A MODEL FOR QUANTIFYING STRATEGIC SUPPLIER SELECTION: EVIDENCE FROM A GENERIC PHARMACEUTICAL FIRM SUPPLY CHAIN

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ABSTRACT

Given today's environment characterized by supply chain risk, green initiatives, increasing customers' value expectations, expanding regulatory compliance, and global economic crisis demand forward looking manufacturing firms to select and maintain suite of competent suppliers. Selection of competent suppliers and how much supplies should be procured from a supplier or suppliers is an important purchasing and supply management issue. Competent suppliers are the linchpin for supply chain effectiveness and the long term survival of firms. Lack of proper selection and evaluation of potential suppliers can retard a firm's supply chain performance, catapult cost, and diminish shareholder value. This paper undertakes a case study on solving the supplier selection process problem in a generic pharmaceutical firm leveraging the analytic hierarchy process (AHP) model and implemented with the support of the Expert Choice Software. The AHP is considered a reliable model for quantifying strategic supplier selection and evaluation problem in a generic pharmaceutical firm.

Keywords:

INTRODUCTION

Suppliers have been acknowledged as the best intangible assets of any business organization (Muralidharan et al. 2002). However, selecting the right suppliers for a long term relationship is a relevant procurement issue that demands judicious attention. According to Tahriri et al. (2008), "supplier selection problem has become one of the most important issues for establishing an effective supply chain system." Indeed, supplier selection and evaluation represents one of the significant roles of purchasing and supply management functions (Chen and Huang, 2007; Millington et al., 2006; Dahel, 2003; England and Leenders, 1975; Lewis, 1943). Tracey and Tan (2001) note that one of the key elements essential to supply chain success is effective purchasing function.

Arguably, purchasing and supply chain plays a crucial role in supply chain management through proper selection of competent suppliers. Weber, Current, and Benton, (1991) affirm that firms cannot successfully produce low cost, high quality products without judicious selection and maintenance of a competent group of suppliers. Lee et al. (2001) and Kumara et al. (2003) emphasize that selection of the best supplier is an essential strategic issue imperative for supply chain effectiveness and efficiency. Kumara et al. (2003) contend that strategic partnership with the right suppliers must be integrated within the supply chain to contain costs, improve quality and flexibility to meet end-customers' value and reduce lead time at different stages of the supply chain. Purchasing and supply management support the management of supplier network

with respect to identification of supplier selection criteria, supplier selection decisions, and monitoring of supplier performance (Jose Gerardo Martínez-Martínez, 2007).

The selection process represents a multi-criteria decision making problem affected by different tangible and intangible attributes such as the traditional attributes, including quality, cost, service, flexibility, and delivery performance reported in the literature (e.g., Weber, Current, & Benton, 1991; Weber & Ellram, 1992; Ellram, 1990; Dickson, 1966; Ghodsypour & O'Brien, 1998; Verma & Pullman, 1998; Krause & Ellram, 1997; Wilson, 1994; Min,1993; Narasimhan, 1983; Swift 1995, Soukup, 1987). 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 (ANP), AHP, AHP/linear programming hybrid, among others.

This paper uses the AHP model developed by Saaty (1980) for supplier selection and evaluation in a generic pharmaceutical company 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 decisions in many fields such as purchasing and supply management, logistics and supply chain management, marketing, engineering, education, and economics.

The remaining portion of this paper is organized as follows. Section 3 presents an abbreviated review of relevant literature on supplier selection and evaluation. Section 4 discusses the research methodology, including case study, data collection and analysis, and research findings. Finally, section 5 presents the conclusions and implications.

LITERATURE

Supplier selection has received a significant coverage in the purchasing and supply management literature (e.g., Petroni & Braglia, 2000; Weber, Current, & Benton, 1991; Weber & Ellram, 1992; Ellram, 1990; Dickson, 1966; Ghodsypour & O'Brien, 1998; Verma & Pullman, 1998; Krause & Ellram, 1997; Wilson, 1994; Min, 1993; Narasimhan, 1983; Swift, 1995; Soukup, 1987). Based on Dickson's (1966) empirical study, 23 criteria were identified which 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.

Kirytopolos et al (2008) utilized ANP approach for the selection and evaluation of suppliers' offers in parapharmaceutical clusters. The supplier selection criteria considered in their study included cost, service, supplier's profile, quality, risk, and other. Their research findings indicate that quality-related issues dominated the decision making process in the parapharmaceutical industry. Their study is valuable and insightful. However, our research differs in three major ways. Our case company is a generic pharmaceutical manufacturing firm.

We integrated regulatory compliance as well as green purchasing criteria that are very important in the innovative pharmaceutical and generic pharmaceutical industries and the application of AHP model using Expert Choice Software for the supplier selection process.

RESEARCH METHODOLOGY

A case study is a research strategy for investigating a contemporary phenomenon within its real life context, when the boundaries between phenomenon and the context are not clearly evident, and in which the multiple source of evidence are utilized (Yin, 1994). Hence a case study research strategy is used to construct an analytic framework for selecting the best supplier.

AHP 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 the complex and unstructured situations. For supplier selection, the derived expert judgments are introduced into the AHP model for each attribute of the hierarchy. Thus, the objective of this research is to develop AHP-based model for supplier selection in a generic pharmaceutical company. Supplier selection process and evaluation represents a typical multi-criteria decision making that entails multiple criteria 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 & Gear, 1983; Dyer & Wendel, 1985). However, because of its usefulness, AHP has been widely used in supplier selection (e.g., Bayazit & Karpak, 2005; Bhutta & Huq, 2002; Chan, 2003; Ghodsypour et al., 1998; Nydick & Hill, 1992; Chan et al., 2007; Maggie & Tummala, 2001; Barbarosoglu & Tazgac, 1997; Onesime et.al., 2004).

The hierarchy structure for supplier selection process in a generic pharmaceutical firm is composed of three levels as depicted in Figure 1. The top level contains the overall goal of the problem, the middle level houses the multiple selection criteria that define the decision alternatives, and the lower level contains competing alternative suppliers.

AHP Model Development for Supplier Selection in a Generic Pharmaceutical Firm

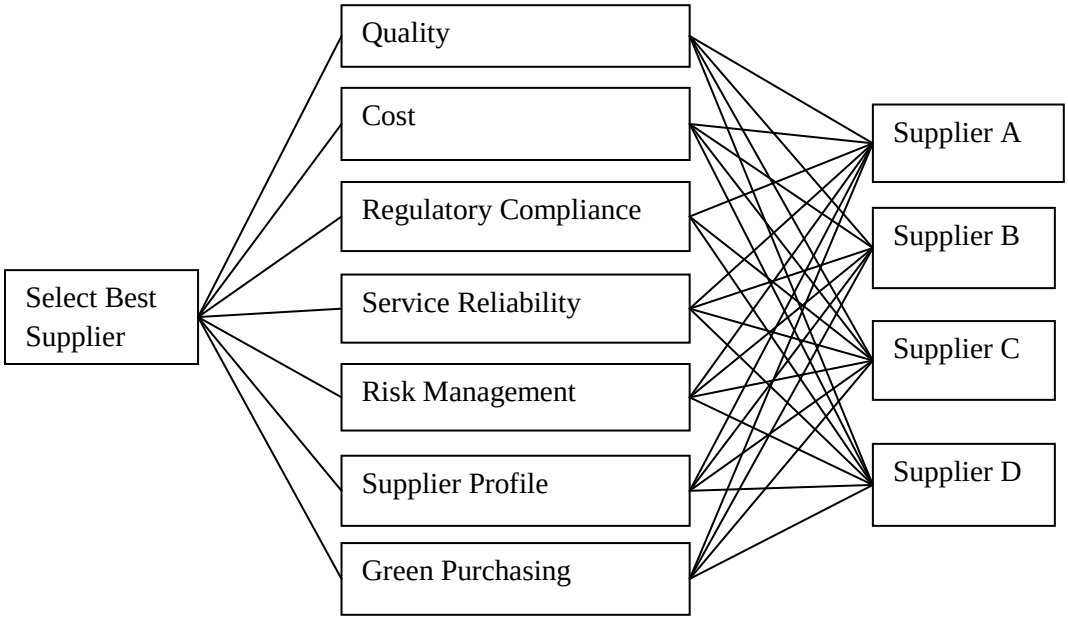
Supplier selection process encompasses four parts, including problem definition; formulation of attributes; qualification of potential suppliers; and the ultimate selection of best suppliers (De Boer et al., 2001). The AHP methodology decomposes a problem and performs pair-wise comparison of all the elements. Saaty (1980, 1990, and 2000) recommended the following steps for applying AHP method in decision making:

(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 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. 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 & Talluri, 2002; Verma & Pullman, 1998; Hirakubo & Kublin, 1998). However, in addition to the integration of regulatory compliance and green purchasing, following other authors as well as Kirytopolos et al (2008) the

current research considered quality, cost, service, risk, and supplier profile to evaluate each of the four suppliers.

Figure 1
The Hierarchical Structure for Supplier Selection



Quality

Quality of raw material and component requirements are very vitally important given that the pharmaceutical industry is the most regulated industry. Because FDA demands quality products from drug manufacturers, it behooves the pharmaceutical firms to select suppliers with supplier's certification, proven record of world-class service and quality raw materials. 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.

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

Regulatory Compliance (RC)

The generic pharmaceuticals industry is under increased pressure from the US Government and the FDA to comply with the rules and regulations governing the quality of its active pharmaceutical ingredients. This also means that the generic pharmaceutical manufacturers are interested in selecting suppliers that can be in compliance with the FDA rules and regulations in terms of the quality of their commodities. Indeed, pharmaceutical firms are more than ever mandated to update their knowledge of existing laws and regulations.

Service

supplier's services are imperative for any manufacturing firm. Pharmaceutical suppliers are expected to provide high-quality active pharmaceutical ingredients as well as support services. Essentially, services include consist of on-time delivery, value added services, and ease of communication.

***Risk Management (RM*)**

Suppliers must be able to proactively mitigate and manage supply risks. The ability of suppliers to help buyers reduce risk can positively affect cost containment, quality improvement, operational efficiency, process improvement and consistency, and supply chain visibility.

Supplier Profile (SP)

This criterion encompasses supplier's reputation, flexibility, capacity, financial health, and production facility.

Green Purchasing (GP)

The process of applying environmental criteria to selection problems. It is increasingly becoming an important criterion when making purchasing decisions. According to Min and Galle (1997), "… purchasing professionals need to address the relationship between environmental factors and supplier selection." Zhu and Geng (2001) contend that purchasing managers can play an important role in selecting suppliers who incorporate environmental friendly practice in their purchasing activities.

(3) Construct a set of pair-wise comparison matrices (n x n) 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 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:

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

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

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 $i, j = 1, 2, 3, \dots, n$).

(4) n(n – 1)/judgments are required to create the set of matrices in step (3). The associated reciprocals are automatically assigned in every pairwise comparison.

(5) Hierarchical synthesis is subsequently deployed to weight the eigenvectors by the weights of the criteria and the total is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

(6) After making all the pairwise comparisons, the consistency is determined by utilizing the maximum eigenvalue, λ_{max}. Specifically,

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

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

Saaty (1990) recommends 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 $a_{ij} * a_{jk} = a_{jk} \ \forall_{ijk}$ (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,

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

Where n is the matrix size or the number of items that are being compared in the matrix. Based on (4) and the appropriate value in Table 1, the consistency ratio (CR) can be determined as:

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

Where
RI represents average random 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.

Table 1
Average RI for Different Numbers of n

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

(7) Steps (3-6) are repeated for all levels in the hierarchy.

THE CASE STUDY

The proposed model is utilized in a case situation. In order to maintain the confidentiality of the company used in the case study, it is referred to as the case company. The case company in question is among the top 10 leading generic pharmaceutical companies as measured by prescriptions filled in the U.S. It has a workforce of more than 1,500 employees. It produces and markets high-quality and cost-effective suite of more than 500 generic pharmaceuticals. A wide range of dosage forms (prescription and over-the-counter) encompasses tablets and capsules, injectables, creams, ointments, inhalants, solutions, liquids and suspensions. They are deployed to deal with major therapeutic categories, including antihypertensive, analgesics, antibiotics, cough/cold, antidepressants, antipsychotics, cardiovascular, anti-infective, anti-inflammatory, oncolytic, antidiabetic, analgesic, dermatology, respiratory, among others. A good number of its pharmaceuticals are listed among the top 250 generics by total prescription volume and has one of the best overall Abbreviated New Drug Application (ANDA) approval records in the generic pharmaceutical industry. The pharmaceuticals are marketed to pharmacy outlets, wholesalers/distributors, and government agencies, as well as medical centers. It plays an important role in providing solution to the challenges faced by the U.S. healthcare system through its manufacture and marketing of generic pharmaceuticals.

Before applying the AHP, the case company did not have any standard method for rating suppliers and did not consider proactive risk management and green purchasing criteria for rating suppliers.

Data Collection and Analysis

A survey questionnaire approach was used for gathering the data to assess the order of importance of the supplier selection criteria. 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. Result of the survey questionnaire technique was then used as input for the AHP. It took a total of 21 judgments (i.e., 7(7-1)/2) to complete the pairwise comparisons shown in Table 2. The other entries are 1's along the diagonal as well as the reciprocals of the 21 judgments. The data shown in the matrix can be deployed to derive estimate of the criteria priorities. The priorities provide a measure of the relative importance of each criterion. Essentially, the following three steps can be utilized to synthesize the pairwise comparison matrix.

1. Total the elements or values in each column
2. Divide each element of the matrix by its column sum
3. Determine the priority vector by finding the row averages

Table 2
Pairwise Comparison Matrix for the seven criteria

	Quality	Cost	RC	SR	RM	SP	GP
Quality	1	1	1	2	1	3	1
Cost	1	1	2	1	1	1	2
RC	1	1/2	1	5	1	5	1
Service	1/2	1	1/5	1	3	2	3
RM	1/3	1	1	1/3	1	5	2
SP	1/3	1	1/5	1/2	1/5	1	5
GP	1	1/2	1	1/3	1/2	1/5	1
Column Totals	31/6	6	32/5	61/6	77/10	86/5	15

Table 3 shows the synthesized matrix for the seven supplier selection criteria. For example, the priority vector associated with quality is obtained as follows: 6/31 + 1/6 + 5/32 + 12/61 + 10/77 + 15/86 + 1/15 = 0.157. The reminder of the priorities for cost, RC, service, RM,

Table 3
Synthesized (or Normalized) Matrix for the Seven Criteria (CR = 0.04<0.1)

	Quality	**Cost**	**RC**	**SR**	**RM**	**SP**	**GP**	**Priority vector**
Quality	6/31	1/6	5/32	12/61	10/77	15/86	1/15	0.157
Cost	6/31	1/6	10/32	6/61	10/77	5/86	2/15	0.102
RC	6/31	1/12	5/32	30/61	10/77	25/86	1/15	0.252
Service	12/31	1/6	25/32	6/61	30/77	10/86	3/15	0.069
RM	18/31	1/6	5/32	18/61	10/77	25/86	2/15	0.201
SP	18/31	1/6	25/32	12/61	50/77	5/86	5/15	0.042
GP	6/31	1/12	5/32	18/61	20/77	25/86	1/15	0.177
							Sum =	1.000

SP, and GP are 0.102, 0.252, 0.069, 0.201, 0.042, and 0.177, respectively. It shows that RC is the best supplier selection criterion, followed by RM, GP, quality, cost, service, and SP. As per the inconsistency reported by the Expert Choice Software, CR = 0.04 < 0.10. This implies that the group decision makers' evaluation is consistent.

Tables 4-10 show the pairwise comparison matrices of four suppliers with respect to each criterion and priorities. This process is similar to the procedure used to create the criteria comparison matrix. For example, the purchasing and supply chain managers compare each pair of suppliers with respect to quality, cost, RC, service, RM, SP, and GP. And the priorities of the suppliers, for each criterion, derived employing the three-step procedure identified in the foregoing.

Table 4
Pairwise Comparison with respect to Quality

Quality	Supplier A	Supplier B	Supplier C	Supplier D	Priority
Supplier A	1	1/2	1/4	1/2	0.110
Supplier B	2	1	1/2	1/2	0.187
Supplier C	4	2	1	2	0.439
Supplier D	2	2	1/2	1	0.265

Table 5
Pairwise Comparison with respect to Cost

Cost	Supplier A	Supplier B	Supplier C	Supplier D	Priority
Supplier A	1	2	1/3	1/3	0.143
Supplier B	1/2	1	1/4	1/3	0.093
Supplier C	3	3	1	2	0.459
Supplier D	3	3	1/2	1	0.305

Table 6
Pairwise Comparison with respect to Regulatory Compliance (RC)

RC	Supplier A	Supplier B	Supplier C	Supplier D	Priority
Supplier A	1	3	1/3	1/3	0.156
Supplier B	1/3	1	1/5	1/3	0.078
Supplier C	1	5	1	2	0.466
Supplier D	3	3	1/2	1	0.299

Table 7
Pairwise Comparison with respect to Service

Service	Supplier A	Supplier B	Supplier C	Supplier D	Priority
Supplier A	1	3	1/3	1/4	0.127
Supplier B	1/2	1	1/7	1/7	0.052
Supplier C	3	7	1	1/2	0.324
Supplier D	4	7	2	1	0.497

Table 8
Pairwise Comparison with respect to RM

RM	Supplier A	Supplier B	Supplier C	Supplier D	Priority
Supplier A	1	2	1/5	1/3	0.113
Supplier B	1/2	1	1/7	1/5	0.064
Supplier C	5	7	1	1/2	0.455
Supplier D	3	5	2	1	0.368

Table 9
Pairwise comparison with respect to SP

SP	Supplier A	Supplier B	Supplier C	Supplier D	Priority
Supplier A	1	2	1/2	1/4	0.129
Supplier B	1/2	1	1/4	1/8	0.047
Supplier C	2	4	1	1/2	0.283
Supplier D	4	8	2	1	0.540

Table 10
Pairwise comparison with respect to GP

GP	Supplier A	Supplier B	Supplier C	Supplier D	Priority
Supplier A	1	3	1/3	1/2	0.174
Supplier B	1/3	1	1/5	1/3	0.080
Supplier C	3	5	1	2	0.477
Supplier D	2	3	1/2	1	0.270

Determination of overall priority

The final phase of the AHP analysis is summarized in Table 11. To determine the overall priority, a simple weighted technique is used. For a given supplier, four priorities are derived, one for each of the four evaluation criteria shown in Tables 4-10. These four priorities are multiplied by the appropriate criteria priorities in satisfying the goal of the hierarchy shown in Table 3, and the outputs of the four multiplications are summed together to determine the supplier score. Each supplier score is the estimated total benefits to be derived from selecting a particular supplier. For illustration purposes, the calculations for determining the overall priority of suppliers are as follows:

Overall priority of supplier A
= 0.157(0.110) + 0.102(0.142) + 0.252(0.156) + 0.069(0.127) + 0.201(0.113) + 0.042(0.129) + 0.177(0.174) = 0.138.

Table 11
Priority Matrix of Supplier Selection Alternatives

Priority	Quality (0.157)	Cost (0.102)	RC 0.252	SR (0.069)	RM (0.201)	SP (0.042)	GP (0.177)	Overall priority vector
Supplier A	0.110	0.142	0.156	0.127	0.113	0.129	0.174	0.138
Supplier B	0.187	0.093	0.078	0.052	0.064	0.047	0.080	0.092
Supplier C	0.439	0.459	0.466	0.324	0.455	0.283	0.477	0.445
Supplier D	0.265	0.305	0.299	0.497	0.368	0.540	0.270	0.325

With respect to the overall priority scores of alternative suppliers, supplier C (0.445) is most preferred followed by supplier D (0.325), supplier A (0.138), and supplier B (0.092), respectively. That is, supplier C > supplier D > supplier A > supplier B. Essentially, supplier A is judged to be the overall best.

CONCLUSIONS AND IMPLICATIONS

Saaty (1980) suggests that AHP is an important supplier selection approach because it supports decision makers in ranking potential suppliers based on the relative significance of the attributes. The AHP-based supplier selection is developed and then applied to a generic pharmaceutical firm. Indeed, 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 includes to reduce costs, attain real-time delivery, ensure world-class quality, mitigate risks, and receive better services (Palaneeswaran, et al., 2006). Selecting competent suppliers can help manufacturing firms such as a generic pharmaceutical firm to contain cost associated with the bottom line.

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APPENDIX

Supplier Selection in a Generic Pharmaceutical Firm Survey Questionnaire

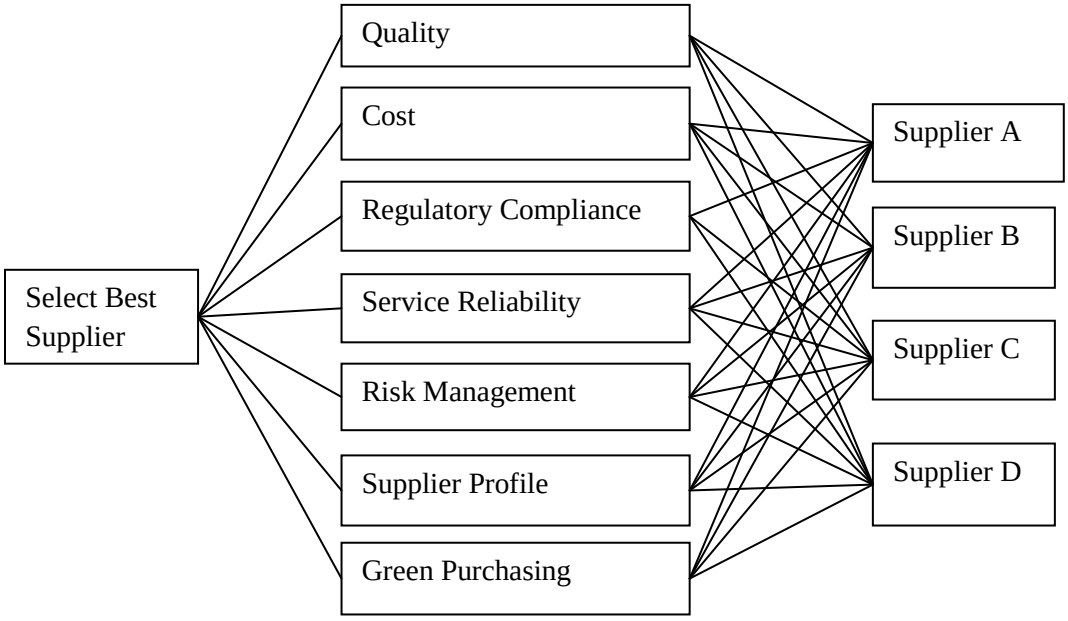
Dear:
My name is _____. I am a professor of Logistics/Supply Chain Management & International Business, Department of Management and Marketing, School of Business, Alabama A & M University, Normal, AL.
I am writing to elicit your opinion as an expert on supplier selection and evaluation. I am investigating the opinions of purchasing managers by means of a survey questionnaire.

This questionnaire leverages Analytic Hierarchy Process (AHP) to model supplier selection in your generic pharmaceutical firm. As an expert on purchasing and supply management, your opinion will be significantly invaluable to this research.

Brief Background

In today's ultra competitive sphere, costs of sourcing commodities from suppliers have become more than ever significant. Supplier selection represents one of the most essential purchasing decisions which can determine the long term sustainability of a firm. In this context, the intent of this research is to apply a multi-criteria analysis by a three-level AHP, to select the best supplier for participation in a generic pharmaceutical firm supply chain. Level 1 represents the ultimate goal the decision maker intends to achieve in supplier selection problem; Level 2 entails the supplier selection criteria including regulatory compliance, quality, cost, service reliability, risk management, supplier profile, and green purchasing; and Level 3 represents prequalified suppliers including suppliers A-D.

Figure 1
The Hierarchical Structure for Supplier Selection



For your opinion as an expert, the pair-wise comparison scale by Saaty, reported in Table 1, can be used to assess or express the importance of one element over another.

Table 1
Saaty Scale - Pairwise Comparison Scale of Preference between two Elements

Preference weights	Definition of Verbal Scale	Explanation
1	Equally preferred or equal importance of both elements	Two activities or elements contribute equally to the objective
3	Moderately preferred or moderate importance of one element over another	Experience and judgment slightly favor activity or element over another
5	Strongly preferred or strong importance of one element over another	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly preferred or very strong importance of one element over another	An activity is strongly favored over another and its dominance demonstrated in practice
9	Extremely preferred or extreme importance of one element over	The evidence favoring one activity over another is of the highest degree possible of affirmation
2,4,6,8	Intermediate values	Used to represent compromise between the preferences listed above or used to compromise between two judgments
Reciprocals of above	In comparing elements I and j if i is 3 compared to j; then j is 1/3 compared to i	

PLEASE SEE EXAMPLES BELOW

Please mark or circle the criteria number (code) that you assess more or equal important than other, with respect to the **goal: "selection of best supplier"** and express on the verbal scale the importance of the more or equal important criteria over the other.

If you mark or circle **"4"** in the following question, means that **"cost"** is **4 times** more important in your expert opinion than the **"quality."**

1	Quality	9	8	7	6	5	4	3	2	1	2	3	***4***	5	6	7	8	9	Cost

Conversely, marking or circling the number **"1"** in the following question, means that **"quality"** is as important as **"cost."**

2	Quality	9	8	7	6	5	4	3	2	***1***	2	3	4	5	6	7	8	9	Cost

Moreover, marking or circling **"4"** in the following question, means that **"quality"** is **4 times** more important than the **"cost."**

3	Quality	9	8	7	6	5	***4***	3	2	1	2	3	4	5	6	7	8	9	Cost

It is my hope that the above examples are very helpful. Please contribute your expert opinion by ***marking (X) or cycling (O)*** for your choice of number.

Major Risk Criteria or Factors

Question1. Please mark or circle the criteria number (code) that you assess more or equal important than other, with respect to the **goal: "to select the best supplier."**

1	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Cost
2	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Regulatory compliance
3	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service reliability
4	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk management
5	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier profile
6	Quality	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Green purchasing
7	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Regulatory compliance
8	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service reliability
9	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk management
10	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier profile
11	Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Green purchasing
12	Regulatory compliance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Service reliability
13	Regulatory compliance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk management
14	Regulatory compliance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier profile
15	Regulatory compliance	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Green purchasing
16	Service Reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk management
17	Service Reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier profile
18	Service Reliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Green purchasing
19	Risk management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier profile
20	Risk management	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Green purchasing
21	Supplier profile	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Green purchasing

Alternative suppliers

Question 2. Please mark or circle the alternative number (code) that you assess more or equal important than other, with respect to criterion **"quality."**

1	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
2	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
3	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
4	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
5	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
6	Supplier C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D

Question 3. Please mark or circle the alternative number (code) that you assess more or equal important than other, with respect to criterion **"cost"**

1	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
2	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
3	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
4	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
5	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
6	Supplier C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D

Question 4. Please mark or circle the alternative number (code) that you assess more or equal important than other, with respect to criterion **"regulatory compliance."**

1	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
2	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
3	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
4	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
5	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
6	Supplier C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D

Question 5. Please mark or circle the alternative number (code) that you assess more or equal important than other, with respect to criterion **"service reliability."**

1	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
2	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
3	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
4	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
5	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
6	Supplier C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D

Question 5. Please mark or circle the alternative number (code) that you assess more or equal important than other, with respect to criterion **"risk management."**

1	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
2	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
3	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
4	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
5	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
6	Supplier C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D

Question 5. Please mark or circle the alternative number (code) that you assess more or equal important than other, with respect to criterion **"supplier profile."**

1	Supplier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
2	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
3	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
4	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
5	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
6	Supplier C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D

Question 5. Please mark or circle the alternative number (code) that you assess more or equal important than other, with respect to criterion **"green purchasing."**

1	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier B
2	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
3	Supplier A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
4	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier C
5	Supplier B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D
6	Supplier C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Supplier D

Once again, thank you so much for your time and for offering your e