Application of Analytical Hierarchy Process (AHP) Technique To Evaluate and Selecting Suppliers in an Effective Supply Chain

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Abstract

With increasingly competitive global world markets, companies are under intense pressure to find ways to cut production and material costs to survive and sustain their competitive position in their respective markets. Since a qualified supplier is a key element and a good resource for a buyer in reducing such costs, evaluation and election of the potential suppliers has become an important component of supply chain management. Most supplier selection models consider the buyer's viewpoint and maximize only the buyer's profit. This does not necessarily lead to an optimal situation for all the members of a supply chain. This paper deals with a brief review of the literature regarding AHP technique and its relevancy to its application in supplier selection process. Supplier selection is a complicated process. This process needs evaluation of multiple criteria and various constraints associated with them. After analysis of the results we found that for manufacturing firms, supplier reliability, product quality and supplier experience are the top three supplier selection problems that needs to be taken up on priority for effective vendor selection.

Keywords: supply chain management; Supplier selection; multi attributive decision making (MADM); Analytic Hierarchy Process (AHP)

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Introduction

In today's global marketplace characterized by globalization, increasing customers' value expectations, expanding regulatory compliance, global economic crisis, and intense competitive pressure, to thrive and survive manufacturing firms must select and maintain core suppliers. Thus, supplier selection and evaluation represents one of the significant roles of purchasing and supply management functions(Chen and Huang, 2006) Weber et al. (1991) attest that "it is impossible to successfully produce low cost, high quality

products without satisfactory selection and maintenance of a competent group of suppliers" Carr and Smeltzer (1999) note that "the purpose of strategic purchasing [and supply management] is to direct all purchasing activities toward opportunities consistent with the firm's capabilities to achieve its long-term goals." Indeed, because purchasing and supply management can play a prominent role in a firm's strategic planning, supply chain management, and profitability.   Supplier selection is one of the key decisions to be made in the strategic planning of supply chains that has far-reaching implications in the subsequent stages of planning and implementation of the supply chain strategies. In traditional/forward supply chain, the problem of supplier selection is not new. First publications on supplier selection in traditional forward supply chains back to the early 1960s (Wang, G., Huang, S. H. and Dismukes, 2004) traditionally, in supply chain literature, the supplier selection problem is treated as an optimization problem that requires formulating a single objective function. However, not all supplier selection criteria can be quantified, because of which, only a few quantitative criteria are included in the problem formulation.

AHP makes the selection process very transparent. It also reveals the relative merits of alternative solutions for a Multi Criteria Decision Making (MCDM) problem. (Drake, P.R., 1998). AHP approach is a subjective methodology (Cheng and Li, 2001); information and the priority weights of elements may be obtained from a decision-maker of the company using direct questioning or a questionnaire method. It is generally agreed in the literature that the following makes the supplier selection decision making process difficult and/or complicated (de Boer, 1998, Murlidharan et.al. 2001).Supplier selection process represents a complex problem and thus a multi-attribute decision making (MADM) problem.

MADM such as the analytic hierarchy process (AHP) model is an important technique that has been used successfully in supplier selection and evaluation Therefore,. this paper uses the AHP model developed by Saaty (1980) for supplier selection and evaluation in manufacturing firms in which the goal being pursued has multiple, often conflicting attributes.

The remaining portion of this paper is organized as follows. Section 2 presents a brief background on advantages and disadvantages of using AHP method. Section 3 presents an abbreviated review of relevant literature on the approaches used in supplier selection and evaluation. Section 4 provides the research methodology, including data collection and analysis. Section 5 discusses the research findings as well as a limited discussion on the sensitivity analysis. Finally, the conclusions and managerial implications are presented in section **6.**

Advantages and Disadvantages of Using AHP Method:

One advantage of AHP is that it illustrates how possible changes in priority at upper levels have an effect on the priority of criteria at lower levels. Moreover, it provides the buyer with an overview of criteria, their function at the lower levels and goals as at the higher levels. A further advantage of AHP is its stability and flexibility regarding changes within and additions to the hierarchy. In addition, the method is able to rank criteria according to the needs of the buyer which also leads to more precise decisions concerning supplier selection. The main advantage of AHP is that the buyer is able to get a good picture of the supplier's performance by using the hierarchy of the criteria and evaluating the suppliers (Omkarprasad and Kumar, 2006).

However, AHP also has some weak points. One of these is the complexity of this method which makes it implementation quite inconvenient. Moreover, if more than one person is working on this method, different opinions about the weight of each criterion can complicate matters. AHP also requires data based on experience, knowledge and judgment which are subjective for each decision-maker. A further disadvantage of this method is that it does not consider risks and uncertainties regarding the supplier's performances (Yusuff et al., 2001). The strength of the AHP method lies in its ability to structure complex, multi-person, multi-attribute, and multi-period problems hierarchically and it is simple to use and to understand. It necessitates the construction of a hierarchy of attributes, sub-attributes, alternatives and so on, which facilitates communication of the problem and the recommended solutions. In addition, the AHP method provides a unique means of quantifying judgmental consistency.

The issues of supplier selection have attracted the interest of researchers since the 1960s, and research studies in this area have increased. A study was conducted to determine what criteria were used in the selection of a firm as a supplier. Most of these criteria during that time were quantitative. During that time the researchers did not give attention to qualitative criteria which had a lower level ranking for the evaluation and the selection of suppliers. Method for decision-making to measure qualitative criteria such as AHP, Fuzzy etc. was used to select suppliers. Nowadays, qualitative methods received more attention in decision-making models for selecting the suppliers.

Consequently, the researchers will focus on qualitative criteria in the future rather than a combination of both qualitative and quantitative criteria with existing methods such as AHP. Nowadays, AHP and Fuzzy AHP as two precise methods for supplier selection decision- making are believed to be useful for managers due to their simplicity in use. Yet again, it is proven that AHP work well in making decision for many types of companies that involves different types of suppliers. Based on above review, it would be not irrational to suggest that the supplier selection issues need further attention in order to harmonies the combination of qualitative and quantitative criteria to develop the best decision-making models for the selection   of   the   best   suppliers.

Literature Review

Ghodsypour and O'Brien (1988) noted that supplier selection models could be broken down into single source and multiple source models. In single source models, one supplier is able to respond to a buyer's demand. In multiple source models, the allocation problem is considered to be the same as the selection problem. Ranking techniques are usually applied to single source models, but in multiple source models mathematical programming models are developed (Degraeve and Roodhooft, 2000). Further developed a multi-period, multi-item, multi-vendor mixed- integer programming model based on the TCO, to determine an optimal ordering and inventory policy and jointly to decide on the best combination of suppliers their model covers the total cost. Incurred, including the purchasing cost, the ordering cost, the transportation costs and so forth. Ghodsypour and O'Brien (1988) developed a decision support system that combined the analytical hierarchy process with linear programming. They first presented a single objective mixed-integer nonlinear programming model to minimize total cost. In that model, they considered quality as a constraint, and then developed a multi-objective model with one of its objectives to maximize the orders quality.

Hong et al. (2005) developed a mixed integer programming model to select right suppliers and maximize revenue while satisfying the customer needs. They considered changes in suppliers' capabilities and customer requirements over the horizon of the problem. In their model, the suppliers which satisfy many parts of the ideal procurement condition are selected more often than other suppliers. Basnet and Leung

(2005) developed a model to combine lot-sizing with supplier selection problem. They considered a multi-period inventory lot-sizing scenario where multiple products could be sourced from a set of selected suppliers in each cycle. The objective function consists of purchasing price, inventory holding cost and transaction cost for minimization and an enumerative search algorithm was proposed to solve the problem.

Kirytopolos et al (2008) utilized analytic network process approach for the selection and evaluation of suppliers. The supplier selection criteria considered in their study included cost, service, supplier's profile, quality, risk, and other. This paper contributes to the existing stream of research by integrating regulatory compliance into supplier's selection process in a production industrial firm supply chain. Supplier selection literature is endowed with various kinds of methodology, including multi-criteria decision-making techniques or decision support systems (e.g., AHP), conceptual papers, empirical research, simulation techniques, among many others. Stream of research that have applied AHP methodology in supplier selection include (e.g., Barbarosoglu and Tazgac 1997; Bhutta and Huq 2002; Chan 2003; Onesime et.al. 2004).

Methodology

Problem of selection of vendor has been dealt with by using questionnaire based study. A structured questionnaire was framed and all the criteria are rated by the professional of various fields. The framework adopted for this study is as shown in **figure1**.
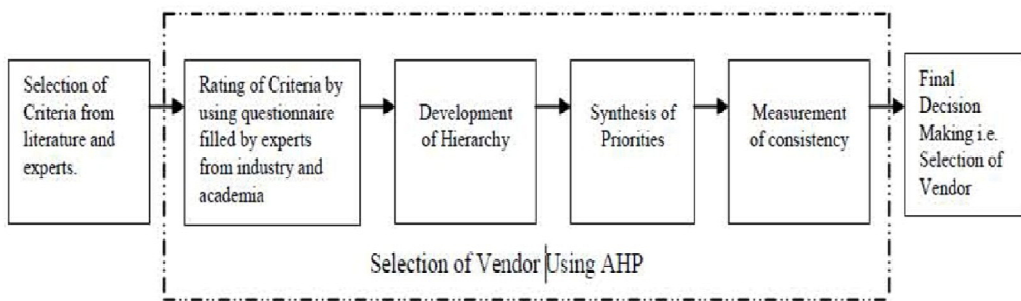

Figure 1: Framework of the study

The foundation of the Analytic Hierarchy Process (AHP) is a set of axioms that carefully delimits the scope of the problem environment (Saaty 1986). It is based on the well- defined mathematical structure of consistent matrices and their associated eigenvector's ability to generate true or approximate weights, Saaty (1980, 1994). The AHP methodology compares criteria, or alternatives with respect to a criterion, in a natural, pair wise mode. To do so, the AHP uses a fundamental scale of absolute numbers that has been proven in practice and validated by physical and decision problem experiments it

converts individual preferences into ratio. Scale weights that can be combined into a linear additive weight for each alternative. The resultant can be used to compare and rank the alternatives and, hence, assist the decision maker in making a choice. It is a powerful operational research methodology useful in structuring complex multi-criterion problems or decisions in many fields such as logistics and supply chain management, marketing engineering, education, and economics. Merits associated with AHP include its reliance on easily derived expert judgment data, ability to reconcile differences (inconsistencies) in expert judgments and perceptions, and the existence of Expert Choice Software that implements the AHP.

Model Development AHP for Supplier Selection

Supplier Selection can help manufacturing firms to contain cost associated with the bottom line. It entails the determination of quantitative and qualitative factors imperative for selecting the best possible suppliers (Chan, 2003). The following steps associated with AHP method for decision making are used:
(1) Clearly define the decision problem and determine its goal.
(2) Structure the hierarchy from top through the intermediate levels to the lowest level. In **Figure 2**, the goal of the problem is located at level 1. Level 2 houses the major attributes. Finally, the alternatives are located at the last level of the hierarchy. The supplier selection criteria and alternative suppliers are identified below.
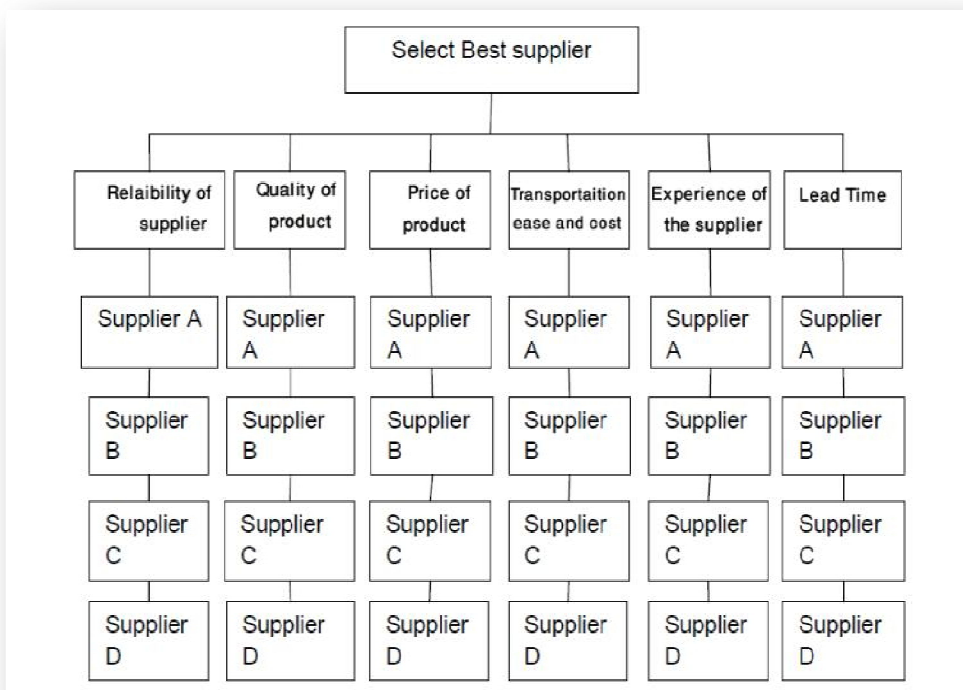

Figure2. The Hierarchical Structure for a manufacturing firm

For supplier selection process and evaluation, manufacturing firms have primarily considered criteria such as quality, service, cost, flexibility, reputation, and financial stability (e.g. Sarkis and Talluri 2002; Verma and Pullman 1998; Hirakubo and Kublin, 1998). However the current research considered quality of product, transportation ease and cost, reliability of vendor, price of product, experience of the supplier, lead time to evaluate each of the four suppliers.

Figure 3.Criteria and Abbreviations Used

S.N	Criteria	Abbreviation used
1	Transportation ease and cost	TC
2	Experience of the supplier	ES
3	Lead time	LT
4	Reliability of the supplier	RS
5	Price of product	PP
,	Quality of product	QP

In AHP, multiple pairwise comparisons are based on a standardized comparison scale of nine levels. Let C= {Cj|j=1, 2... n} be the set of criteria. The result of the evaluation matrix in which every element aij (i, j=1, 2... n) is the quotient of weights of the criteria, as shown:

(1)

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \quad = a_{11} = 1, \quad a_{ji} = \frac{1}{a_{ij}}, \quad a_{ij} \neq 0.$$

Eigenvalue and Eigenvector

Saaty (1990) recommended that the maximum eigenvalue, λ_{max}, can be determined as:

(2)

$$\lambda_{max} = \sum_{j=1} a_{ij} \, W_j \Big/ W_i.$$

Where λ_{max} is the principal or maximum eigenvalue of positive real values in judgment matrix, W_j is the weight of jth factor, and W_i is the weight of ith factor.

If A represents consistency matrix, eigenvector X can be determined as

$$(A - \lambda_{max}I)X = 0 \qquad (3)$$

Consistency Test

Both AHP and Expert Choice Software does not impose on the manufacturing firms to be perfectly consistent, rather a consistency test is performed to examine the extent of consistency as well as each judgment once the priorities are determined. Saaty (1990) recommended using consistency index (CI) and consistency ration (CR) to check for the consistency associated with the comparison matrix.

A matrix is assumed to be consistent if and only if $a_{ij} * a_{jk} = a_{jk}$ $\forall_i$ $_{jk}$ (for all i, j, and k). When a positive reciprocal matrix of order n is consistent, the principal eigenvalue possesses the value n. Conversely, when it is inconsistent, the principal eigenvalue is greater than n and its difference will serve as a measure of CI. Therefore, to ascertain that the priority of elements is consistent, the maximum eigenvector or relative weights/λ_{max} can be determined. Specifically, CI for each matrix order n is determined by using (3):

$$CI = (\lambda_{max} - n)/n - 1 \qquad (4)$$

Where n is the matrix size or the number of items that are being compared in the matrix. Based on (3), the consistency ratio (CR) can be determined as:

$$CR = CI/RI = [(\lambda_{max} - n)/n - 1]/RI. \qquad (5)$$

Where RI represents average consistency index over a number of random entries of same order reciprocal matrices shown in Table 1. CR is acceptable, if it is not greater than 0.10. If it is greater than 0.10, the judgment matrix will be considered inconsistent. To rectify the judgment matrix that is inconsistent, decision-makers' judgments should be reviewed and improved. However, Byun (2001) suggested that .20 might still be acceptable.

Table.1 The Reference Values of RI for Different Numbers of n

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Data Collection and Analysis

A survey questionnaire approach was used for gathering relational data to assess the order of importance of the supplier selection criteria. Thus, from the hierarchy tree, we developed a questionnaire to enable pairwise comparisons between all the selection criteria at each level in the hierarchy. The pairwise comparison process elicits qualitative judgments that indicate the strength of a group of decision makers' preference in a specific comparison according to Saaty's 1-9 scale. A group of purchasing and supply

chain managers was requested to respond to several pairwise comparisons where two categories at a time were compared with respect to the goal. The result of the survey questionnaire technique was then used as input for the AHP. The matrix of pairwise comparisons of the criteria or attributes given by the manufacturing firms in the case study is shown in Table 2. The judgments are entered utilizing Saaty's pairwise comparison preference scale explained in step 3.

Table 2. Pairwise Comparison Matrix with respect to Goal

Goal	RS	QP	LT	PP	TC	ES
Reliability pf supplier (RS)	1	1	3	3	5	1
Quality of product (QP)	1	1	2	3	3	1
Lead time (LT)	1/3	1/2	1	1	1	1
Price of product (PP)	1/3	1/3	1	1	1/2	1/3
Transportaition ease and cost (TC)	1/5	1/3	1	2	1	1/3
Experience of the supplier (ES)	1	1	1	3	3	1

Tables 3-8 show the judgments of a group of decision makers regarding the relative importance of the suppliers A, B, C, and D with respect to quality of product, transportation, ease and cost, reliability of supplier, price of product, experience of the supplier, lead time.

Table3.Pairwise comparison with respect to reliability of supplier criterion

Reliability of supplier (RS)	A	B	C	D	priority	Rank
A	1	2	1	3	0.348	2
B	1/2	1	1/3	1	0.142	3
C	1	3	1	3	0.389	1
D	1/3	1	1/3	1	0.128	4

Table4.Pairwise comparison with respect to quality of product criterion

Quality of product(QP)	A	B	C	D	priority	Rank
A	1	1/3	1/5	1	0.095	3
B	3	1	1/3	3	0.249	2
C	5	3	1	5	0.560	1
D	1	1/3	1/5	1	0.095	3

Table5.Pairwise comparison with respect to price of product criterion

Price of product(PP)	A	B	C	D	priority	Rank
A	1	2	1	1/3	0.190	3
B	1/2	1	1/3	1/5	0.089	4
C	1	3	1	1/2	0.232	2
D	3	5	2	1	0.489	1

Table6.Pairwise comparison with respect to lead time criterion

Lead time (LT)	A	B	C	D	priority	Rank
A	1	5	1/2	1/3	0.182	3
B	1/5	1	1/7	1/7	0.048	4
C	2	7	1	1	0.362	2
D	3	7	1	1	0.407	1

Table7.Pairwise comparison with respect to transportation eases and cost criterion

| Transportation eases and cost (TC)	A	B	C	D	priority	Rank
A	1	3	1/3	1/3	0.147	3
B	1/3	1	1/7	1/5	0.061	4
C	3	7	1	1	0.411	1
D	3	5	1	1	0.381	2

Table8.Pairwise comparison with respect to experience of the supplier criterion

Experience of the supplier(ES)	A	B	C	D	priority	Rank
A	1	3	1/3	1/3	0.147	3
B	1/3	1	1/5	1/7	0.061	4
C	3	5	1	1	0.381	2
D	3	7	1	1	0.411	1

Results and Discussions

The priorities obtained from the group decision makers' judgments are depicted in Figure 3. It shows that is reliability of supplier the best supplier selection criterion, followed by quality of product, experience of the supplier, lead time, transportation ease and cost, price of product. Thus, suggesting that the decision makers in the case of manufacturing firms should integrate the preceding criteria into supplier selection decision. The inconsistency or referred to as CR is $0.07 < 0.10$ reported by the Expert Choice Software. This implies that the group decision makers' (purchasing and supply chain managers') evaluation is consistent.

Figure4. Priority weights for the major criteria
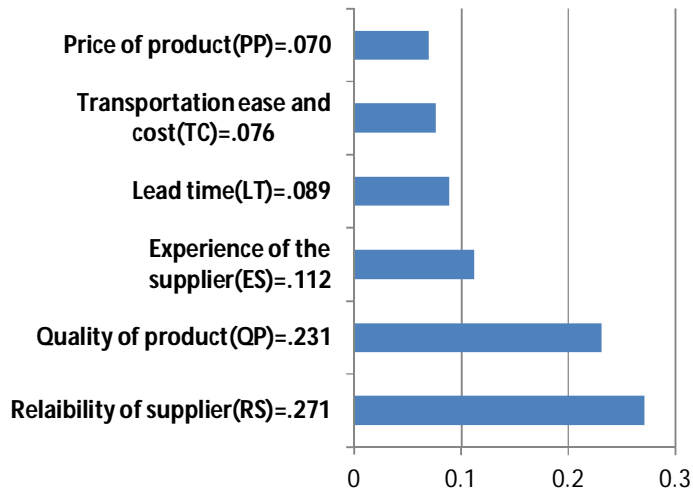
Conclusions and Implications

AHP approach helps decision makers to rank alternative suppliers based on the decision makers' subjective judgments regarding the importance of the attributes. The role of supplier selection process and evaluation has become more than ever imperative for supply chain performance. Supplier selection process and evaluation represents one of the key activities that organizations must integrate into their core strategic decisions. Selecting and evaluating the right suppliers is the quintessential aspect of strategic purchasing and supply chain management that can affect manufacturing firms. The primary objectives of supplier selection and evaluation include reducing costs, attaining real-time delivery, ensuring world-class quality, mitigating risks, and receiving better services.

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