International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Supplier Selection Using AHP and F-AHP Approach: A Case Study

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Abstract: ***Supplier selection is a process by which an organization identifies, evaluate and contract with suppliers. To get the quality material at a reasonable cost and at right time, proper supplier selection is must. Looking to its importance, various methods have been developed for this purpose. Supplier selection process becomes complicated in case of multiple supplier and number of criteria's. Therefore, widely used multi criteria decision making tool Analytical Hierarchy Process (AHP) and Fuzzy AHP can be utilized as an approach for supplier selection problem. This paper focuses on application of AHP and Fuzzy AHP for determining the best supplier in medium scale industry***.

Keywords: Analytical Hierarchy Process (AHP), Fuzzy AHP.

1. Introduction

Supplier selection is defined as the ‘‘process of finding the suppliers being able to provide the buyer with the right quality products and/or services at the right price, at the right quantities and at the right time. Basically there are two types of supplier selection problems . In single sourcing type, one supplier can satisfy all the buyer's needs. In the multiple sourcing type, no supplier can satisfy all the buyer's requirements. Hence the management wants to split order quantities among different suppliers [3]. Supplier Selection is important task of any purchasing department. The main objective of supplier selection process is to reduce purchase risk, maximize overall value to the purchaser, and develop closeness and long-term relationships between buyers and suppliers, which is effective in helping the company to achieve "Just-In-Time" (JIT) production [6]. Supplier evaluation and selection are very important to the success for any industry because the cost and quality of goods and services sold are directly related to the cost and quality of goods and services purchased. Therefore, purchasing and supplier selection have an important role in the supply chain process. Traditionally, vendors are selected on their ability to meet the quality requirements, delivery schedule, and the price offered. The problem of finding and evaluating the most suitable vendors usually emerges when the purchase is complex, high-dollar value, and perhaps critical. The supplier selection process is a multi-objective decision, encompassing many tangible and intangible factors in a hierarchical manner [5]. Supplier selection problem is affected by different tangible and intangible criteria such as quality, price, delivery, technical capability and many more. So selecting the right supplier by a decision maker with reduce purchasing cost improves competitive ability and increase customer satisfaction[2].

2. Case Study

The medium scale industry considered here is established in1986.It has 750 employees with turnover nearly equal to 125 crore. The industry has 9001-2008 ISO certification. The main products are Ginning and Pressing machine, center trolly, precleaner, lint cleaner, steam humidificator, etc. To optimize the average annual inventory cost, industry is planning to adopt scientific approach in selection the best supplier. On this basis the objectives of this paper are;

- To select best supplier using AHP
- To select best supplier using Fuzzy AHP
- Comparasion of result and recommendation of best supplier.

3. Analytic Hierarchy Process (AHP)

AHP, developed by Saaty, addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem [8]. The process makes it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria. The AHP method is based on three principles: first, structure of the model; second, comparative judgment of the alternatives and the criteria; third, synthesis of the priorities. In the first step, a complex decision problem is structured as a hierarchy. AHP initially breaks down a complex multicriteria decision-making problem into a hierarchy of interrelated decision criteria, decision alternatives. With the AHP, the objectives, criteria and alternatives are arranged in a hierarchical structure similar to a family tree. A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria that define alternatives in the middle, and decision alternatives at the bottom [2]. The second step is the comparison of the alternatives and the criteria. Once the problem has been decomposed and the hierarchy is constructed, prioritization procedure starts in order to determine the relative importance of the criteria within each level. The pair-wise judgment starts from the second level and finishes in the lowest level, Fig.1 shown AHP Hierarchical model .

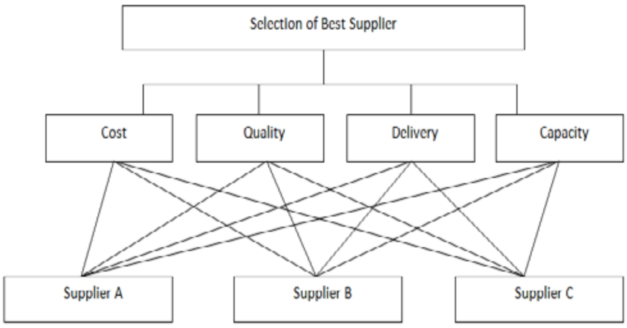

Figure 1: Hierarchical structure of the problem

3.1 Application of AHP

Steps for AHP are follows

1) Rating of criteria using questionnaire filled by experts from industry. scale of preference is mentioned in Table 1 (Appendix)
2) Development of Hierarchy and Comparasion matrix of criteria and alternatives w. r. t. each criteria.
3) Synthesis of priorities, in which calculate the eigenvector or relative weights and λmax for each matrix of order n, compute the consistency index for each matrix of order n by the formulae:
   CI =(λmax -n)/(n-1)
   The consistency ratio is then calculated using the formulae:
   CR=CI/RI, It must be less than 0.10
   where Random Consistency Index (RI) varies depending upon the order of matrix. Tables 2 shows(Appendix) the value of the Random Consistency Index (RI) for matrices of order 1 to 10 obtained by approximating random indices using a sample size of 500 [8].
4) Selection of supplier according to highest ranking.

For the purpose of priority calculation, assistance of Online CGI Software was taken into consideration for AHP and for FAHP, calculation is done manually

Table 3: Comparison Matrix for Criteria

Criteria	*Cost*	*Quality*	*Delivery*	*Capacity*
Cost	1	1	3	5
Quality	1	1	3	5
Delivery	1/3	1/3	1	3
Capacity	1/5	1/5	1/3	1

Table 4: Priorities of criteria

Criteria	*Local Priorities*	*Global Priorities*
Cost	0.3898	0.3898
Quality	0.3898	0.3898
Delivery	0.1523	0.1523
Capacity	0.0679	0.0679
λ max=4.0434, C.R.=C.I./R.I.=0.014/0.89=0.0162<0.10		

Table 5: Comparison Matrix for Alternatives w. r. t. Cost

Alternatives	*A*	*B*	*C*
A	1	1/3	5
B	3	1	7
C	1/5	1/7	1

Table 6: Priorities of Supplier w. r. t. Cost

Alternatives	Local Priorities	Global Priorities(L.P.*0.3898)
A	0.2789	0.1087
B	0.6491	0.2530
C	0.0719	0.0280
λ max =3.0648,C.R.=C.I./R.I.=0.0324/0.52=0.0623<0.10		

Table 7: Comparison Matrix for Alternatives w. r. t. Quality

Alternatives	*A*	*B*	*C*
A	1	5	1/3
B	1/5	1	1/7
C	3	7	1

Table 8: Priorities of Supplier w. r. t. Quality

Alternatives	Local Priorities	Global Priorities(L.P.*0.3898)
A	0.2789	0.1087
B	0.0719	0.0280
C	0.6491	0.2530
λ max =3.0648,C.R.=C.I./R.I.=0.0324/0.52=0.0623<0.10		

Table 9: Comparison Matrix for Alternatives w. r. t. Delivery

Alternatives	*A*	*B*	*C*
A	1	5	7
B	1/5	1	3
C	1/7	1/3	1

Table 10: Priorities of Supplier w. r. t. Delivery

Alternatives	Local Priorities	Global Priorities(L.P.*0.1523)
A	0.7306	0.1112
B	0.1883	0.0286
C	0.0809	0.0123
λ max =3.0648,C.R.=C.I./R.I.=0.0324/0.52=0.0623<0.10		

Table 11: Comparison Matrix for Alternatives w. r. t. Capacity

Alternatives	*A*	*B*	*C*
A	1	5	5
B	1/5	1	1
C	1/5	1	1

Table 12: Priorities Of Supplier w. r. t. Capacity

Alternatives	Local Priorities	Global Priorities(L.P.*0.0679)
A	0.7142	0.0484
B	0.1428	0.0097
C	0.1428	0.0097
λ max =3,C.R.=C.I./R.I.=0/0.52=0<0.10		

Table 13: Final Priorities of Alternatives and Criteria

Supplier	*Cost*	*Quality*	*Delivery*	*Capacity*	*Total*
A	0.1087	0.1087	0.1112	0.0484	0.3770
B	0.2530	0.0280	0.0286	0.0097	0.3193
C	0.0280	0.2530	0.0123	0.0097	0.3030
Total	0.3898	0.3898	0.1523	0.0679	1.0000

The sum of priorities for the supplier

A=0.3770, B=0.3193, C=0.3030.It means that supplier A satisfying all the criteria i.e. we suggest supplier A is the best supplier.

4. Fuzzy AHP

The Analytic Hierarchy Process (AHP) is a powerful and flexible decision-making process to help managers set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered. By reducing complex decisions to a series of one-on-one comparisons, then synthesizing the results, many researchers have concluded that AHP is a useful, practical and systematic method for vendor rating. it has certainly, been applied successfully. However, in many practical cases the human preference model is uncertain and decision-makers might be reluctant or unable to assign exact numerical values to the comparison judgments. For instance, when evaluating different suppliers, the decision-makers are usually unsure about their level of preference due to incomplete and uncertain information about possible suppliers and their performances [7]. Since some of the supplier evaluation criteria are subjective and qualitative, it is very difficult for the decision-maker to express the strength of his preferences and to provide exact pair-wise comparison judgments. For this reason, a methodology based on fuzzy AHP can help us to reach an effective decision. By this way we can deal with the uncertainty and vagueness in the decision process.

Since basic AHP does not include vagueness for personal judgments, it has been improved by benefiting from fuzzy logic approach. In F-AHP, the pair wise comparisons of both criteria and the alternatives are performed through the linguistic variables, which are represented by triangular numbers [4]. If the uncertainty (fuzziness) of human decision-making is not taken into account, the results from the models can be misleading. Fuzzy theory has been applied in a variety of fields since its introduction. fuzzy AHP methods is proposed to solve various types of problems. The main theme of these methods is using the concepts of fuzzy set theory and hierarchical structure analysis to present systematic approaches in selecting or justifying alternatives [1]. In this study, the extent analysis method by Chang (1992, 1996) is adopted because the steps of this approach are relatively easier, less time taking and less computational expense than many other fuzzy AHP approaches, and at the same time, it can overcome the deficiencies of conventional AHP. The approach not only can adequately handle the inherent uncertainty and imprecision of the human decision making process but also can provide the robustness and flexibility needed for the decision maker to understand the decision problem. To decide the final priority of different decision criteria, triangular fuzzy numbers is used in pair-wise comparison, and the extent analysis method for the synthetic value of the pair-wise comparison is applied definition and membership function of fuzzy numbers shown in table 14 (Appendix)

Table 15: Comparison matrix for criteria by using fuzzy scale

	Cost	*Quality*	*Delivery*	*Capacity*
Cost	1,1,3	1,1,3	1,3,5	3,5,7
Quality	1,1,3	1,1,3	1,3,5	3,5,7
sDelivery	1/5,1/3,1	1/5,1/3,1	1,1,3	1,3,5
Capacity	1/7,1/5,1/3	1/7,1/5,1/3	1/5,1/3,1	1,1,3

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_1}^{j}$$

=(1,1,3)+(1,1,3)+(1,3,5)+(3,5,7)+…………..+(1,1,3)
=(15.8857,26.4003,50.6667)

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_1}^{j}\right]^{-1} = (1/50.6667, 1/26.4003, 1/15.8857)$$

$$\sum_{j=1}^{m} M_{g_1}^{j} = (1,1,3)+(1,1,3)+(1,3,5)+(3,5,7)=(6,10,18)$$

$$\sum_{j=1}^{m} M_{g_2}^{j} = (6,10,18)$$

$$\sum_{j=1}^{m} M_{g_3}^{j} = (2.4,4.667,10)$$

$$\sum_{j=1}^{m} M_{g_4}^{j} = (1.4857,1.7333,4.6667)$$

The fuzzy synthetic degree values of control criterion, for cost can be calculated as follows:

$$F_1 = \sum_{j=1}^{m} M_{g_i}^{j} \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1}$$

=(6,10,18) ×(1/50.6667,1/26.4003,1/15.8857)
=(0.1184,0.3788,1.3317)

Then fuzzy synthetic degree values of control criterion for quality, delivery and capacity can be calculated as follows:

F_2 =(0.1184,0.3788,1.3317)
F_3 =(0.0473,0.1768,0.6295)
F_4 =(0.0293,0.0656,0.2937), (F_1,F_2,F_3,F_4 are fuzzy synthetic degree value for cost, quality, delivery and capacity respectively.)

A convex fuzzy number can be calculated as follows:
$V(F \geq F_1, F_2, \ldots, F_k) = \min V(F \geq F_i)$, i=1,2,….k
$d(F_i) = \min V(F_i \geq F_k) = w'_i$, k=1,2,……,n and $k \neq i$
$V(F_1 \geq F_2)=1$, $V(F_1 \geq F_3)=1$, $V(F_1 \geq F_4)=1$,
$V(F_2 \geq F_1)=1$, $V(F_2 \geq F_3)=1$, $V(F_2 \geq F_4)=1$,
$V(F_3 \geq F_1) = \frac{n_1^- - n_2^+}{((n_1^- - n_1) - (n_2^+ - n_2))}$
= 0.7181,
$V(F_3 \geq F_2)=0.7181$,
$V(F_3 \geq F_4)=1$,
$V(F_4 \geq F_1)=0.3636$
$V(F_4 \geq F_2)=0.3636$
$V(F_4 \geq F_3)=0.6891$

The weight vectors are calculated as follows:

$d(F_1) = \min V(F_1 \geq F_2, F_3, F_4) = \min(1,1,1) = 1$
$d(F_2) = \min V(F_2 \geq F_1, F_3, F_4) = \min(1,1,1) = 1$
$d(F_3) = \min V(F_3 \geq F_1, F_2, F_4) = \min(0.7181,0.7181,1) = 0.7181$
$d(F_4) = \min V(F_4 \geq F_1, F_2, F_3) = \min(0.3636,0.3636,0.6891) = 0.3636$
$W' = (d(F_1), d(F_2), d(F_3), d(F_4))$

=(1,1,0.7181,0.3636)

After normalization, the normalized weight vector of control criteria is:

W=(0.3245,0.3245,0,2330,0.118).

Similar procedures are carried out to calculate relative importance weight of each alternative with respect to each criterion is follows:

Table 16: Comparison matrix for alternatives w. r. t. Cost

	Supplier A	*Supplier B*	*Supplier C*
Supplier A	1,1,3	1/5,1/3,1	3,5,7
Supplier B	1,3,5	1,1,3	5,7,9
Supplier C	1/7,1/5,1/3	1/9,1/7,1/5	1,1,3

The normalized weight vector of alternatives w. r. t. Cost is: W_{cost}=(0.3961,0.5456,0.0582).

Table 17: Comparison matrix for alternatives w. r. t. Quality

	Supplier A	*Supplier B*	*Supplier C*
Supplier A	1,1,3	3,5,7	1/5,1/3,1
Supplier B	1/7,1/5,1/3	1,1,3	1/9,1/7,1/5
Supplier C	1,3,5	5,7,9	1,1,3

The normalized weight vector of alternatives w. r. t. Quality is: $W_{quality}$ =(0.4092,0.0569,0.5338).

Table 18: Comparison matrix for alternatives w. r. t. Delivery

	Supplier A	*Supplier B*	*Supplier C*
Supplier A	1,1,3	3,5,7	5,7,9
Supplier B	1/7,1/5,1/3	1,1,3	1,3,5
Supplier C	1/9,1/7,1/5	1/5,1/3,1	1,1,3

The normalized weight vector of alternatives w. r. t. Delivery is: $W_{Delivery}$ =(0.618,0.3203,0.0616).

Table 19: Comparison matrix for alternatives w. r. t. Capacity

	Supplier A	*Supplier B*	*Supplier C*
Supplier A	1,1,3	3,5,7	3,5,7
Supplier B	1/7,1/5,1/3	1,1,3	1,1,3
Supplier C	1/7,1/5,1/3	1,1,3	1,1,3

The normalized weight vector of alternatives w. r. t. Capacity is:

$W_{Capacity}$ =(0.5796,0.2102,0.2102).

The priority weights of the three suppliers obtained by multiplying the priority weights of criteria to the suppliers' weights with respect to all criteria.

Table 20: Priority weight of each criteria are as follows

W_{Cost}	$W_{Quality}$	$W_{Delivery}$	$W_{Capacity}$
0.3961	0.4092	0.618	0.5796
0.5456	0.0569	0.3203	0.2102
0.0582	0.5338	0.0616	0.2102

Table 21: Priority weights of each supplier are as follows :

Supplier	*Cost*	*Quality*	*Delivery*	*Capacity*	*Total Weight of supplier*
A	0.1285	0.1327	0.1439	0.0683	0.4734
B	0.1770	0.0184	0.0746	0.0248	0.2948
C	0.0188	0.1732	0.0143	0.0284	0.2311
Total	0.3245	0.3245	0.2330	0.118	1.0000

The sum of priorities for the supplier A=0.4734, B=0.2948, C=0.2311. It means that supplier A satisfying all the criteria i.e. We suggest supplier A is the best supplier.

5. Conclusion

In both AHP and FAHP, Supplier 'A' has highest ranking, so supplier A is best supplier among three. By applying the model, decision makers can evaluate the performance of each supplier on various factors and determine the overall ranking of the supplier. In medium scale industry it was found that cost and quality has equal importance and followed by delivery and capacity. In AHP, single numbers were introduced for comparison and in F-AHP triangular fuzzy members were introduced into the conventional AHP in order to improve the judgments of decision makers and experts. The ranking of criteria have been made according to their final scores on the basis of weight. In AHP cost and quality percentage is 38.98 % and in FAHP it is 32.43% and 15.23% for delivery (AHP) and 23.28 %(FAHP) (Q-D) AHP= 23.75%, (Q-D) FAHP=9.15%. it show that the difference between cost or quality and delivery is14.60 it is very large as compare to rating in AHP than FAHP, so we can conclude that FAHP gives accuracy and includes uncertainty and vagueness.

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Appendix Tables

Table 1: Scale of Preference between Two Element (Sanjay Kumar et.al)

S. No.	*Preference weights/level of importance*	*Definition*	*Explanation*
1	1	Equally preferred	Two activities contribute equally to the objective
2	3	Moderately preferred	Experience and judgment slightly favour one activity over another
3	5	Strongly pre-ferred	Experience and judgment strongly or essentially
4	7	Very strongly preferred	An activity is strongly favoured over another and its dominance demonstrated in practice
5	9	Extremely preferred	The evidence favouring one activity over another is of the highest degree possible of affirmation
6	2,4,6,8	Intermediates values	Used to represent compromise between the preferences listed above
7	Reciprocals	Reciprocals for inverse comparison	

Table 2: Average random index (RI) based on Matrix Size (Sanjay Kumar et.al)

S.No.	Size of Matrix (n)	Random Consistency Index (RI)
1	1	0
2	2	0
3	3	0.52
4	4	0.89
5	5	1.11
6	6	1.25
7	7	1.35
8	8	1.40
9	9	1.45
10	10	1.49

Table 14: Definition and membership function of fuzzy numbers (Rajeev Jain et.al)

Intensity of Importance	*Fuzzy number*	*Definition*	*Membership function*
1	$\tilde{1}$	Equally important/preferred	(1, 1, 3)
3	$\tilde{3}$	Moderately more important/preferred	(1, 3, 5)
5	$\tilde{5}$	Strongly more important/preferred	(3, 5, 7)
7	$\tilde{7}$	Very strongly more important/preferred	(5, 7,9)
9	$\tilde{9}$	Extremely more important/preferred	(7, 9, 11)