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Supplier Selection by Fuzzy AHP -- A Case in an Agro Chemical Industry

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Abstract: *In a purchasing department of an industry, selecting supplier is one of the most important activities. The decision making of selecting the best supplier, the firms can save material costs, quality and can increase other competitive advantage. This decision becomes complicated when it becomes multiple suppliers, multiple criteria, and imprecise parameters. And also the uncertainty and vagueness of the expert's opinion is the prevalent characteristic of the problem. Therefore, it uses a multi criteria decision making method namely Fuzzy AHP and this can be utilized as an approach for supplier selection problem. In this case study, supplier selection problem of an industry of agro chemical is investigated and for the solution, a fuzzy analytical hierarchy process based methodology is used to select the best supplier firm providing the most customer satisfaction for the criteria determined. The supplier with the highest priority weight is selected as the best supplier.*
Keyword: *Fuzzy AHP, Supplier selection.*

I. Introduction

1. Fuzzy Analytic Hierarchy Process (Fahp)

The AHP decision-making process is not able to make uncertainty and vagueness involved in human judgments to an exact number or ratio. The main difficulty in AHP is its inability in mapping human judgments. Therefore to handle this uncertainty and vagueness, an extension of the AHP model, the Fuzzy AHP method [1], has been applied to fuzzy decision-making problems. By the method of fuzzy AHP, the weights of evaluative factors are determined.

The steps involved in calculating the weights of evaluative factors are as given below: A matrix Ã is formed by the fuzzy pair wise comparisons.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ \dots & \dots & \dots & \dots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & 1 \end{bmatrix} \qquad \text{(i)}$$

Where a ̃ _ij = (l_ij,m_ij,u_ij) is the fuzzy comparison value element i to element j and are the minimum value, the most plausible value and the maximum value of the triangular fuzzy number [2].
r ̃_1= (a ̃_i1⊗a ̃_i2⊗……⊗a ̃_in)^(1/n) , for i = 1, 2… n,
………………..(i)
w ̃_i = r ̃_i/((r ̃_(1)⊕r ̃_2⊕…⊕r ̃_n)) , for i =1, 2 ….n,
…………………..(ii)

$$\tilde{w}_i = \frac{\tilde{r}_i}{(\tilde{r}_1 \oplus \tilde{r}_2 \oplus \dots \oplus \tilde{r}_n)} \text{ ,for } i = 1, 2 \dots n, \quad \dots\dots\dots\dots(iii)$$

Where r ̃_1 is the geometric mean [3] of the fuzzy comparison value of element i to each element, and
w ̃_i is the fuzzy weight of the i^thelement.
The fuzzy weight vector w ̃_i is constructed as
W ̃ =(w ̃_(1),w ̃_2,…,w ̃_n)^T……….. (iv)

II. Case Study In An Agro Chemical Company

The Fuzzy AHP methodology for the selection of best supplier has been applied to an Agro Chemicals Company, which produces fertilizers for agricultural purpose in India and abroad. The hierarchal structure of the supplier selection for the related company can be represented in the Figure 1. Such that, the weights of the criteria and the alternative should be calculated. Therefore, these two parts will be separately analyzed.

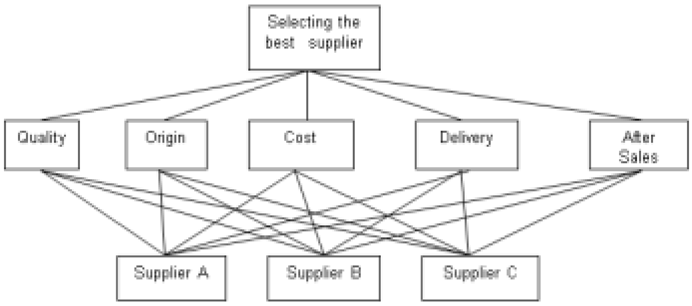

Figure 1. The hierarchy of the criteria and the alternatives

2.1 Determining the weights of criteria

To determine the criteria and to evaluate the alternatives for the supplier selection process, a survey is done with the experts like purchase manager, production manager and logistics manager. The survey is done by distributing questionnaires to experts and from that answers of the questionnaires it gets individual matrices. These individual matrices made survey with the experts are averaged to form a final matrix i.e. group decision making. Then, the consistency test is checked to this matrix. In order to determine the weights of criteria the judgment matrix formed will be the pair wise comparison matrix between criteria with respect to the objective selecting the best supplier is shown in Table 1.

Table I

Pair wise comparison matrix made between criteria

Criteria	Quality	origin	cost	Delivery	After sales
Quality	(1,1,1)	(1,1,1)	(3,4,5)	(5,6,7)	(4,5,6)
origin	(1,1,1)	(1,1,1)	(4,5,6)	(6,7,8)	(5,6,7)
cost	(1/5,1/4,1/3)	(1/6,1/5,1/4)	(1,1,1)	(1/4,1/3,1/2)	(2,3,4)
Delivery	(1/7,1/6,1/5)	(1/8,1/7,1/6)	(2,3,4)	(1,1,1)	(1/6,1/5,1/4)
After sales	(1/6,1/5,1/4)	(1/7,1/6,1/5)	(1/4,1/3,1/2)	(4,5,6)	(1,1,1)

After getting crisp matrix, we get $\lambda max = 5.39$, CI = 0.098 and CR = 0.089 is less than an 10%, is consistent.
The geometric mean and weights of criteria is calculated by the equations (ii), (iii) & (iv) of section 1 as follows:

Geometric mean for quality;

$\tilde{r}_1 = (1*1*3*5*4)^{(1/5)}, (1*1*4*6*5)^{(1/5)}, (1*1*5*7*6)^{(1/5)} = (2.26, 2.60, 2.91)$

Geometric mean for origin;

$\tilde{r}_2 = (1*1*4*6*5)^{(1/5)}, (1*1*5*7*6)^{(1/5)}, (1*1*6*8*7)^{(1/5)} = (2.60, 2.91, 3.20)$

Geometric mean for cost;

$\tilde{r}_3 = (1/5*1/6*1*1/4*2)^{(1/5)}, (1/4*1/5*1*1/3*3)^{(1/5)}, (1/3*1/4*1*1/2*4)^{(1/5)} = (0.44, 0.55, 0.70)$

Geometric mean for delivery;

$\tilde{r}_4 = (1/7*1/8*1/4*4*1)^{(1/5)}, (1/6*1/7*3*1*1/5)^{(1/5)}, (1/5*1/6*4*1*1/4)^{(1/5)} = (0.36, 0.43, 0.51)$

Geometric mean for after sales;

$\tilde{r}_5 = (1/6*1/7*1/4*4*1)^{(1/5)}, (1/5*1/6*1/3*5*1)^{(1/5)}, (1/4*1/5*1/2*6*1)^{(1/5)} = (0.54, 0.57, 0.60)$

Weight obtained for quality;

$\tilde{W}_1 = \tilde{r}_1 \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \tilde{r}_3 \oplus \tilde{r}_4 \oplus \tilde{r}_5)^{(-1)} = (2.26, 2.60, 2.91) \otimes (1/(2.91+3.2+0.7+0.51+0.6), 1/(2.6+2.91+0.55+0.43+0.57), 1/(2.26+2.6+0.44+0.36+0.54))$

$= (2.26, 2.60, 2.91) \otimes (0.126, 0.142, 0.161) = 0.374$

Similarly weight obtained for origin;

$\tilde{W}_2 = (2.60, 2.91, 3.2) \otimes (0.126, 0.142, 0.161) = 0.419$

Weight obtained for cost;

$\tilde{W}_3 = (0.44, 0.55, 0.70) \otimes (0.126, 0.142, 0.161) = 0.082$

Weight obtained for delivery;

$\tilde{W}_4 = (0.36, 0.43, 0.51) \otimes (0.126, 0.142, 0.161) = 0.062$

Weight obtained for after sales;

$\tilde{W}_5 = (0.54, 0.57, 0.60) \otimes (0.126, 0.142, 0.161) = 0.082$

By normalizing we get,
W̃_1= 0.374/1.019 = 0.367
W̃_2 = 0.419/1.019 = 0.411
W̃_3 = 0.082/1.019 =0.080
W̃_4 = 0.062/1.019 = 0.060
W̃_5 = 0.082/1.019 = 0.080

Determining weights of alternatives with respect to criteria

The pair wise comparison made between alternatives A, B and C done by the data obtained from the experts of the company with respect to each criteria: quality, origin, cost, delivery and after sales. The weights thus obtained will be the local weights of each alternative with the respective criteria. This is given in Table II to Table VI.

Table II

Pair wise comparison matrix of alternatives w.r.t. criteria quality:

Quality	A	B	C
A	(1,1,1)	(1/6,1/5,1/4)	(1/8,1/7,1/6)
B	(4,5,6)	(1,1,1)	(1/4,1/3,1/2)
C	(6,7,8)	(2,3,4)	(1,1,1)

After converting into crisp matrix, we get λmax = 3.125, CI = 0.068, CR = 0.090 which is less than 10% and is consistent. By similar calculation that has done to determine the weights of criteria in the previous section 2.1, geometric mean of A , B and C and weights of each alternative w . r. t. criteria quality is computed . Thus, normalized weights for alternatives A, B and C w. r. t. criteria quality are W̃_qA = 0.073, W̃_qB = 0.285, W̃_qC = 0.641.

Table III

The pair wise comparison matrix of alternatives w. r. t. criteria origin

Origin	A	B	C
A	(1,1,1)	(5,6,7)	(6,7,8)
B	(1/7,1/6,1/5)	(1,1,1)	(3,4,5)
C	(1/8,1/7,1/6)	(1/5,1/4,1/3)	(1,1,1)

Normalized weights for alternatives A, B and C w. r. t. criteria origin are W̃ _oA = 0.738, W̃_oB = 0.189, W̃_oc =0.073.

Table IV

The pair wise comparison matrix of alternatives w. r. t. criteria cost

Cost	A	B	C
A	(1,1,1)	(4,5,6)	(5,6,7)
B	(1/6,1/5,1/4)	(1,1,1)	(1/4,1/3,1/2)
C	(1/7,1/6,1/5)	(2,3,4)	(1,1,1)

Normalized weights of alternatives w. r. t. criteria cost are W̃_cA = 0.716, W̃_cB = 0.099 and W̃_cC = 0.186.

Table V

The pair wise comparison matrix of alternatives w. r. t. criteria delivery

Delivery	A	B	C
A	(1,1,1)	(1/8,1/7,1/6)	(5.3,6.3,7.3)
B	(6,7,8)	(1,1,1)	(5.3,6.3,7.3)
C	(1/7.3,1/6.3,1/5.3)	(2,3,4)	(1,1,1)

Normalized weights of alternatives w. r. t. criteria delivery are $\tilde{W}_{dA} = 0.254$, $\tilde{W}_{dB} = 0.628$, $\tilde{W}_{dC} = 0.117$

Table VI
The pair wise comparison matrix of alternatives w. r. t.. criteria after sales

After Sales	A	B	C
A	(1,1,1)	(4,5,6)	(5,6,7)
B	(1/6,1/5,1/4)	(1,1,1)	(1/4,1/3,1/2)
C	(1/7,1/6,1/5)	(2,3,4)	(1,1,1)

Normalized weights of alternatives w. r. t. criteria after sales are $\tilde{W}_{aA} = 0.716$,
$\tilde{W}_{aB} = 0.099$, $\tilde{W}_{aC} = 0.186$.

The global weights of alternatives A, B and C are obtained by multiplying the weights of criteria with the local weights of alternatives. It is shown in the Table VII. The alternative which has the maximum value of global weights is the best supplier or alternative.

Table VII
Local weights and Global weights of alternatives and selecting the best supplier:

Criteria (weights)	Supplier A		Supplier B		Supplier C	
	Local wts	Global wts	Local wts	Global wts	Local wts	Global wts
Quality (0.367)	0.073	0.027	0.285	0.105	0.641	0.235
Origin(0.411)	0.738	0.303	0.189	0.078	0.073	0.030
Cost (0.080)	0.716	0.057	0.099	0.008	0.186	0.015
Delivery (0.060)	0.254	0.015	0.628	0.038	0.117	0.007
After sales (0.080)	0.070	0.057	0.099	0.0079	0.186	0.015
	Total ---	0.459	--	0.2369	--	0.302

III. Conclusion

The Fuzzy AHP methodology, in this paper, is applied to determine the best supplier for purchasing raw materials like MOP, P2O5, and Ammonia in an Agro Chemicals company. The pair wise comparison made between criteria and between alternatives from the survey conducted with experts of the company. The comparison was made in a fuzzy AHP approach. According to obtained results, the alternative A (as one of the supplier) is determined as the best supplier or alternative, while C is determined as second best alternative and B is the worst alternative.

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