SUPPLIER SELECTION AND EVALUATION – AN INTEGRATED APPROACH OF QFD & AHP

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ABSTRACT

In current scenario strong competitive pressure forces several organizations to available their products and services, cheaper, faster and improved than the rivals to their valuable customer. Managers have come to comprehend that they cannot do it individually without suitable vendors. Supply Chain Management empower the flows of material, information and funds in a association consisting of customers, suppliers, manufacturers and distributors, which beings raw materials, maintain by internal operations complete with distribution of finished goods. In the continually changing world, assortment of appropriate vender is facilitating in supply chain management, selection of right vendor is extremely useful part of purchasing department. This paper seeks to propose a methodology to integrate the Analytical Hierarchy Process (AHP) for right supplier selection and evaluation and Quality Function Deployment (QFD) analysis to enhance the effectiveness of outsourcing decisions. A selection that combines the subjective factors and objective factors and attitude of the decision maker decide the best supplier in the supply chain management system. The proposed integrated model could be used for supplier selection, which involves several quantitative and qualitative factors. Also could be used to determining the optimum order quantity. The propose method is a group decision making approach which shadows the traditional approaches of supplier selection.

Keywords – Multi-criteria Decision Making, Operation Research, Supplier selection & evaluation, Analytical Hierarchy Process, Quality Function Deployment

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1. **INTRODUCTION**:

In todays market forces demands to every organization to convert itself into a virtual organization, for cost-effectiveness and better quality. By the virtual corporation we mean that the main function of the company is to make the core of the product and depend on a large number of suppliers for the rest of the sub-assembly needed for blending the product. Therefore a large number of the work is outsourced. So, the quality of the product not only depends on the organization but also the raw materials supplied for the sub assembly from the suppliers. Business today is in a global environment and no one can stop this process of globalization. This has created a competitive market regardless of location or primary market. This competition has given customers tremendous freedom of choice, which ultimately increases their expectations by leaps and bounds. Strong competitive pressure forces many organizations to provide their products and services, faster, cheaper and better than the competitors to customers. That is why organizations have to strengthen their supply chain by identifying and partnering with the strongest suppliers. The suppliers should also fulfil certain conditions provided by the company like health and safety, finance, environmental responsibilities etc. Therefore supplier selection and evaluation in supply chain management is one of the most critical functions for the success of an organization and is a multi-criterion decision making process including both tangible and intangible factors. According to *Kumar ET al. (2004)* has observed that supplier selection deals with issues related to the selection of right suppliers and their quota allocations. When making the decision of supplier selection, enterprises should begin by developing a common understanding of their specific issues and objectives. They should learn as much as possible about suppliers' system to lessen their superficial similarities, they should prevent project costs from escalating by asking suppliers to commit to long-term pricing strategies, they should evaluate how closely the suppliers meet specification and how well they will be able to boost control system performance *(Woll,2000).* Most of the companies are spending considerable amount of their revenue on purchasing, which involve selection of appropriate suppliers.

In this study an integrated approach of Analytical Hierarchy Process (AHP), Quality Function Deployment (QFD) and Selection Index (SI) is proposed for rating and choosing the best supplier using cost as the prime index of selection. The following sections are organized as follows: section 2 shows the past research done by the researchers, followed by the notations used in the paper work .Then AHP method has been discussed in section 4. Section 5 includes the discussion of the assumptions and proposed methodology. Validation of the methodology is highlighted in section 6. The analysis of the result is discussed in the section 8. Finally, we conclude the paper in section 9.

2. LITERATURE REVIEW:

Selection of appropriate suppliers is one of the fundamental strategies for enhancing the quality of output of any organisation, which has a direct influence on the company's reputation. The importance of supplier selection has been stressed in the literature (*Weber et al., 1991*). As pointed out by (*Bhutta and Huq, 2002)*, the supplier selection problem requires the consideration of multiple objectives, and hence can be viewed as a multi-criteria decision making (MCDM) problem. Many more methods and procedures, including simple weighted rating , AHP, multi-attribute utility theory, mathematical Programming, game theory, principal components analysis and neural networks, have also been suggested in the literature (*Leenders et al.,2006; Monczka et al., 2002; Talluri et al., 2006*). DEA has also been suggested in the literature for vendor performance evaluation (Weber, 1996*; Weber and Desai, 1996*; *Weber et al., 1998, 2000; Narasimhan et al., 2001; Talluri et al., 2006; Wu et al., 2007).* Many researchers formulated the supply selection problem as various types of mathematical programming models. Such as Linear Programming (*Talluri and Narasimhan, 2005; Ng, 2008)*, integer linear programming (*Talluri, 2002; Hong et al., 2005*), integer non-linear programming (*Ghodsypour and O'Brien, 2001*), Goal Programming (Karpak et al., 2001) etc.

Many researchers applied integrated AHP approaches to evaluate the performance of suppliers and select the best supplier. Such as integrated AHP and Bi-negotiation (*Chen and Huang, 2007*), integrated AHP and DEA (*Ramanathan, 2007; Saen, 2007; Sevkli et al., 2007*), integrated AHP, DEA and artificial neural network (*Ha and Krishnan, 2008*), integrated AHP and Fuzzy (*Kahraman et al., 2003; Chan and Kumar, 2007*), integrated AHP and mixed integer non-linear programming (*Mendoza and Ventura, 2008*), integrated AHP and GP (*Wang et al.,2004,2005; Kull and Talluri, 2008; Percin,2006; Mendoza et al.,2008*). The most popular individual approach adopted in supplier evaluation and selection literature is DEA followed by mathematical programming, AHP and so on. But there are various integrated approaches for supplier selection and it was noticed that the integrated AHP approaches are more relevant due to its simplicity, ease of use and great flexibility (*Ho, 2008*). A prominent weakness of AHP is the shortcoming of AHP due to different judgement by different individuals. It has been criticized that AHP lacks a firm theoretical basis by *Belton and Gear (1983)*.

However, these criticisms were proved invalid by Harker and Vargas (1987) with a theoretical work and examples. There argument was that AHP (Bottani and Rizzi, 2008) is based completely upon firm theoretical establishment and examples as literature survey and routine of various corporations, organizations, agencies demonstrate that AHP is feasible, exploitable management tool for decision making. In Quality Function Deployment (QFD) approach for supplier selection, A house of quality was constructed to identify the features that the purchased product should have in order to satisfy the customers' requirements, and then to identify the relevant supplier assessment criteria (Bevilacqua et al., 2006).The present paper therefore incorporates Selection Index with Cost as the factor with AHP and QFD for acquiring an optimized value and finding the best potential supplier.

3. **NOTATION**:

Dj = Degree of importance for the j^{th} technical requirement; (j = 1, 2 . . . n);

Kij = Quantified relationship between the i^{th} customer requirement and the j^{th} technical criteria in the central relationship matrix; (i = 1, 2... n); (j = 1, 2... n);

Ci = Importance weighing of the i^{th}customer requirement; (I - 1, 2 ... n);

Xj= Overall score for the j^{th} Supplier-Alternative; (j = 1, *2*...);

Tij = PV value of the j^{th} alternative on the i^{th} Technical criteria; (i=1, 2 ... n); (j=1, 2 ... n);

τ_{max} = Principal Eigen Value, I.I. = Inconsistency Index.

R.I. = Random Inconsistency Indices. , I.R. = Inconsistency Ratios.

W_i = Final Weight age (Supplier's Ratings) of i^{th} supplier, G.M = Geometric mean

P.V = Priority vector, C.R = Consistency ratio

S_1 is Supplier 1; S_2 is Supplier *2*, S_3 Is Supplier 3

OFM is the objective factor measure

OFC is the objective factor cost

SFM is the subjective factor measure

SI_i is the supplier selection index i^{th} supplier

CF is the Cost Function

4. **ANALYTICAL HIERARCHY PROCESS**:

The analytic hierarchy process (AHP), originally developed by *Thomas Saaty in 1971* (*Saaty, 1980; Saaty and Vargas, 1981; Saaty and Vargas, 2000*), is a process designed for solving complex problems involving multiple criteria. It is a popular technique often used to model subjective decision making processes because it is conceptually simple, easy to understand, and robust enough to handle the complexities of real-world decisions. The AHP divides a complex decision problem into a hierarchical system of decision elements. A pair-wise comparison matrix of these elements is constructed, and then the normalized principal eigenvector is calculated for the priority vector, which provides a measure of the relative importance (weight) of each element. The procedure for the AHP can be summarized in four steps as follows:

i. *Constructing the hierarchical system*

ii. *Making pair-wise comparisons for the criteria and for the decision alternatives*

iii. *Calculating the weights and testing the consistency*

iv. *Calculating the overall priorities for the decision alternatives*

A consistency ratio (CR) that estimates the degree of inconsistency should be checked. If inconsistency ratio is<10% then the level of inconsistency is acceptable. Otherwise the inconsistency of the decision matrix is high and the decision maker is advised to revise the elements of the matrix.

5. **PROPOSEDMETHODOLOGY:**

The following criteria have been taken in the supplier selection process:

1. *All the* suppliers have similar qualitative and quantitative criteria in the evaluation process.
2. In the analysis, the different Production Capacity of each Supplier has been taken into consideration.

The proposed methodology integrating AHP and QFD (Bhattachariyya *et al., 2005) for a* Supplier Selection Problem comprises the following steps:

Step 1: The various criteria needed by the customer are identified.

Step 2: The technicalities required to satisfy the customer needs are identified.

Step 3: Central Relationship Matrix is prepared using the specialized knowledge of QFD team.

Step 4: Subsequently, degree of importance for the customer requirements is calculated taking in account the Analytical Hierarchy Process.

Step 5: After that, the degree of importance for the technical requirements is calculated using the following equation: $(DOI) = Dj = \sum_{i=1}^{m} K_{ij}\, C_i$ (1)

Step 6: Normalization of the degree of importance of the respective technical factors are done using: $(DOI)_{norm} = \overline{DJ} = \frac{Dj}{\sum_{j=1}^{n} Dj} \times 100$ (2)

Step 7: Eventually, the pair wise comparison matrices are structured for each technical requirement using Saaty's nine-point scale.

Step 8: Now, we integrate the above performed steps (6 & 7) in a single table, where the calculated normalized values of the degree of the importance are substituted on one side and the respective data obtained from the five pair wise matrices are transferred to the cumulative table on the other side.

Step 9: Overall Weightings of the Suppliers S_1, S_2 and S_3 are calculated using equation (3).

$X_j = \sum_{j=1}^{n} \overline{DJ} T_{ij}$ (3)

Step 10: The Normalization of the weightings of all the three selected suppliers are done. The normalized weights of the Service Providers accounts for the respective Subjective Factor Measure for the i^{th} Supplier are substituted in the following equation (4).

$SI_i = C.F[\alpha \times SFM_i + (1-\alpha) \times OFM_i]$ (4)

Where, $OFM_i = 1/ [OFC_i \sum_{i=1}^{n} 1/OFC_i]$

α is the attitude of the- decision maker, $\alpha \geq 0 but\ \alpha \leq 1$

n is the number of Suppliers (n=3 in the present case).

6. VALIDATION OF THE PROPOSED METHODOLOGY:

The proposed methodology has been validated as follows:

Step 1: The various criteria needed by the customer are –

- Quality , Cost , Design flexibility , After Sale Service , On Time Delivery

Step 2: The technicalities required to satisfy the customer needs are –

- Reliability , J IT system , Adequate Resources , Corporate and social responsibilities , Ability in IT Technology

Step 3: The central relationship matrix displaying the degree of relationship between each customer requirement and the corresponding technical requirement is constructed. Here the vertical columns are the Customer Requirements and the horizontal rows are the Technical Requirements respectively. The symbol and the corresponding weights of the symbols used in the matrix are as follows:

Table: 1 Central Relationship Matrix

	Reliabilit	JIT	Adequate-	Corporate and	Ability in IT
Quality	•	*	0	-	*
Cost	•	•	•	•	•
Design	•	-	•	-	0
After Sales	•	•	•	0	-
On Time.	•	•	0	•	-

- • Strong = 9 * Medium = 5 0 Weak = 1
- \- No Relationship Exists = 0

Step 4: A decision matrix is constructed to measure the relative degree of importance for each customer requirement, based on the proposed methodology. This is a matrix of 5x5 elements as shown in the matrix below.

The PV values of this decision matrix are [0.2296, 0.4705, 0.04633, 0.0692, and 0.01847] which are obtained by successive normalizations of the evaluated Geometric Mean of each rows.

$$D_{ij} = \begin{pmatrix} 1.000 & 0.25 & 5.000 & 4.000 & 2.000 \\ 4.000 & 1.000 & 6.000 & 5.000 & 3.000 \\ 0.200 & 0.167 & 1.000 & 0.5000 & 0.200 \\ 0.250 & 0.200 & 2.000 & 1.000 & 0.250 \\ 0.500 & 0.333 & 5.000 & 4.000 & 1.000 \end{pmatrix}$$

Here Eigen Value and the Consistency of thedecision matrix are verified using the Consistency Equations. The Results obtained are *as* follows;

τ_{max} = 5.3574 (5) I.I. = 0.08935 (6) R.I. = 1.1S80 (7)

I.R. = 7.5421% (8)

Thus we observe that I.R. <10%, so the level of inconsistency present in the information stored in 'Dij' matrix is acceptable. The QFD team, then, puts the PV values into the Transformation matrix as shown in Step 5, 6**.**

Step 5, 6: The degree of importance for the technical requirements and the corresponding Normalization of the value are calculated as shown in the table 2 below:

TABLE 2: House of Quality

		TECHNICAL REQUIREMENTS					
		Reliability	JIT	Adequate Resources	Corporate and	Ability in IT	Importance Weighing
C R	Quality	•	*	0	-	*	0.2429
	Cost	*	•	*	*	•	0,4846
	Design	•	-	*	-	0	0.0383
	After Sales	•	*	*	o	-	0.0696
	On Time .Delivery	*	•	o	*	-	0.1617
	Degree Of importance for	*4.791*	6.177	3.493	4.121	5.807	
	Normalized Degree Of	19.60	25.63	14.30	16.83	23.70	

Step 7: The pair wise comparisons of the suppliers for each technical requirement are as follows:

For "*Reliability*" criterion, T1:

	S_1	S_2	S_3
S_1	1	5	2
S_2	1/5	1	1/7
S_3	1/2	7	1

For "*Just in Time System*" criterion, T2:

	S_1	S_2	S_3
S_1	**1**	***6***	**9**
S_2	**1/6**	**1**	**3**
S_3	**1/9**	**1/3**	**1**

For an “*Adequate Resources*” criterion, T3:

	S_1	S_2	S_3
S_1	1	4	7
S_2	1/4	1	3
S_3	1/7	1/3	1

For “Corporate and Social

	S_1	S_2	S_3
S_1	1	4	9
S_2	1/4	1	5
S_3	1/9	1/5	1

For “*Ability in it Technology*” criterion, T5:

	S_1	S_2	S_3
S_1	1	9	5
S_2	1/9	1	1/4
S_3	1/5	4	1

Step 8: The calculated normalized value of the degree of importance has been put under the column weights while the values obtained from the pair wise matrices are put under the column of weight of the supplier.

TABLE 3: Final Weightages of the Suppliers.

		Important Weight Of Supplier					
Technical	Weights	S_1	S_2	S_3	I.I.	I.R.=I.I./R.I	I.R. (%)
T_1	24.64	0.5416	0.0766	0.3817	0.05805	O.O879	8.79
T_2	28.53	0.7704	0.1617	0.0677	0.02520	0.0381	3.81
T_3	12.91	0.7050	0.2109	0,0840	0.01530	0.0231	2.31
T_4	12.91	0.7087	0.2310	0.0601	0.0336	0.0509	5,09
T_5	20.97	0.7428	0.0632	0.1938	0,03495	0.0529	5,29
	Overall	69.167	13.534	I7.263			

Step 9: Ranking of all the supplier alternatives and selection of the best one using the analogy 'the higher the better" (Ray *et at.*., 2010). From above table 3 it is clear that $S_2<S_3<S_1$ i.e. S_1 has precedence over S_3 and S_2.Thus, Service Provider S_1 is selected, as it has the highest overall score.

Step 10: The normalized weights of the Service Providers are as follows;

$S_1 = 0.6916 \quad S_2 = 0.1353 \quad S_3 = 0.1726$

Step 11: Putting the values of OFC_i in equation (2) we calculate the values of OFM_i, which are shown in the following Table:

TABLE 4: Cost Index.

Supplier	Normalized weightages/Subjective Factor Measure(SFM_i)	Objective factor Cost of Supplier(OFC_i)	Objective Factor Measure(OFM_i)
S_1 S_2 S_3	O.6916 O.1353 O.172	S 1000 $ 1500 S 1300	0.4105 0.2736 0.3157

Further we incorporate this value OFM_i and SFM_i in Equation (1) to obtain the following equations of SI:

$$SI_1=0.4705[\alpha \times 0.6919 + (1-\alpha) \times 0.4105]$$

$$SI_2=0.4705 [\alpha \times 0.1353 + (1-\alpha) \times 0.2736]$$

$$SI_3=0.4705[\alpha \times 0.1726 + (1-\alpha) \times 0.3157]$$

7. **RESULT ANALYSIS**:

In this section, we *focus*, on comparing alternative suppliers with respect to the five technical criteria - reliability, JIT system, adequate resource, corporate and social responsibilities, and ability in IT technology. The factors of each criterion will be analyzed to understand why S_1 outperforms the others.

The comparison of alternative suppliers with respect to "reliability" is shown in matrix-1 Reliability is very important not only because it is related to safety, but also because it has significant financial impacts. A low customer rating will affect sales, and could result in a long-term financial crisis. Although cheap products can win the market temporarily, if the quality and reliability do not meet customer expectations, the obtained market share will be lost. In this case S_1 outperforms the other in terms of satisfying the customer's requirement, Therefore, in the reliability point of view S_1 will help to minimize the financial loss.

The comparison of alternative supplier with respect to "JIT" system is shown in matrix.2. S_1 gets the highest score because the customer recognizes that S_3 does not depend on the JIT system. But supplier S_3 assures the supply of product in time, In the JIT system point of view, collaborating with S_3 will help to minimize Storage cost.

The comparison of alternative suppliers with respect to "adequate resource." is shown in matrix 3. S_1 gets the highest score because it focuses on the capacity of the company. In the resource point of view S_1 is the best performer.

The supplier's performance rating depends on the manufacturing environment and sanitary facilities like workshop temperature, air pollution, and noise and workshop sanitary situation. Satisfactory sanitary environment usually implies the high efficiency. Satisfactory environment can assure the staff's satisfaction and high quality products. According to the corporate and social responsibilities, S_1gets the highest score (Matrix 4).

It's important to recognize the supplier's ability in operating the electronic data interchange (EDI) and enterprise resource planning (ERP) system and efficiently employing the information communication such as linking the customers in manufacturing plans, product design, engineering data and product supplying date. According to the matrix 5, S_1 scores the highest weight age.

8. CONCLUSION:

In this paper, a proper evaluation and supplier selection methodology has been deduced by the integration of three processes name AHP, QFD and SI. The paper highlights the effectiveness of the projected model. Identification of customer requirements and technical requirements is done thorough QFD method. AHP is employed to deduce the significance of evaluating factors and also to evade the problem arising from the traditional QFD model. It is evident from AHP and QFD model that Supplier 1 stands-out to be the best supplier with an overall weightage of S_2 69.167. This result is further validated by Selection Index graph which shows that Supplier 1 has the highest optimum quantity. In the proposed model, both Qualitative and Quantitative has been considered simultaneously and an overall score has been evaluated for the three suppliers, on an extensive pair wise comparison of factors is carried out.

This approach provides us with many advantages. The first and the foremost is that both cardinal and ordinal factors are measured for the evaluation of alternative suppliers. This guarantees that the evaluated supplier has the highest quality, better reliability, lowest cost etc. Secondly, the quantity ordered is optimum.Thirdly; the proposed method is a group decision making approach. Therefore the projected approach Shadows the traditional approaches of supplier selection. The limitation of the proposed approach is due to AHP. Decision makers have to compare each cluster in the same level in a pair wise fashion based on their own experience and knowledge.

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