0360
Customer Service	0.0643	CS1 CS2 CS3	0.0430 0.0146 0.0067
Technology Support	0.0713	TS1 TS2 TS3 TS4	0.0189 0.0331 0.0131 0.0062

Table 3. Performance of supplier with respect to Quality's sub-criteria

Supplier	Q1	Q2	Q3	Q4
S1	0.0237	0.0678	0.0596	0.0693
S2	0.1012	0.1012	0.1091	0.0674
S3	0.0995	0.0604	0.0625	0.0655
S4	0.1010	0.1050	0.0839	0.0636
S5	0.0454	0.0540	0.0523	0.0619
S6	0.0399	0.0358	0.0379	0.0602
S7	0.0423	0.0428	0.0487	0.0586
S8	0.0183	0.0227	0.0205	0.0570
S9	0.1008	0.0875	0.0966	0.0555
S10	0.0246	0.0323	0.0334	0.0541
S11	0.1176	0.0906	0.1025	0.0527
S12	0.0257	0.0296	0.0357	0.0514
S13	0.1030	0.0910	0.0917	0.0501
S14	0.0292	0.0333	0.0325	0.0488
S15	0.0294	0.0342	0.0316	0.0477
S16	0.0272	0.0352	0.0303	0.0465
S17	0.0515	0.0555	0.0506	0.0454
S18	0.0197	0.0209	0.0205	0.0443

Using those weights and all five steps in VIKOR, the values for S, R, and Q are given in Table 4

Table 4. Utility measure, regret measure, index

Supplier	Utility measure ***S***	Regret measure ***R***	Index ***Q***
S1	0.53	0.22	0.80
S2	0.13	0.04	0.00
S3	0.30	0.09	0.26
S4	0.19	0.05	0.08
S5	0.54	0.16	0.64
S6	0.60	0.16	0.69
S7	0.59	0.16	0.68
S8	0.78	0.22	1.00
S9	0.18	0.05	0.07
S10	0.68	0.22	0.93
S11	0.23	0.08	0.18
S12	0.68	0.22	0.92
S13	0.27	0.08	0.22
S14	0.68	0.19	0.84
S15	0.67	0.19	0.83
S16	0.71	0.22	0.95
S17	0.51	0.13	0.53
S18	0.78	0.22	1.00

Based on the smallest value Q, the result shows that S2 is at the top ranking followed by S9 and S4.

4. Conclusion

FAHP-VIKOR has been implemented for choosing the right supplier in an automotive manufacturing company. Results show that there is no overlap value in FAHP-VIKOR which can help the decision maker to select the supplier. It is suggested that combination FAHP with other multi criteria approaches may provide more significant information for the decision maker in establishing an effective supply chain system.

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