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Research Article

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Deploying F-AHP and QFD Methodology for Supplier's Selection

Aizaz Khan, Rehman Akhtar

University of Engineering and Technology, Peshawar

Abstract This research paper is about supplier selection using Fuzzy Analytic Hierarchy Process (F-AHP) and Quality Function Deployment (QFD) methodology. Supplier selection is the multi criteria problem. Supplier selection has great importance because it helps to decrease total lead time and ultimately reducing the total cost of the final product. To achieve this purpose the voice of the customer is very important and in this case the company is the customer. House of Quality (HOQ) is used to decide needs of the industries from the suppliers while Fuzzy Analytic Hierarchy Process (F-AHP) is used to determine the supplier and also helps in deciding which supplier is better as compared to other and which supplier accomplish their goals according to the requirements of the company.

Keywords F-AHP, QFD, Supplier Selection

Introduction

Supplier selection has great importance for any type of industries in the world. Because supplier selection directly affects the whole supply chain and bad decisions in the supplier selection results in the high cost of the final product. In the modern day world industries need to reduce cost in order to survive in this competitive market and supplier selection directly affects the cost of the final product. Selection of the supplier who provides reliable raw material in lower cost become the most important element of supply chain and to establish a win-win relationship between industry and the suppliers. To compete and beat the competitions the industries are more and more dependent on the suppliers. Long term relationship between industry and the supplier can result in the reduction of waste material with in the supply chain. Bad choice of the supplier will harm the competitiveness of an industry. Therefore, industries should have minimal number of reliable suppliers and have the long-term relationship with the suppliers. In supply chain management supplier selection is also a very important factor and wrong choice of supplier can have severe effects on the whole supply chain. In the modern day industries are getting competitive, therefore the need of taking a decision fast and accurately becomes more and more important especially selection of the supplier is the most important decision which must be made quickly and accurately otherwise it can affect the whole supply chain, which in turn results in the high cost of the final product. For quick decision making Operation research techniques are very useful. E.g. data mining method, mathematical programing and problem structuring approach. But many industries do not put effort in supplier selection which results in high product cost.

In modern competitive market manufacturers need to coordinate and respond quickly, therefore the whole supply chain has made industries and suppliers relationship very important [1]. In Pakistan there is little to none long term relationship between the industries and suppliers. Having long term relationship helps the manufacturer in fast decision making, which gives them a competitive advantage over their competitors [2]. Therefore the industries are required to have a long term relationship with the suppliers, which makes the effective supplier selection process very important for success of the industry [3]. Analytic Hierarchy Process (AHP) is another useful technique which can be useful in supplier selection [4] but there are not much industries in Pakistan that are using Analytic Hierarchy Process (AHP) in supplier selection. This research will focus on using the Fuzzy Analytic Hierarchy Process (F-AHP) and Quality Function Deployment (QFD) together to find out the needs of the industry from the supplier and ultimately selecting the supplier which best meet the needs of the industry.

Literature Review

Supplier selection is the most important decision making for Industry as it affect the whole supply chain. Supplier section is a multi-criteria problem where there are a number of factors that affects the decision making e.g. cost, technical capacity, lead time etc. But the most important criteria for selecting a supplier is the ability of supplier to meet required quality [Dickson (1966)] [5]. Weber (1991) [6] found that most of the industries are using multiple criteria for supplier selection like cost, delivery time, technical capacity and location. Willis (1993) used Analytic Hierarchy Process (AHP) to evaluate the performance of the suppliers. Lee et al. (2001) [7] proposed Supplier Selection and Management System (SSMS) and explained its applications. William Ho et al. (2010) [8] reviewed more than 70 journals and concluded that AHP-GP is most popular approach for multi-criteria problems. Bhattacharya et al. (2010) [9] used a combination of Quality Function Deployment (QFD), Cost Factor Measure (CFM) and Analytic Hierarchy Process (AHP) for multi-criteria supplier selection. Vinodh et al. (2010) [10] and Punniyamoorthy et al. (2011) [11] used Fuzzy AHP to found out the relative weight of each supplier with respect certain criteria. Mithat Zeydan et al. (2011) [12] also used Fuzzy AHP to find out the weight of each criteria and then used DEA to rank those suppliers. Analytic Hierarchy Process (AHP) uses three parts to solve a problem. Issue that need to be solved is the 1st part while the 2nd part is all available alternatives that can be used to solve the problem. In 3rd and last part certain criteria is used to find out the best possible alternative. Fuzzy Analytic Hierarchy Process (F-AHP) approach along with Quality Function Deployment (QFD) is used by many researchers to find out the best suppliers based on certain criteria. However, the proposed F-AHP-QFD methodology has not been used in Pakistan for supplier selection.

Proposed Methodology

The research is use F-AHP and QFD methodology for selection of the supplier. Using F-AHP requires data about the requirements of the industry from the supplier's (What's) and what criteria is required by the supplier to meet the industry requirements (How's). This data is collected from the industry management. After data collection the F-AHP and QFD methodology is used to find out the individual sore of each criterion based on certain criteria specified by industry management. Individual scores of each supplier is analyzed and Supplier best meeting industry requirement is selected.

Following are the FAHP-QFD methodology steps.

1. Identify the needs of the industry from the suppliers (WHAT's) based on the customer requirements.
2. Determine technical requirements by the supplier to complete requirements of the industries (HOW's).
3. Use of F-AHP to find out the weight of WHAT's.
4. Relationship matrix is formed.
5. Use of QFD to find weights of each criterion.
6. Use of F-AHP to find the individual scores of each supplier.
7. Rank the suppliers based on their individual scores.

The following figure explains the steps which are used to solve this problem.

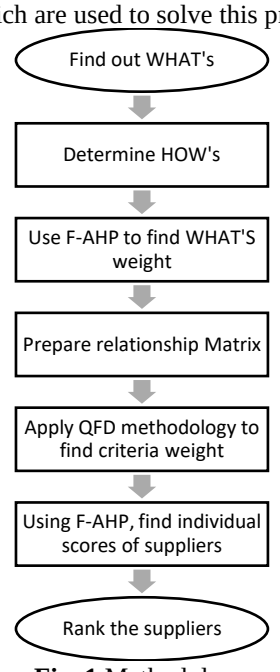

Fig. 1 Methodology

Fuzzy Analytic Hierarchy Process (F-AHP):

Analytic Hierarchy Process (AHP) was developed in late 1970's by Thomas L. Saaty, who developed Analytic Hierarchy Process (AHP) for organizing and analyzing complex decisions. Analytic Hierarchy Process (AHP) is a method for ranking decision alternatives and selecting the best one when the decision maker has multiple objectives or criteria. Fuzzy Analytic Hierarchy Process (F-AHP) is very useful methodology for multiple criteria decision-making in fuzzy environments. Fuzzy Analytic Hierarchy Process (F-AHP) utilizes the individual experiences of the management personal and divide a complex decision making to simple pair-wise comparisons. Relative importance of each factor is obtained by filling special designed questionnaire by senior management personal. Fuzzy Analytic Hierarchy Process (FAHP) has an advantage that it is designed to handle situations in which the subjective judgments of individuals constitute an important part of the decision process. Fuzzy Analytic Hierarchy Process (FAHP) also checks the consistency of the decision which eliminates the biasness in decision making.

Fuzzy Analytic Hierarchy Process (F-AHP) involve following steps.

Step 1: In first step a complex problem is broken down into its components. A graphical representation of the problem is developed involving overall goal on top followed by criteria and decision alternatives at the bottom.

Step 2: Fuzzy Analytic Hierarchy Process (F-AHP) has a scale to rate the relative preference of two items. The scale has values from 1 to 9 where 1 is equally preferred, 3 is moderately preferred, 5 is strongly preferred while 7 is very strongly preferred and 9 is extremely preferred.

Table 1: AHP Preference Scale

Saaty Scale	Definition	Fuzzy Triangular Scale
9	Extremely Preferred	(9,9,9)
8	Very Strongly Preferred to Extremely Preferred	(7,8,9)
7	Very Strongly Preferred	(6,7,8)
6	Strongly to Very Strongly Preferred	(5,6,7)
5	Strongly Preferred	(4,5,6)
4	Moderately to Strongly Preferred	(3,4,5)
3	Moderately Preferred	(2,3,4)
2	Equally to Moderately Preferred	(1,2,3)
1	Equally Preferred	(1,1,1)

Step 3: In this step relative priority of each decision alternative in terms of the criterion is estimated through a procedure called synthesization. Pairwise comparison matrix is formed and relative priority vector is found out using synthesizing procedure.

Step 4: In this step the consistency of pairwise judgments are checked by computing consistency ratio. If consistency ratio is below 0.1 then the pairwise judgment is consistent enough while the pairwise judgment is inconsistence if the consistency ratio is above 0.1. Consistency Ratio is calculated by using formula

$$CR = CI/RI$$

Where CR = Consistency Ratio, CI= Consistency Index and RI is Random Index

Consistency Index is calculated by formula

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

While the Random Index value is obtained from a table where its value depends on the number of elements being compared.

Table 2: Random Index Value

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Step 5: In this step priority ranking is developed by adding the product of the criterion priority and the priority of decision alternative.

F-AHP QFD Methodology Steps:

Step1: Find the characteristics required by the industry to be fulfilled by the suppliers (WHATs).
Step 2: Define the criteria required to accomplish characteristics (HOWs).
Step 3: Use Fuzzy Analytic Hierarchy Process (F-AHP) to find out the weight of required characteristics.
Step 4: Relationship Matrix is formed.
Step 5: House of Quality (HOQ) is used to find of the relative weight of each criteria.
Step 6: Use Fuzzy Analytic Hierarchy Process (F-AHP) to find out the individual score of each supplier.

Step 7: Find out the supplier ranking by multiplying supplier scores with weight of criteria.

RESULTS AND DISCUSSION

The study is performed on industry producing surgical products. For supplier selection combination of both F-AHP and QFD methodologies is used. 60 questionnaires were distributed to industry management. 46 questionnaires were received.

Step 1: Characteristics required by the industry to be fulfilled by the supplier are Cost, Lead Time, Quality and Past Performance.

Step 2: The criteria required by the supplier to achieve required characteristics are Experience, ISO Certification, Technology, Location, and Raw Material.

Step 3: Management compared the characteristics and a matrix is formed. With the help of this matrix Fuzzy Analytic Hierarchy Process (F-AHP) is used to find the weights of each characteristic.

Table 3: Pairwise Comparison Matrix

	Quality	Lead Time	Past Performance	Cost
Quality	1	4	6	5
Lead Time	1/4	1	4	3
Past Performance	1/6	1/4	1	1/2
Cost	1/5	1/3	2	1

Table 4: Pairwise Comparison Matrix Fuzzy

	Quality	Lead Time	Past Performance	Cost
Quality	(1,1,1)	(3,4,5)	(5,6,7)	(4,5,6)
Lead Time	(1/5,1/4,1/3)	(1,1,1)	(3,4,5)	(2,3,4)
Past Performance	(1/7,1/6,1/5)	(1/5,1/4,1/3)	(1,1,1)	(1/3,1/2,1/1)
Cost	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1,2,3)	(1,1,1)

Now Geometric mean of each what is calculated. Then the sum of values are found and then the reverse is also calculated and the values are written in ascending order.

Table 5: Geometric Mean

Criteria	Geometric Mean		
Quality	2.783	3.309	3.806
Lead Time	1.046	1.316	1.606
Past Performance	0.312	0.379	0.508
Cost	0.451	0.604	0.782
Sum	4.592	5.608	6.702
Reverse (Power Of -1)	0.218	0.178	0.149
Ascending Order	0.149	0.178	0.218

Table 6: Relative Fuzzy Weight

Criteria	Relative Fuzzy Weightage		
Quality	0.41	0.59	0.83
Lead Time	0.16	0.23	0.35
Past Performance	0.05	0.07	0.11
Cost	0.07	0.11	0.17

Table 7: Defuzzification

Criteria	Non-Fuzzy Weight Mi	Normalized Weight Ni
Quality	0.61	0.58
Lead Time	0.25	0.24
Past Performance	0.07	0.07
Cost	0.12	0.11
Sum	1.05	1

Table 8: λ_{max} Values

	Quality	Lead Time	Past Performance	Cost	Sum	For λ_{max}
Quality	0.58	0.96	0.42	0.55	2.51	4.32
Lead Time	0.15	0.24	0.28	0.33	0.99	4.15
Past Performance	0.10	0.06	0.07	0.06	0.28	4.06
Cost	0.12	0.08	0.14	0.11	0.45	4.02

Table 9: Consistency Ratio

λ_{max}	4.14
n	4
n-1	3
CI	0.046
CR	0.051

λ_{max} = 4.14, Consistency Index CI = 4.6% and Consistency Ratio CR = 5.1%. As Consistency Ratio is below 10% which is well within limits.

Step 4: Relationship matrix is formed to see the effect of HOWs on WHATs. Score of 9, 3 and 1 are given for High, Medium and Low impact respectively.

Table 10: Relationship Matrix

	Experience	ISO Certification	Technology	Location	Raw Material
Quality	M	H	H	L	L
Lead Time	L	L	L	M	L
Past Performance	H	L	L	L	L
Cost	M	M	H	L	M

Step 5: House of Quality (HOQ) is used to find the relative weight of each criteria. Which shows that Technology and ISO certifications are two main criteria both at 36% and 32% respectively.

Table 11: Quality Function Deployment

	Experience	ISO Certification	Technology	Location	Raw Material	Sum
Quality	1.74	5.23	5.23	0.58	0.58	13.36
Lead Time	0.24	0.24	0.24	0.72	0.24	1.68
Past Performance	0.62	0.07	0.07	0.07	0.07	0.90
Cost	0.33	0.33	1.00	0.11	0.33	2.10
Sum	2.94	5.87	6.53	1.48	1.22	18.04
Relative Weight	16.29	32.53	36.21	8.20	6.77	

Step 6: Fuzzy Analytical Hierarchical Process (F-AHP) is used to find out the individual score for each supplier.

Table 12: Individual Score Of each supplier

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Experience	0.27	0.50	0.13	0.10
ISO Certification	0.16	0.47	0.27	0.10
Technology	0.13	0.26	0.50	0.11
Location	0.14	0.08	0.28	0.50
Raw Material	0.22	0.50	0.21	0.07

Step 7: Supplier rating is found out by multiplying individual score of supplier with relative weight. On the basis of rating of suppliers Supplier 2 is the best choice, followed by Supplier 3, Supplier 1 and Supplier 4.

Table 13: Supplier Priority Ranking

	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Relative Weight
Experience	0.27	0.50	0.13	0.10	16.29
ISO Certification	0.16	0.47	0.27	0.10	32.53
Technology	0.13	0.26	0.50	0.11	36.21
Location	0.14	0.08	0.28	0.50	8.2
Raw Material	0.22	0.50	0.21	0.07	6.77
Supplier Rating	16.9478	36.8897	32.7235	13.439	

CONCLUSION

Applying F-AHP and QFD methodology result in much better selection of the suppliers which affects the whole supply chain and ultimately results in low cost of the final product. Supplier 2 is selected using combination of F-AHP and QFD methodologies, based on Cost, Lead Time, Quality and Past Performance. Supplier 2 has a Supplier Rating of 36.89, Supplier 3 is second having Supplier Rating of 32.72 while Supplier 1 and Supplier 4 are on last with Supplier Rating of 16.94 and 13.44 respectively.

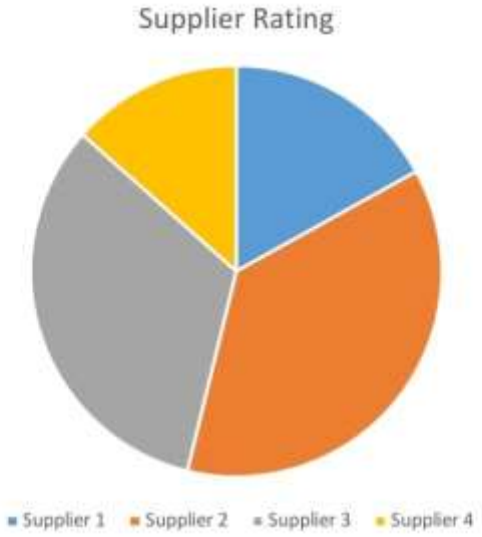

Figure 2: Supplier Rating

In this paper, implementation of F-AHP and QFD methodologies are used for better decision making for selection of the suppliers on the basis of Cost, Lead Time, Quality and Past Performance. QFD is used to find out the requirements of the Company which is the customer in this case. While F-AHP is used to find out the rank of the suppliers on the bases of the required criterion. F-AHP also shows which criteria has most impact on decision making.

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