A Decision Support System for Supplier Selection in a Chemical Firm Supply Chain: A Case Study Leveraging Analytic Hierarchy Process Model

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Abstract. Supplier selection has been acknowledged as one of the most important function of purchasing and supply chain management and thus a crucial decision for chemical firms. This paper discusses multi-criteria decision making employing Analytic Hierarchy Process (AHP) model for supplier selection problem in a chemical firm. Supplier selection attributes are developed by using previous literature and through a survey questionnaire sent to a group of decision makers in a chemical firm. Based on the literature review, eight major attributes were identified. Supplier selection lends itself to a multi-criteria decision making problem as suppliers can be evaluated based upon a number of attributes. Leveraging the identified attributes, an AHP model is developed for prioritizing and/or ranking the suppliers. Expert Choice software is utilized in implementing the AHP model as well as performing the sensitivity analysis. Previous studies suggest that quality, cost and delivery Performance are considered the most important criteria when selecting a supplier. However, in the current study, we found that risk management, green purchasing, and CSR supply chain criteria are the most important for the selection of right supplies followed by cost, delivery Performance etc.

Keywords: AHP, Supplier Selection, Sensitivity Analysis, Green Purchasing, Corporate Social Responsibility Supply Chain, Risk Management, Chemical Firm Supply Chain

Introduction. In today's hypercompetitive global marketplace environment, selecting the right suppliers is inordinately imperative to the survival and success of any manufacturing firm. Choi and Hartley (1996) note that "determining which suppliers to include in the supply chain has become a key strategic consideration" for many companies. Indeed, supplier selection process and evaluation has become one of the essential parts of logistics and supply chain management. The need to select high quality suppliers is imperative because they are vital resource for manufacturing firms seeking to attain competitive advantage (e.g., Monczka et al. 1993; Handfield and Pannesi 1995; Richardson 1993; Handfield et al. 1999; Weber et al. 1991). Therefore, chemical firms must select potential suppliers that can deliver world-class quality at least cost to meet and exceed customer requirements. Arguably, suppliers, the quintessential part of supply chain can play a crucial role in supporting manufacturing firms deliver customers' value expectations. And to meet customers' value expectations means that manufacturing firms must endeavor according to Onesime et al. (2004), "to obtain products at the right cost, in the right quantity, with the right quality at the right time from the right source…" through the selection of world-class suppliers. Pi and Low (2005) assert that the purchasing function directly contributes to a firm's competitiveness through its influence on quality, purchasing cost, technology, and supplier responsiveness. Selecting the right suppliers can have considerable direct impact on organizations' cost/price, quality, lead time, delivery reliability, technology, availability of its products, and time-to-market of new products (Robert et al. 1999; Pearson and Ellram 1995; Sarkis and Talluri 2002; Bobler and Burt 1996). Li et al. (1997) describe the primary objective of supplier selection process as a strategy to mitigate purchase risk, develop mutual and long term relationships between the buying firms and suppliers, and optimize overall value expectation of the buyer. However, wrong selection of suppliers can erode the financial and competitive position of a firm.

The selection process simply entails the evaluation of different alternative suppliers based on the relevant criteria. This selection process represents a multi-attribute decision making problem affected by different tangible and intangible attributes such as the identified traditional attributes, risk management, environmental or green purchasing, ethically and corporate social responsibility (CSR) supply chain. A number of methodologies that have been used in supplier selection and evaluation studies include linear weighting models, the categorical model, weighted point model, total cost of ownership, multiple attribute utility theory, artificial neural network, principal component analysis, analytic network process, AHP, combined AHP and linear programming, among others.

The present research leverages AHP model developed by Saaty (1980) for supplier selection in a chemical firm in which the goal being pursued has multiple, often conflicting attributes. AHP is a multi-attribute decision making process which enables decision makers set priorities and deliver the best decision when both quantitative and qualitative aspects of a decision must be considered. AHP encompasses three basic functions, including structuring complexity, measuring on a ration scale, and synthesizing. 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 (Calantone et al., 1998).

The objective of this research is to identify relevant criteria or attributes for selecting the best supplier for a Chemical firm and extend the AHP-based model which incorporates the identified attributes into the supplier selection process and evaluation. Because supplier selection problem represents a typical multi-attributes decision making problem, the AHP methodology is chosen to assist purchasing and supply chain managers in their supplier selection problem. The AHP-based model has been acknowledged in the purchasing and supply chain management literature as a reliable approach that can assist decision makers to effectively select suppliers for long-term collaborative relationship.

The remainder of this paper is organized into the following major sections. In section 2, we present a brief background on the chemical industry, including the challenges and issues confronting it. In section 3, review of literature is presented. In section 4, we address the applicability of AHP methodology to supplier selection in a chemical firm supply chain. In section 5, we present the methodology employed to develop the AHP model. In section 6, we discuss the empirical results. Finally, section 7 presents the conclusions and managerial implications.

Background on Chemical Industry. The chemical industry produces chemicals that are used to produce virtually everything for the end-users. The chemical industry is the most diverse of U.S. industries, represented by about 10,000 organizations that transform raw materials, including oil, natural gas, air, water, metals, and minerals into different commodities. In 2007, BASF chemical firm purchased about 500,000 different raw materials and technical goods as well as services for plant construction, maintenance and logistics (http://report.basf.com/2007/en/managementsanalysis/supplychain.html). Like many firms, global chemical firms seek suppliers who possess global capabilities, are reliable and responsive in supply, and service and quality. Chemical firms expect their suppliers to deliver world-class service and raw materials that will enable them attain competitive strategic advantage. For suppliers that meet the value expectations will be rewarded with large volumes of purchases of commodities. Also, increasing customer demands and environmental complexity are the key trends driving change in the chemical industry. However, chemical industry is challenged with increasing manufacturing cost (raw material cost, energy cost, price and margin pressure); increasing global operations in emerging markets; and increase risk and regulation (financial compliance, global trade compliance, and environmental compliance). The chemical industry is facing new regulatory challenges such as homeland security.

The chemical industry is experiencing growing instability in terms of consolidation, regulatory compliance, globalization and global volatility in feed stock prices present significant threat. A combination of technological advancements, health, safety and privacy issues, and unrelenting demanding customer base add to the volatile challenges, market opportunities, and threats to chemical firms (IBM Consulting Services 2004).

Literature Review. Supplier selection has received a significant coverage in the purchasing and supply management literature (e.g., Petroni and Braglia 2000; Weber et al. 1991; Weber et al. 1992; Ellram 1990; Dickson 1966; Ghodsypour and O'Brien 1998; Verma and Pullman 1998; Krause and Ellram 1997; Youssef et al. 1996; Wilson 1994; MIN 1993; Motwani et al. 1999; Narasimhan 1983; Swift 1995; Akine 1993; Soukup 1987). Based on Dickson's (1966) empirical study, 23 criteria were identified that purchasing managers generally consider when selecting a supplier. Of the identified criteria, quality, on-time delivery, and supplier's performance history were found vital in supplier selection regardless of the type of purchasing environment. Dempsey (1978) identified quality, delivery capability, and technical capability as imperative in supplier selection. Ellram (1990) emphasized the need not only to base supplier selection decisions on the traditional price and quality criteria but also on longer term and qualitative attributes such as strategic match and evaluation of future manufacturing capabilities.

Although these and other past studies considered the traditional supplier selection attributes such as quality, cost, flexibility and delivery Performance, they have not considered adequate integration of contemporary issues such as environmental initiatives (Handfield et al. 2002; Humphreys et al. 2002). In addition to the traditional selection attributes, the current research considers green purchasing, ethical and CSR supply chain, and risk management.. Supplier selection literature is endowed with all 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., Handfield et al. 2002; Barbarosoglu and Tazgac 1997; Bhutta and Huq 2002; Chan 2003; Onesime et.al. 2004). This research contributes to the existing stream of research by integrating green supply chain purchasing, ethical and CSR supply chain, and risk management into supplier selection process in a chemical firm supply chain

Research Methodology. Saaty (1980) developed AHP that can be used to handle relatively complex multi-attribute decision making problems. It enables a decision maker to represent the simultaneous interaction of several factors in complex and unstructured situations. For supplier selection, the derived expert judgments are introduced into the AHP model for each attribute of the hierarchy. Supplier selection problem is a typical multi-attributes decision making that entails multiple attributes that can be both qualitative and quantitative. AHP is selected because it permits decision-makers to model a complex problem in a hierarchical structure; showing the relationships of the overall goal, criteria, and alternatives. Although the positive attributes associated with AHP has been widely reported in the literature, there has been a small number of descending opinions (e.g., Belton and Gear, 1986; Dyer and Wendel, 1985). However, because of its usefulness, AHP has been widely used in supplier selection (e.g., Bhutta and Huq 2002; Chan 2003; Ghodsypour et al. 1998; Nydick and Hill 1992; Chan et al. 2007; Maggie and Tummala 2001). The hierarchy structure for supplier selection problem in a chemical firm is composed of three levels as depicted in Figure 1. The top level contains the overall goal of the problem, the middle level contains the multiple selection criteria that define the decision alternatives, and the lower level contains competing alternative suppliers.

Model Development of AHP for Supplier Selection Problem. Supplier selection process encompasses four parts, including problem definition; formulation of attributes; qualification of potential suppliers; and the ultimate selection of best suppliers (De Boer et al. 2001). The AHP methodology decomposes a problem and performs pair-wise comparison of all the elements. For chemical firms, which suppliers are the best and how much supplies should be procured from suppliers selected are vitally essential procurement problems. Often, decision makers determine the best supplier from evaluating suppliers with qualitative supplier selection criteria by way of a decision support system. Supplier Selection enables manufacturing firms such as chemical 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 as follows.

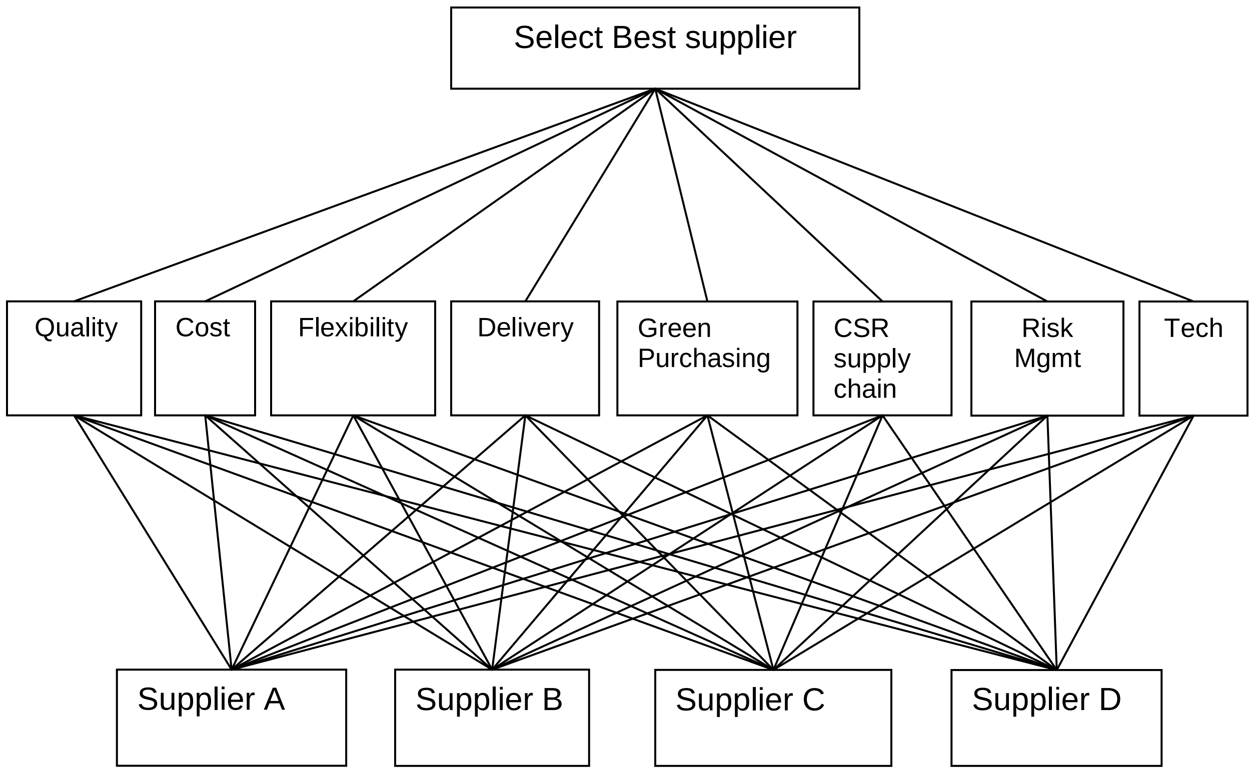
(1) Clearly state the decision problem and the overall goal.

(2) Structure the hierarchy from top through the intermediate levels to the lowest level. In Figure 1, 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.

Description of Criteria and Alternative Suppliers. Historically, organizations have primarily considered criteria such as quality, service, price/cost, flexibility, reputation, and financial stability when selecting and evaluating suppliers (e.g. Sarkis and Talluri 2002; Verma and Pullman 1998; Hirakubo and Kublin, 1998). However, in today's competitive environment, ethical and corporate social responsibility supply chain, regulatory compliance mandate, environmental/green supply chain, and post 9/11 safety and security requirements pressure are growing, thus prompting organizations to consider them in supplier selection. Therefore, the identified attributes used for supplier selection for a chemical firm include the following:

Quality. Quality of raw material and component requirements are very essential in the chemical industry. Because customers demand quality products and services from manufacturers, it behooves them to select suppliers with proven record of world-class service and quality raw materials. For example, chemical firms' suppliers are required to provide top-notch commodities as well as services. Lin et al. (2005) note that quality management practices are imperative in supplier selection strategies. Gonzales et al. 2004 found that quality is the most significant attribute in supplier selection.

Figure 1. The Hierarchical Structure of AHP Model for a Chemical Firm



Cost. Cost has traditionally been considered as one of the most important aspects of supplier selection criteria in the purchasing and supply management literature.

Flexibility. It is imperative for a chemical firm to select suppliers with flexibility given that chemicals encompasses many raw materials and components that require large outlay to be spent on converting them into thousands of final products. With proper flexibility, the manufacturers and suppliers could reduce risk associated with predictable and unpredictable surprises. Proper flexibility can reduce unnecessary costs.

Delivery Performance. Ability of suppliers to deliver on-time as promised.

Green Purchasing. The pursuit of green initiative by way of green purchasing can improve firms' environmental as well as financial performance (Zhu and Geng, 2001). Arguably, "Suppliers face increasing pressure from their customers to improve their environmental performance. When firms downstream in the supply chain seek to achieve such improvements themselves, they frequently request … their suppliers adopt greener practices" (Delmas and Montiel, n.d). Industries of all type are requiring their suppliers to achieve international environmental management standard ISO 14001certification. For example, many firms are requiring their suppliers to implement better environmental management practices (Plambeck and Denend 2008; Darnall 2006; Handfield et al. 2002; Walton, Handfield, and Melnyk 1998). According to Handfield et al. (2002), "Dow Chemical only uses suppliers who are part of the voluntary ''Responsible Care'' initiative [RCI]." Similarly, BASF evaluates both potential and existing suppliers on the basis of environmental protection, occupational safety, and social responsibility standards. (http://www.basf.com/group/corporate/en/sustainability/management-and-instruments/supply-chain).

Corporate Social Responsibility (CSR) Supply Chain. Embracing ethical and CSR supply chain is more than ever seen as crucial to the long term sustainability and profitability of manufacturing firms. In today's global marketplace, consumers are interested in knowing the labor conditions under which the products they purchase are produced and how their operations impacts the environment and economic growth of the host communities along the firms' supply chains (Harrison et al. 2005; Shaw and Clarke 1998; Strong 1996). Carter and Jennings (2004) examined the need for CSR in the purchasing activities. Chemical firms are increasingly under pressure to be ethically and socially responsible in their conduct of global business operations. As a result, they are more than ever requiring suppliers to embrace RCI. Handfield et al. (2002) defines RCI as "… a dedication of responsibility to the community regarding chemicals, chemical transportation and manufacturing, as well as safe disposal and prompt reporting." In accordance with the United Nations' Global Compact Initiative, BASF mandates it suppliers not to either employ children or employ forced or bonded laborers. Also, its procurement requirements specify that suppliers must comply with the International Labor Organization's (ILO) employment standards (http://www.basf.com/group/corporate/en/sustainability/ Management-and-instruments/supply-chain).

Risk Management. This is a disciplined approach to mitigating and managing both predictable and unpredictable surprises. For example, to ensure the safe and secure distribution of its raw materials, intermediates and products worldwide, Dow Chemical developed a comprehensive risk management program. The program includes baseline requirements such as: Compliance with transportation safety and security regulations; global implementation of RCI; development and implementation of uniform Dow supply chain standards which include the use of Most Effective Technology and Loss Prevention Principles (LPP); and a process for conducting reviews, audits and assessments of Dow and supply chain partner operations. Indeed, chemical firms rely on their suppliers to operate and deliver chemical products reliably, safely, securely, and in a sustainable manner (Mathes 2006).

Technology. For the manufacturers, technology is imperative for maintaining and improving product and services. The technological advancement of suppliers is important to the quality of their supplies. There is a direct relationship between technology and the quality of commodities provided by suppliers.

Alternative Suppliers. The suppliers are identified as supplier A, Supplier B, Supplier C, and Supplier D, respectively.

(3) Construct a set of pair-wise comparison matrices for each of the lower levels. The pairwise comparison is made such that the attribute in row *i* (*i = 1,2,3,4…n)* is ranked relative to each of the attribute represented by *n* columns. The pair-wise comparisons are done in terms of which element dominates another (i.e. based on relative importance of the elements). These judgments are then expressed as integer values 1 to 9 in which a_{ij} = 1 means that *i* and *j* are equally important; a_{ij} = 3 signifies that *i* is moderately more important than *j*; a_{ij} = 5 suggests that *i* is strongly more important than *j*; a_{ij} = 7 indicates that *i* is very strongly more important than *j*; a_{ij} = 9 signifies that *i* is extremely more important than *j*;

Establishment of Pairwise Comparison Matrix *A*. Assuming C_1, C_2, C_3, …C_n to be the set of elements and a_{ij} representing a quantified opinion or judgment on a pair of elements C_i, C_j. The relative importance of two elements C_i, C_j is assessed using a preference scale on an integer-valued 1-9 developed by Saaty (2000) for pairwise comparisons. According to Saaty, a value of 1 between two criteria indicates that both equally influence the affected node, while a value of 9 indicates that the influence of one criterion is extremely more important than the other. It allows the transformation of qualitative judgments and/or intangible attributes into preference weights (level of importance) or numerical values. The pairwise comparisons are accomplished in terms of which element dominates or influences the order. AHP is then used to quantify these opinions that can be represented in *n-by-n* matrix as follows:

$$A=[a_{ij}]=w_i/w_j=\begin{bmatrix} w_1/w_2 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix}=\begin{bmatrix} 1 & a_{12} & \dots & a_{in} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix} \quad (1)$$

If c_i, is judged to be of equal importance as c_j, then $(a_{ij}) = 1$
If c_i, is judged to be more important than c_j, then $(a_{ij}) > 1$
If c_i, is judged to be less important than c_j, then $(a_{ij}) < 1$

$$(a_{ij}) = 1/a_{ji}, \qquad (i, j = 1, 2, 3, \dots, n),\ a_{ij} \neq 0.$$

Where matrix *A* represents a reciprocal matrix, a_{ij} is the inverse of the entry a_{kj} which indicates the relative importance of C_i compared with attribute C_j. As an example, $a_{12} = 3$ indicates that C_1 is 3 times as important as C_2. In matrix *A*, it becomes the case of assigning the *n* elements C_1, C_2, C_3, … C_n a set of numerical weights W_1, W_2, W_3, …W_n, that represents the recorded experts' judgments. If *A* is a consistency matrix, the links between weights W_i and judgments a_{ij} are given by $W_i / W_j = a_{ij}$ (for *i, j* = 1, 2, 3, …, *n*).

Eigenvalue and Eigenvector. Saaty (1990) recommended that the maximum eigenvalue, λ_{max}, can be determined as

$$\lambda_{max} = \sum_{j=1}^{n} a_{ij}\ W_j/W_i. \quad (2)$$

Where λ_{max} is the principal or maximum eigenvalue of positive real values in judgment matrix, W_j is the weight of j^{th} factor, and W_i is the weight of i^{th} factor.
If A represents consistency matrix, eigenvector X can be determined as

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

Consistency Test. Both AHP and Expert Choice Software does not impose on the pharmaceutical 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):

$$CI = (\lambda_{max} – n)/n – 1 \quad (4)$$

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:

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

Where RI represents average consistency index over a number of random entries of same order reciprocal matrices shown in Table 2. CR is acceptable, if its value is less than or equal to 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	1.51

Data Collection and Results. A survey questionnaire approach was used for gathering relational data to assess the order of importance of the supplier selection criteria. Through interview and survey of the purchasing and supply chain managers of a chemical firm, 8 relevant criteria were identified for supplier selection process and evaluation. Base on the identified criteria and 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 chemical firm in the case study is shown in Table 2. The judgments are entered utilizing the Saaty's pairwise comparison preference scale explained in no. 3.

Table 2. Pairwise Comparison Matrix with respect to Goal

Goal	QPS	Cost	Flex	DP	GP	CSRSS	RM	Tech
Quality of product & service(QPS)	1	1	3	5	1/5	1/7	1/3	1
Cost	1	1	3	1	1/5	1/7	1/7	1/3
Flexibility (Flex)	1/3	1/3	1	1	1/7	1/6	1/5	1/2
Delivery performance (DP)	1/5	1	1	1	1/7	1/7	1/3	1/4
Green purchasing (GP)	5	5	7	7	1	1	1	5
CSR supply chain (CRSS)	7	7	6	7	1	1	1	3
Risk management (RM)	3	7	5	3	1/5	1/3	1	7
Tech	1	3	2	4	1/5	1/3	1/7	1

Employing pairwise comparison matrix as shown above in Table 2, 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. The priorities obtained from the group decision makers' judgments are depicted in Figure 2. It shows that corporate social responsibility supply chain is the best supplier selection criterion, followed by green purchasing, risk management, and technology. Thus, suggesting that the decision makers in the case chemical firm should integrate the preceding criteria into supplier selection decision. However, the traditional selection criteria (quality, cost, delivery performance, and flexibility

Figure 2. Priority weights for the major criteria

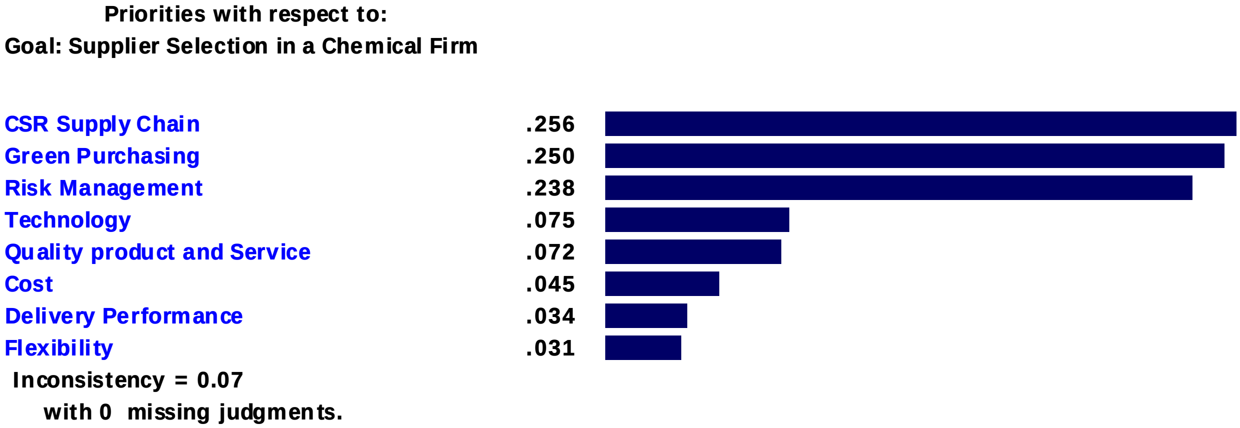


Table 3-10 show the pairwise comparisons associated with the alternative suppliers. There are eight 4 x 4 matrices of judgments. That is, there are seven attributes and four suppliers to be pairwise compared for each attribute. Essentially, Table 3-10 depict the judgments of a group of decision makers regarding the relative importance of the suppliers A, B, C, and D with respect to quality product/service, cost, flexibility, delivery performance, green purchasing, CSR supply chain, risk management, and technology, respectively.

Table 3. Pairwise comparison with respect to quality product/service criterion

Quality Product/Service	A	B	C	D	Priority
A	1	3	3	1/7	0.161
B	1/3	1	1	1/9	0.065
C	1/3	1	1	1/7	0.070
D	7	9	7	1	0.704

Table 4. Pairwise comparison with respect to cost criterion

Cost	A	B	C	D	Priority
A	1	1/3	3	1/7	0.098
B	3	1	5	1/4	0.220
C	1/3	1/5	1	/9	0.047
D	7	4	9	1	0.635

Table 5. Pairwise comparison with respect to Flexibility criterion

Flexibility	A	B	C	D	Priority
A	1	1/3	5	1/4	0.136
B	3	1	7	1/3	0.276
C	1/5	1/7	1	1/9	0.040
D	4	3	9	1	0.548

Table 6. Pairwise comparison with respect to delivery performance criterion

Delivery performance	A	B	C	D	Priority
A	1	3	3	1/5	0.177
B	1/3	1	2	1/9	0.080

C	1/3	½	1	1/9	0.057
D	5	9	9	1	0.686

Table 7. Pairwise comparison with respect to Green purchasing criterion

Green Purchasing	**A**	**B**	**C**	**D**	**Priority**
A	1	1	1/5	1/3	0.096
B	1	1	1/7	1/5	0.077
C	5	7	1	1	0.456
D	3	5	1	1	0.371

Table 8. Pairwise comparison with respect to CSR supply chain criterion

CSR Supply Chain	**A**	**B**	**C**	**D**	**Priority**
A	1	3	5	1/3	0.243
B	1/3	1	3	1/7	0.101
C	1/5	1/3	1	/9	0.049
D	3	7	9	1	0.607

Table 9. Pairwise comparison with respect to risk management criterion

Risk Management	**A**	**B**	**C**	**D**	**Priority**
A	1	1	5	1	0.311
B	1	1	3	1	0.278
C	1/5	1/3	1	1/7	0.067
D	1	1	7	1	0.344

Table 10. Pairwise comparison with respect to technology criterion

Technology	**A**	**B**	**C**	**D**	**Priority**
A	1	1	3	1	0.284
B	1	1	5	1	0.321
C	1/3	1/5	1	1/5	0.074
D	1	1	5	1	0.321

Table 11 reports on the priority scores of alternative suppliers. With respect to the overall priority scores of alternative suppliers, supplier D (0.439) is most preferred followed by supplier A (0.219), supplier B (0.186), and accept risk (0.161), respectively.

Table 11. Priority scores of alternative suppliers

Attribute	**Alternatives**	**Priority Scores**	**Ranks**
Quality Product & Service (0.072)			
	Supplier A	0.161	2
	Supplier B	0.065	4
	Supplier C	0.070	3
	Supplier D	0.704	1
CR = 0.05 < .10			
Cost (0.045)			
	Supplier A	0.098	3
	Supplier B	0.220	2

Supplier C	0.047	4
Supplier D	0.635	1
CR = 0.05 < .10		
Flexibility (0.031)		
Supplier A	0.136	3
Supplier B	0.276	2
Supplier C	0.040	4
Supplier D	0.548	1
CR = 0.06 < .10		
Delivery Performance (0.034)		
Supplier A	0.177	2
Supplier B	0.080	3
Supplier C	0.057	4
Supplier D	0.686	1
CR = 0.04 < .10		
Green Purchasing (0.250)		
Supplier A	0.096	3
Supplier B	0.077	4
Supplier C	0.456	1
Supplier D	0.371	2
CR = 0.02 < .10		
CSR Supply Chain (0.256)		
Supplier A	0.243	2
Supplier B	0.101	3
Supplier C	0.049	4
Supplier D	0.607	1
CR = 0.03 < .10		
Risk Management (0.238)		
Supplier A	0.331	2
Supplier B	0.278	3
Supplier C	0.067	4
Supplier D	0.344	1
CR = 0.03 < .10		
Technology (0.075)		
Supplier A	0.284	2
Supplier B	0.321	1
Supplier C	0.074	3
Supplier D	0.321	1
CR = 0.01 < .10		
Overall		
Supplier A	0.219	2
Supplier B	0.182	3
Supplier C	0.161	4
Supplier D	0.439	1

Sensitivity Analysis on the Priority Weights of Criteria. With the aid of Expert Choice Software, AHP-based model provides an opportunity for decision makers to perform the sensitivity analysis (SA) of the decision criteria. If group of decision makers believe that an attribute might be more or less important than originally indicated, they can drag that attribute's bar to the right (increase) or left (decrease) and then observe the impact on alternatives. The objective of the SA is to determine how the small changes (perturbation) in input parameters, including quality, cost, flexibility, delivery performance, green (environmental) purchasing, CSR supply chain, risk management, and technology will impact the ranking of the alternative suppliers. Min (1994) emphasized that "the sensitivity analyses are necessary because changing the importance of criteria requires different levels of resource commitment …" If the global marketplace environmental conditions change, priorities of the chemical firm may change as well. Indeed, SA can enable group of decision makers to assess what may happen if the priority weights of the criteria change. Because of limitation of space we investigated few sensitivity analysis of the impact of changing priority of the criteria on the alternative suppliers' ranking. For performance SA in Figure 3 and dynamic SA in Figure 4, the alternative supplier ranking is as follows: supplier D, supplier A, supplier B, and supplier C.

In Figures 5-6, when the traditional criteria as well as the CSR supply chain, and risk management criteria priority weights were increased, the ranking of suppliers remained insensitive or stable. That is, suppliers D, A, B, and C, respectively However, when green purchasing priority increased from 0.26 (Figure 3) to 0.32 (Figure 5) the supplier ranking became sensitive or unstable. The same was the case when green purchasing priority increased from 25.0 (Figure 4) to 34.2 (Figure 5). That is, the new supplier ranking as follows: suppliers D, A, C, and B, respectively.

Figure 3. Performance sensitivity analysis on supplier selection

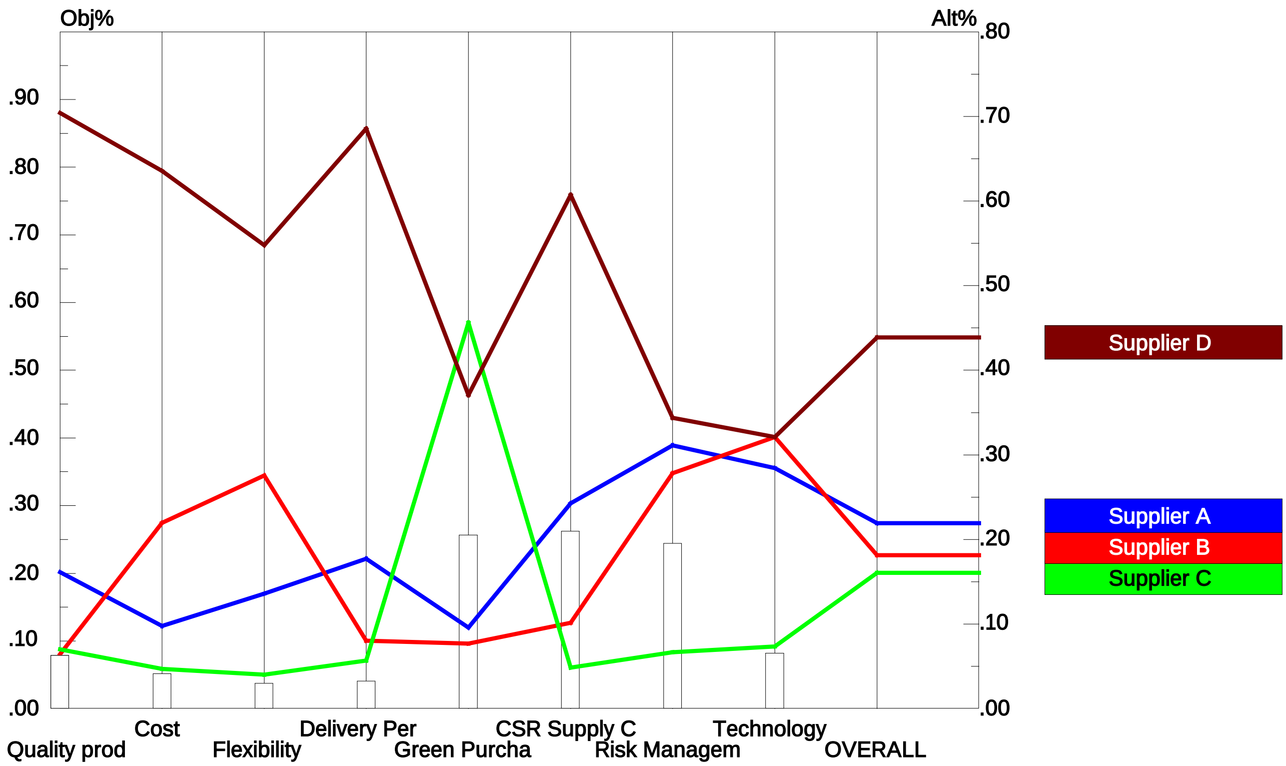


Figure 4. Dynamic sensitivity analysis on supplier selection

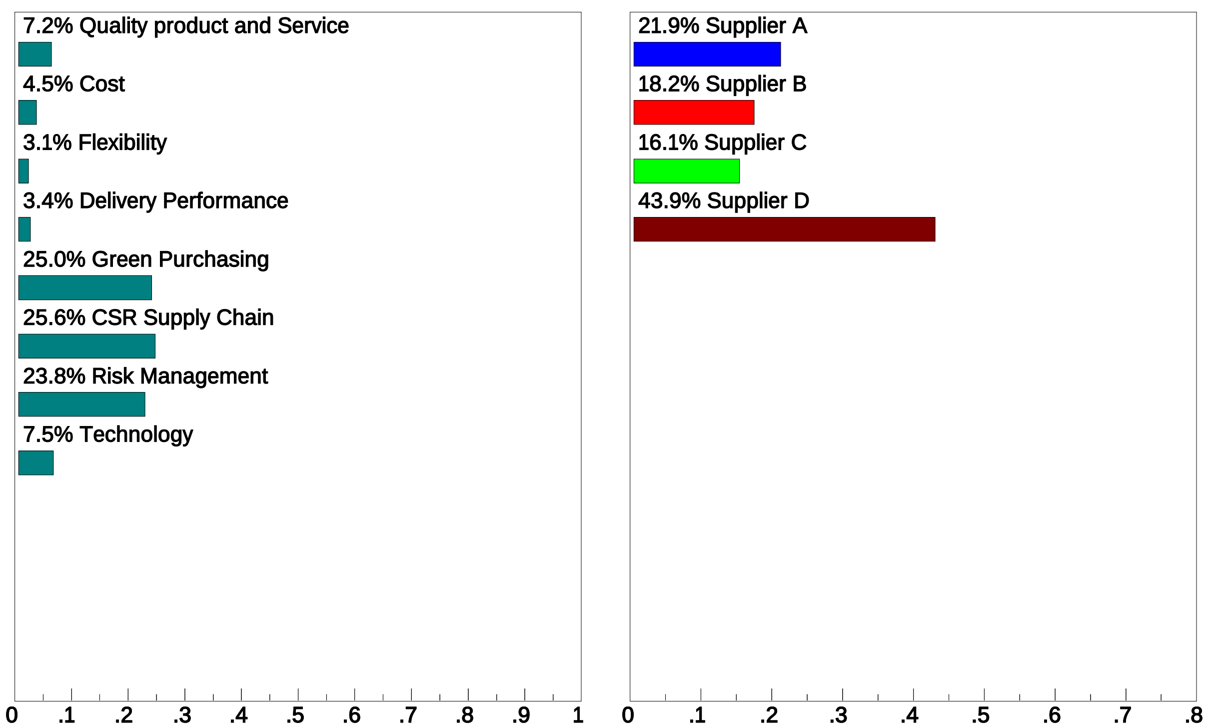


Figure 5. Performance sensitivity analysis on supplier selection

after changing green purchasing priority value

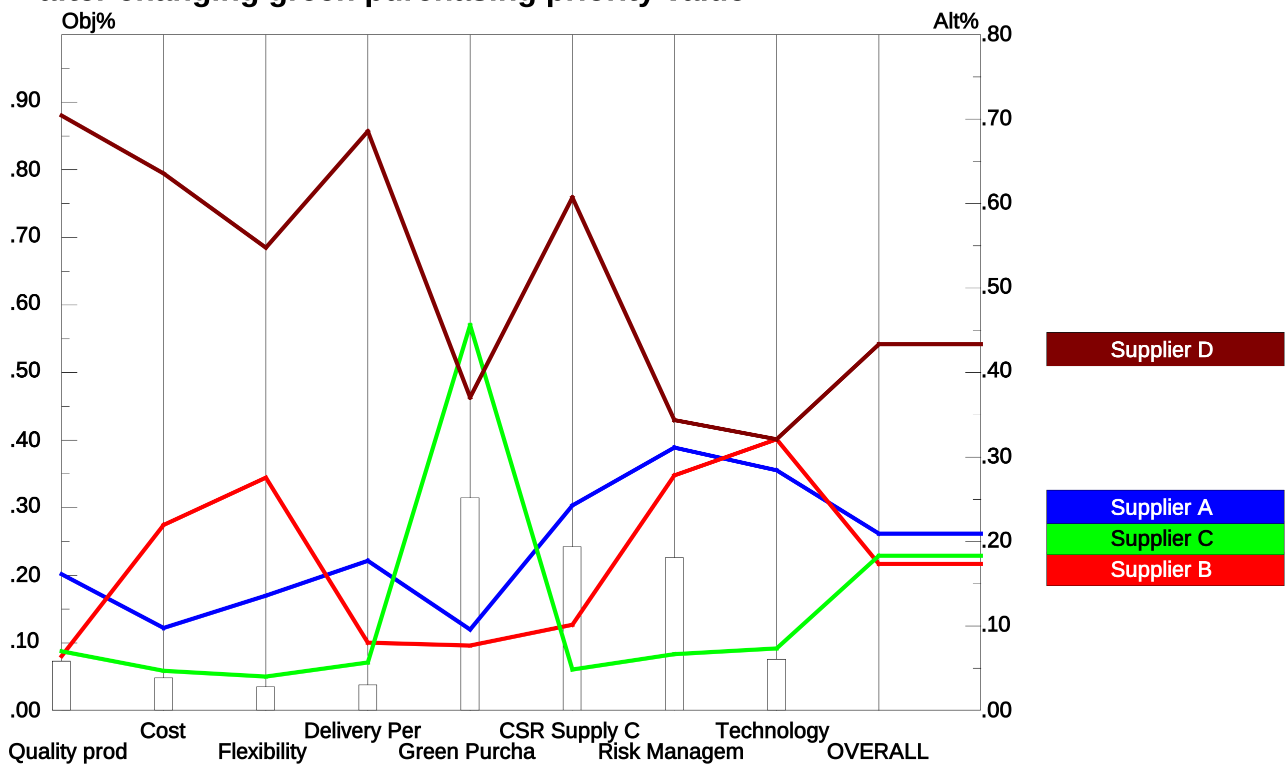
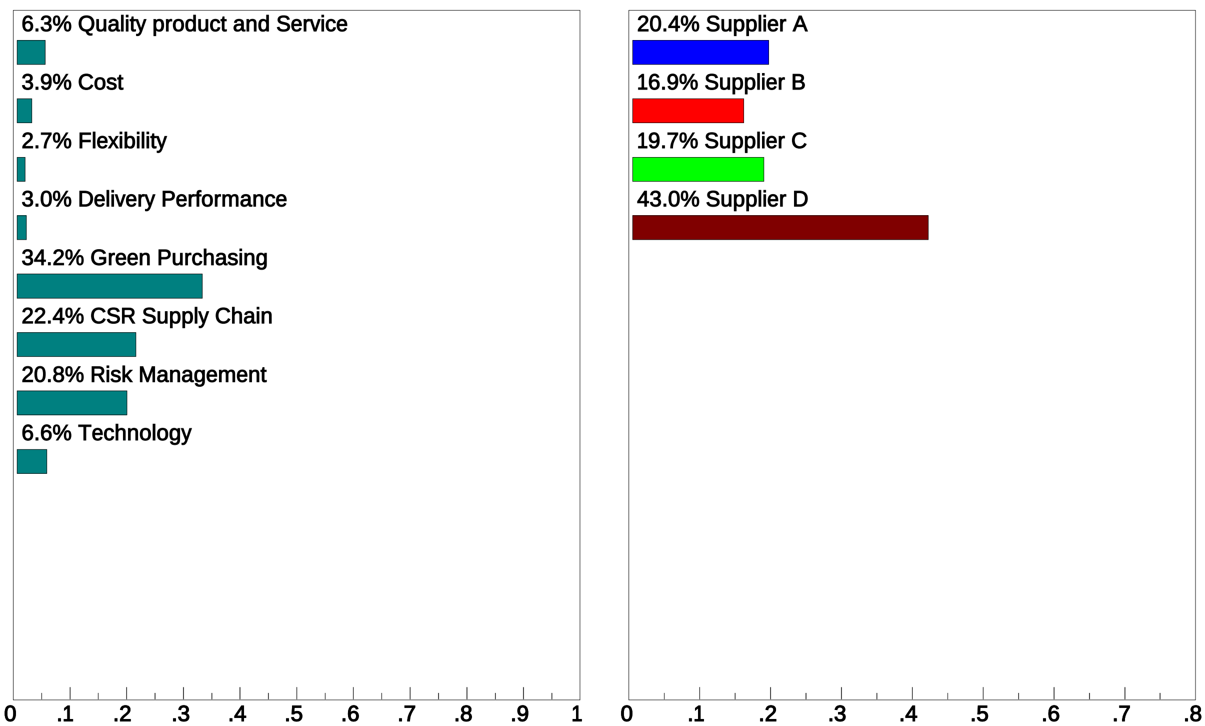


Figure 6. Dynamic sensitivity analysis on supplier selection after changing green Purchasing priority value



Conclusions and Managerial Implications. Supplier selection is an important purchasing function for any firm. However, in today's changing and hypercompetitive global business environment, purchasing and supply chain managers are faced with the daunting challenge of selecting the right suppliers for long-term collaborative and trusting relationship that will supply them with the requisite commodities. Indeed, supplier selection process is an essential problem facing the chemical firm under study as selecting the right suppliers represents a long term investment. A well executed supplier selection process can be the linchpin for achieving supply chain performance and competitive advantage. However, to accomplish these objectives means that "… an efficient supplier selection process needs to be in place and of paramount importance for successful supply chain management (Sonmez 2006).

Selecting the best supplier for a chemical firm can be defined as a multi-attribute decision making problem encompassing quantitative and qualitative attributes. A multi-attribute decision making methodology such as AHP is beneficial in actively involving purchasing and supply chain managers with diverse conflicting objectives to reach a consensus decision. Thus, the AHP-based model is utilized to select the right suppliers since it can handle both quantitative and qualitative attributes.

A group decision-making process can be enhanced by a systematic and logical method to evaluate priorities based on opinions or judgments of purchasing and supply chain managers within the chemical firm. Although the traditional criteria are still relevant in supplier selection process and evaluation decision, this research revealed that CSR supply chain followed by green purchasing, and risk management, are the most important criteria to consider. For example, according to Humpreys (2003), "in the long term, environmental [or green purchasing and CSR supply chain] issues will become important [factors] for a company to consider." This insightful revelation underscores the growing imperative for green or environmental purchasing and CSR supply chain that purchasing and supply chain managers must consider when selecting suppliers for long-term and trusting relationships. It also means that selection of suppliers is not only based on economic criteria. Arguably, those firms that incorporate green purchasing and CSR supply chain criteria into the supplier selection process and evaluation will not only boost their supply chain performance, but they will also sustain and grow supply chain profitability.

Based on the AHP-based methodology, the best supplier selected was supplier D. Thus, the proposed AHP-based supplier selection decision support system was successful in aiding a group of purchasing and supply chain managers to select the best supplier for a chemical firm supply chain. Indeed, the AHP model proved useful in the group decision making and curtailed the time associated with supplier selection process exercise.

Finally, the premier contribution of this research was the identification of new important attributes for supplier selection problem in a chemical firm. The new attributes integrated into supplier selection process include green purchasing, CSR supply chain, and risk management. Another contribution pertains to the extension of a decision support system model for supplier selection in a chemical firm supply chain. The decision support system model for supplier selection process was successfully extended leveraging AHP approach.

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