AHP Approach for Supplier Evaluation and Selection in a Pharmaceutical Manufacturing Firm in Ghana

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Received: January 18, 2012 Accepted: April 1, 2012 Online Published: May 16, 2012

doi:10.5539/ijbm.v7n10p49 URL: http://dx.doi.org/10.5539/ijbm.v7n10p49

Abstract

In today's highly competitive environment, improper evaluation and selection of the right suppliers can hinder an organizations supply chain performance. The aim of this study is to present a suitable methodology for the evaluation and selection of suppliers in a pharmaceutical manufacturing firm in Ghana. Specifically, the study sought to use the Analytic Hierarchy Process methodology to select the most appropriate raw material suppliers of the artemether-lumefantrine anti-malarial drug for the case study organization. A review of literature identified quality, cost, reliability, regulatory compliance, risk, financial position and supplier profile as the most important criteria for supplier selection. The study however used the three criteria of quality, price and reliability/capacity for selecting the best suppliers. The results suggest that the AHP makes it easier to evaluate, rank and select efficient suppliers for manufacturing firms in a timely and reliable manner. Based on the research findings, the quality selection criterion is most favoured, followed by reliability/capacity, and price. Regarding the selection of the suppliers, the research recommended S & D Chemicals as the best supplier of Active Pharmaceutical Ingredients (APIs) and Hellmuth Carroux as the best supplier of Excipients for the case study firm.

Keywords: supply chain management, supplier selection, Multi-Criteria Decision Making (MCDM), Analytic Hierarchy Process (AHP), pharmaceutical industry, Ghana

1. Introduction

Supplier evaluation and selection has become a very important area of consideration for purchasing managers in today's highly competitive environment. As the cost of raw materials purchased for production usually constitute a higher percentage of the total cost of finished products, it has become increasingly necessary for organizations to get the best value for money from suppliers. "In most industries, the cost of raw materials and component parts constitutes the main cost of a product, such that in some cases it could account for up to 70%" (Tahriri et al., 2008). Suppliers play an important role in achieving the objectives of the supply management. Thus, it is clear that supply selection is a problem that cannot be easily overlooked as the purchasing department's ability to contract the best suppliers for the organization could lead to significant cost reductions. Because of the importance of medicine in society, conducting supply chain management researches in the pharmaceutical industry cannot be overemphasized. Hence, supplier selection in this industry is studied.

Ghana has 32 registered pharmaceutical manufacturers producing oral and topical finished dosage forms, of which six are considered to be major producers and 14 medium scale producers. The six major producers are Ayrton Drugs, Danadams Ltd, Ernest Chemists Limited, LaGray Chemical Company, Kinapharma and Phytoriker (Harper and Gyansa-Lutterodt, 2007). The Ghanaian pharmaceutical market is made up of approximately 30% locally produced drugs and 70% imported products; the latter originating mainly from India and China (Harper, Gyansa-Lutterodt, 2007). Even though several opportunities abound for the growth of the pharmaceutical industry in Ghana, numerous challenges and constraints have made it highly difficult for the industry to grow and operate at full capacity. Factors such as local manufacturer focus on supplying OTC products (as opposed to prescription-essential drugs) in a saturated and intensely competitive OTC market; WHO prequalification compliance with international standards; high local manufacturing costs; difficulties exporting products to other countries in the sub-region due to a complex and irrational supply chain are just a few of the challenges that beset the Ghanaian pharmaceutical industry (Harper and Gyansa-Lutterodt, 2007).

One important health issue that the Ghanaian pharmaceutical industry is bent on resolving is the problem of

malaria. Malaria is a prevalent and endemic disease in the whole of Sub - Saharan Africa. "An examination of the 2002 Global burden of disease WHO report shows the top causes of death in Africa to be HIV/AIDS, respiratory tract infections, cardiovascular disease, and malaria" (Harper and Gyansa-Lutterodt, 2007). According to the World Health Organization, Ghana had an estimated 7.2 million cases of malaria in 2006. Of those cases, 3.9 million of them occurred in children under five years old. Malaria is thus considered a nationwide problem (Voices of malaria free future Ghana, 2009). Thus, the demand for quality anti-malarial drugs is always high in Ghana which places pharmaceutical manufacturers of anti-malarials under pressure to supply the ever increasing demand of the drug.

To reach the final consumer with quality anti-malarial drugs, pharmaceutical manufacturers must select and work with the right suppliers of anti-malarial raw materials. This research considered the case of a major pharmaceutical manufacturing firm in Ghana (Ernest Chemists Limited) that produces various kinds of medicines for the Ghanaian and some other Sub - Saharan African market. The company outsources both the active pharmaceutical ingredients (API) (efficiency of the medicine is related to these ingredients) as well as the excipients (these include flavoring and coloring ingredients, absorbers, and cohesive) that are used in the manufacture of the various drugs. Even though the company deals with numerous suppliers of raw materials that the researchers could have considered, because of the serious nature of the malarial situation in Ghana, the suppliers of the raw materials used in the production of the artemether-lumefantrine anti-malarial drug were considered for the study.

To efficiently evaluate and select the best suppliers of this drug for the case study firm, the analytic hierarchy process approach, which is a Multi-Criteria Decision Making (MCDM) technique, was utilised. Among a host of decision making tools that have been used in the supply selection problem such as 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, and linear programming among others, the analytic hierarchy process stands out as a very interesting and powerful approach in the literature for supply evaluation and selection studies (De Boer et al., 1998).

The rest of the paper is organized as follows. Section two gives the literature review. Section three presents the research methodology used. Section four describes the research findings, analyses discussion of the results. Section five presents the conclusions and implications.

2. Literature Review

A review of the literature on Supply Chain Management (SCM) indicates that there is an explosion of research that has been done in the area in recent times. One interesting area of research in SCM has been the supplier evaluation and selection studies. Different MCDM techniques have been adopted by researchers to solve the supplier evaluation and selection problem in diverse sectors. Some of these studies are summarized below.

2.1 Studies on Supplier Selection

The AHP approach was used to carry out an analysis of strategic supplier selection and evaluation in a generic pharmaceutical firm supply chain (Enyinda, et al., 2010). The researchers developed a model to aid them in the evaluation and selection of the important criteria and hence the best supplier for a pharmaceutical manufacturing firm. The selected criteria for the evaluation were regulatory compliance, quality, cost, service, supplier profile and risk. The researchers recommended that supplier selection process and evaluation represents one of the key activities that organizations must integrate into their core strategic decisions. Based on their research findings, the regulatory compliance selection criterion was most favored, followed by quality, risk, cost, supplier profile, and service. The model also enabled the researchers to select the best supplier for the case company.

The analytic network process was used to model the selection of an appropriate telecommunications infrastructure technology, capable of deploying e-services in rural areas of developing countries (Gasiea et al., 2010). The researchers utilized a typical conceptual rural telecommunications infrastructure selection model to guide their study. The model was made up of criteria or factors including environmental factors, regulatory factors, economic factors, infrastructure factors, technical factors and social factors that were supposed to aid the researchers in their evaluation analysis and selection of an appropriate telecommunications infrastructure technology. The paper illustrates the use of the ANP method, by taking pair-wise comparisons from various experts that informed the outcome of the research. The researchers concluded by stating that no real life conclusions should be drawn from their study as each telecommunication infrastructure provider will have its own set of criteria.

The DEA model was used for supplier evaluation and selection to serve as a tactical decision-making tool in

purchasing decisions (Amindoust et al., 2010). The researchers compared the overall supplier performances and presented the application through a case study for a manufacturing firm. Six evaluating factors were considered in the model in which there are three inputs related to the supplier capability and three outputs related to the supplier performance. The input factors consisted of technical capability, production facilities and capacity, and financial position. The output factors were made up of price, quality and delivery. The model was able to show the efficient and inefficient suppliers, enabled the ranking of efficient suppliers and increased the possibility of benchmarking different suppliers and identifying their possible failures.

A case-based reasoning system was developed for valuers in Bangkok; Thailand (Pacharavanich et al., 2000). The study examines the usefulness of the system for the valuation of townhouses in the country. The researchers followed the processes for constructing a prototype case-based reasoning system by first selecting the factors of residential valuation. They then developed the cases and weights to build up the case - based reasoning systems that was effectively utilized in the valuation process. Even though the researchers noted some limitations in their study such as the incompleteness of the factors they considered and low sample size, they were nevertheless positive that the research does show that the system has potential to become a viable commercial tool for the valuation of residential property in Bangkok.

The total cost of ownership approach was used to analyse a hybrid electromagnetism-like algorithm for supplier selection in make to order planning (Mirabi et al., 2010). The study presented an application of the electromagnetism-like algorithm to supplier selection in the production planning process where there are multiple products and customers and also there are capacity constraints. The researchers wanted to find out what raw material to order, what quantities to order, which suppliers to order from and finally in which periods. The researchers developed a novel electromagnetism-like algorithm model which was compatible to consider all costs imposed to the production section so as to enable the selection of a special supplier that managers are faced with in the real world. The researchers concluded from their numerical results that electromagnetism algorithm exhibits impressive performances with small error ratios.

A fuzzy AHP approach was utilized for evaluating and selecting the best supplier of maize starch in a pharmaceutbcical industry (Khorasani et al., 2011). The results of their study show that the factors related to cost and price, quality, organization of supplier, services, and technical skills of supplier are the major criteria for assessing and choosing the best supplier of maize starch in the pharmaceutical industry. Instead of utilising the original AHP methodology, the researchers used the Fuzzy AHP approach because they recognized it as a better approach than the original AHP. They quoted (Leung and Cao, 2000) who noted that a large number of researchers believe that there is a kind of uncertainty in experts' opinions as far as the AHP is concerned, and thus, when doing pair-wise comparisons and assigning ratios to them, the decision making would be imprecise and unreliable. This explains the researchers' decision to use the Fuzzy AHP approach instead of the original AHP. The researchers developed a hierarchical model to aid them in their study. This model enabled them to arrive at the major factors for assessing and choosing the best suppliers of maize starch in the pharmaceutical manufacturing company.

A multi-criteria group decision making method based on fuzzy sets approach was adopted for a supplier selection problem (ASBBS Annual Conference: Las Vegas, 2010). The objective of this study was based on the fact that if organizations can select the right supplier then they can significantly save the costs of the purchasing processes and improve the company's overall competitive advantage. The Fuzzy approach required the researchers to first use linguistic variables to assess the weights for each decision maker. After this, the rating and weights of suppliers and criteria were assessed by use of the linguistic variables. Finally, suppliers were ranked in terms of their scores in each criterion and the top suppliers were selected.

The mathematical programming approach was also used to study supply chain optimization policy for a supplier selection problem (Gheidar-Kheljani et al., 2010). This approach was expressed as a concave minimization problem and a near optimal solution was generated by considering properties such as limitation of the number of suppliers and convexity of feasible solution area. The researchers argued that most supplier selection models consider the buyer's viewpoint and maximize only the buyer's profit which does not necessarily lead to an optimal situation for all the members of a supply chain. They therefore consider a combination of a supplier selection model and a co-ordination model in a centralized supply chain that will bring benefits to both the buyer and supplier. The objective function is to minimize the total cost of the supply chain which includes the costs of the buyer and the suppliers. The researchers realized that in other supplier selection models only buyer's cost is minimized without guaranteeing the total supply chain cost being minimized.

2.1.1 Conclusion of Supplier Selection Studies

Sixty articles from various journals and conferences were reviewed from 2000 to 2011 to find out the most prominent MCDM methodology followed by researchers (Agarwal et al., 2011). The researchers studied the different MCDM approaches that have been used in the literature and then the most prominent approach was identified. The researchers discovered that even though the most widely applied methodology was data envelopment analysis (DEA), mainly attributed for its robustness, they recommended the use of the AHP to aid the researchers and decision makers in meeting the challenging task of the supplier selection problem effectively in the future.

2.2 Supplier Selection Criteria: A Review of Weber's Study

Several criteria for supplier evaluation and selection have been proposed by researchers since 1966. One significant study that considered the multi-objective nature of vendor selection was done by Dickson in 1966 (Weber et al., 1991). This study ranked the importance placed on as much as 23 criteria by purchasing agents and managers.

Weber and other researchers reviewed as much as 74 articles which address vendor selection criteria in manufacturing and retail environments (Weber et al., 1991). Their research made use of Dickson's 23 criteria in ranking and analyzing the various supplier selection criteria that has appeared in the literature in recent times. The researchers discovered that net price, delivery and quality were discussed in 80%, 59% and 54% of the 74 articles reviewed respectively, and that these three criteria were rated as having extreme or considerable importance by Dickson. Moreover, production facilities and capability and technical capability were discussed in 31% and 20% of the articles respectively and were also rated by Dickson as having considerable importance. Geographical location was discussed in 22% of the articles and was rated as having average importance. According to the researchers, several criteria (such as warranties and claim policies, communication system, impression, labor relations record, amount of past business, and reciprocal agreements) have received little attention in the last five years.

With the advent of the Just In Time (JIT) strategy by organizations, the strategic importance of some of these criteria has changed to reflect the need of this concept. For instance, even though geographical location had average importance in the Dickson study; however, most organizations applying the JIT strategy have come to consider this factor as very important to their supplier selection criteria.

Dickson's 23 criteria for evaluating and selecting suppliers gave the researchers an insight regarding the necessary factors employed in the supplier evaluation and selection problem (Weber et al., 1991). However, factors employed in current studies on supplier evaluation and selection (Tahriri et al., 2008; Kumar et al., 2009; Enyinda et al., 2010) such as quality, cost, reliability, delivery, trust, quality certification of the vendor, regulatory compliance, risk, financial position, supplier profile and management and organisation were considered by the researchers to be considerably important factors in conducting similar researches on supplier evaluation and selection in recent times.

Considering the factors used for supplier evaluation and selection studies in recent times (Tahriri et al., 2008; Kumar et al., 2009; Enyinda et al., 2010) as well as the factors that the organization under study (Ernest Chemists Limited) considered important for evaluating and selecting their suppliers as far as the organizations purchasing constructs were concerned, the following criteria were selected by the researchers in collaboration with the firm under study for evaluating and selecting the best suppliers based on the AHP methodology:

i. Quality: this criterion includes suppliers' reputation with respect to FDB standards, supplier's current certification, quality of raw materials and proven record of world class service;

ii. Price: this factor includes the competitive pricing of suppliers, terms of credit, value added services and payment modes;

iii. Reliability / Capacity: this measure consists of delivery time, ease of communication, the ability to manage risk, production facility and financial health of the supplier.

3. Methodology

This research was conducted at Ernest Chemists Limited in Ghana. The firm deals with numerous suppliers of raw materials as it produces diverse forms of pharmaceuticals. Five raw material suppliers of artemether-lumefantrine anti-malarials were considered for the study. Two of these suppliers' supply raw materials for the manufacture of APIs for artemether- lumefantrine while three supply excipients for the manufacture of the same drug. One supplier, however, supplies raw materials of both API's as well as excipients.

The General Manager of the manufacturing division served as the focal respondent to the study. It must be said that the selection of this case respondent did not affect the credibility of the research as the general manager, being the top executive at the manufacturing division, had in-depth knowledge, understanding and experience with respect to the company's pharmaceutical raw material suppliers. Thus, the purposive or judgmental sampling technique was applied to select the case respondent for this study.

3.1 The Analytic Hierarchy Process Approach

The AHP approach has come to be recognized by most experts as a powerful tool for supplier evaluation and selection. The AHP methodology makes it possible to elicit both qualitative as well as quantitative data to arrive at a desired goal. The methodology makes use of various qualitative and mathematical approaches to examine the various data and make informed conclusions based on the data collected.

In AHP, preferences between alternatives are determined by making pair-wise comparisons. The function of the pair-wise comparisons is to find the relative importance of the various criteria which is rated by the nine-point scale developed by Saaty (Taylor, 2010). This scale indicates the level of relative importance from equal, moderate, strong, very strong to extreme level by 1, 3, 5, 7, and 9, respectively. The intermediate values between two adjacent comparisons are denoted by 2, 4, 6, and 8. The nine point scale developed by Saaty has been accepted by most experts as a very scientific and reasonable basis for comparing two alternatives (Taylor, 2010). A fundamental, but very rational assumption for comparing alternatives with the AHP is given as follows: If criteria A is absolutely more important than criteria B and is rated at 9, then B must be absolutely less important than A and is graded as 1/9. These pair-wise comparisons are carried out for all factors to be considered and the matrix is completed as depicted in Table 1 (Coyle, 2004; Taylor, 2010).

Table 1. The AHP Pair-Wise Comparison Values between Two Elements

Verbal Judgement or Preference	Numerical Rating
Equally preferred	1
Equally to moderately preferred	2
Moderately preferred	3
Moderately to strongly preferred	4
Strongly preferred	5
Strongly to very strongly preferred	6
Very strongly preferred	7
Very strongly to extremely preferred	8
Extremely preferred	9

Source: Taylor (2010); Developed by Saaty

The goal of this research is to evaluate and select the best suppliers for the firm under study. To arrive at the desired goal, the following mathematical steps put forward by (Taylor, 2010) for evaluating and selecting the desired alternative based on the AHP approach was followed:

i. Develop a pair-wise comparison matrix for each decision alternative (selected suppliers) for each criterion.

ii. Follow the synthesization methodology:

a) Sum the values in each column of the pair-wise comparison matrices.

b) Divide each value in each column of the pair-wise comparison matrices by the corresponding column sum. The results represent the normalized matrices.

c) Average the values in each row of the normalized matrices. The results give the preference vectors.

d) Combine the vectors of preferences for each criterion (from step ii c) into one preference matrix that shows the preference for each supplier for each criterion.

iii. Develop a pair-wise comparison matrix for the criteria.

iv. Compute the normalized matrix by dividing each value in each column of the matrix by the corresponding column sum.

v. Develop the preference vector by computing the row averages for the normalized matrix.

vi. Compute an overall score for each decision alternative by multiplying the criteria preference vector (from step v) by the criteria matrix (from step ii d).

vii. Rank the decision alternatives, based on the magnitude of their scores computed in step vi.

3.1.1 Checking for Consistency

The pair-wise comparisons from the expert within the firm under study always have to be checked and validated for consistency to ensure the reliability of the final AHP results. AHP evaluations are based on the assumption that the decision maker is rational, i.e., if A is preferred to B and B is preferred to C, then A is preferred to C. A Consistency Ratio (CR) of 0 means that the judgments are perfectly consistent. According to Saaty, if the CR is greater than 0.1 the judgments are untrustworthy because they are too close for comfort to randomness and the exercise is therefore valueless or must be repeated. However, in practice, consistency ratios of more than 0.1 sometimes have to be accepted. For instance, an inconsistency of 10% or less must sometimes be accepted even though the adjustment is small as compared to the actual values of the eigenvector entries (Haas and Meixner, 2009; Coyle, 2004).

3.1.2 Calculation of Consistency Ratio

To calculate the consistency ratio, we first calculate λ_{max} which enables us to calculate the consistency index and hence the consistency ratio.

Now, considering the equation $[A_x=\lambda_{max}x]$, where A is the preference matrix and x is the eigenvector, we have λ_{max}=average$|A_x/x|$

Consistency index, CI is given by $CI=[\lambda_{max}-n]/[n-1]$

With the information above, the consistency ratio is calculated. The Consistency Ratio (CR)=CI/RI, where CI is the consistency index and RI is the index for the corresponding random matrix. The values of RI is taken from Saaty's table as depicted in Table 2 below. The upper row (n) is the order of the random matrix, and the lower row is the corresponding index of consistency for random judgments as depicted in Table 2. Each of the numbers in this table is the average of CI's derived from a sample of randomly selected reciprocal matrices of AHP method (Haas and Meixner, 2009).

Table 2. The Reference Values of RI for Different Values of n

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

Source: Enyinda et al (2010); Developed by Saaty

3.2 Data Collection and Analyses

An interviewer-administered questionnaire was used for gathering relational data to assess the order of importance of the supplier selection criteria and the various factor pair-wise comparison ratings for each of the selected criteria. Saaty's 1-9 scale enables pair-wise comparisons to be done on the various attributes. These pair-wise comparisons show the strength of the decision maker's opinions regarding the various attributes. Two categories at a time were compared with respect to the overall goal of selecting the best suppliers. The result of the interviewer- administered questionnaire which is shown as Table 3 was then used as input for the AHP.

4. Analysis and Discussion of Results

4.1 Analyses

This section presents the analyses and the discussion of the empirical study.

Table 3. Pair-wise Comparison Matrix with Respect to the Selected Criteria

CRITERIA	Quality	Price	Reliability/Capacity
Quality	1	5	3
Price	0.2	1	0.3333
Reliability/Capacity	0.3333	3	1

Source: Field survey, 2011

Table 3.1. Pair-wise Comparison Matrix and Column Sums of the Selected Criteria

CRITERIA	Quality	Price	Reliability/Capacity
Quality	1	5	3
Price	0.2	1	0.3333
Reliability/Capacity	0.3333	3	1
Column sums	1.5333	9	4.3333

Source: Field survey, 2011

Table 3.2. Normalized Column Sums with Respect to the Selected Criteria

CRITERIA	Quality	Price	Reliability/Capacity
Quality	0.6522	0.5556	0.6923
Price	0.1304	0.1111	0.0769
Reliability/Capacity	0.2174	0.3333	0.2308
	1	1	1

Source: Field survey, 2011

Table 3.3. Normalized Column Sums and Row Averages with Respect to the Selected Criteria

CRITERIA	Quality	Price	Reliability/Capacity	Row averages
Quality	0.6522	0.5556	0.6923	0.6334
Price	0.1304	0.1111	0.0769	0.1061
Reliability/Capacity	0.2174	0.3333	0.2308	0.2605
				1

Source: Field survey, 2011

From the criteria pair-wise comparison matrix in Table 3, the case study firm strongly prefers the quality criterion to the price criterion and hence gives it a rate of 5 from Saaty's table depicted in Table 1. The company's preference value of price to quality is simply the reciprocal (or inverse) of its preference for quality to price, which in this case, will be 1/5 as depicted in Table 3. The company also moderately prefers the quality criterion to the reliability/capacity criterion and hence assigns it a value of 3 from Saaty's table. Similarly, the company's preference value of reliability/capacity to quality is simply the reciprocal (or inverse) of its preference for quality to reliability/capacity, which in this case, will be 1/3 as depicted in Table 3.The company also moderately prefers the reliability/capacity criterion to the price criterion and hence assigns it a value of 3 from Saaty's table. On the other hand, the company's preference value of price to reliability/capacity is simply the reciprocal (or inverse) of its preference for reliability/capacity to price, which in this case, will be 1/3 as depicted in table 3. Any criterion compared to itself is equally preferred with a value of 1.

4.1.1 Checking for Consistency

After the pair-wise comparisons are determined from the purchasing or supply chain expert in the firm under study, the next stage was to calculate a Consistency Ratio (CR) to measure how consistent the judgements have been relative to large samples of purely random judgments. This was done before the pair-wise comparisons could be analyzed using the AHP method.

The Consistency Ratio (CR)=CI/RI, where CI is the consistency index and RI is the index for the corresponding random matrix. We considered $[A_x=\lambda_{max}x]$, where A represents the pair-wise comparison matrix and X represents the eigenvector or row averages as depicted in Tables 3 and Table 3.3 respectively.

Now,

$$\overbrace{\begin{bmatrix} 1 & 5 & 3 \\ 0.2 & 1 & 0.3333 \\ 0.3333 & 3 & 1 \end{bmatrix}}^{A} \overbrace{\begin{bmatrix} 0.6334 \\ 0.1061 \\ 0.2605 \end{bmatrix}}^{X} = \overbrace{\begin{bmatrix} 1.9454 \\ 0.3196 \\ 0.7899 \end{bmatrix}}^{AX} = \lambda_{max} \overbrace{\begin{bmatrix} 0.6334 \\ 0.1061 \\ 0.2605 \end{bmatrix}}^{X}$$

$$\lambda_{max}=average\ [1.9454/0.6334,\ 0.3196/0.1061,\ 0.7899/0.2605]$$

$$=\frac{3.0714+3.0123+3.0322}{3}=\frac{9.1159}{3}=3.0386$$

Consistency index (CI) is found by:

$$CI=(\lambda_{max}-n)/(n-1)=\frac{3.0386-3}{3-1}=\frac{0.0386}{2}=0.0193$$

The values of RI is taken from Saaty's Table as depicted in Table 2

Thus, Consistency Ratio (CR)=0.0193/0.58=0.0333<0.1, so the evaluations for the criteria pair-wise comparisons are consistent.

Once the pair-wise comparisons of the selected criteria were determined, the AHP approach was utilized to find out the most preferred criterion, the second most preferred criterion and the third most preferred criterion. Taylor's approximation method for synthesization was utilized in applying the AHP methodology to realize this objective (Taylor, 2010).

Taylor's approximation method for synthesization was utilized as follows:

Step 1: The values in each column of the pair-wise comparison matrix are added. The fractional values have been converted to decimals as depicted in Table 3.1.

Step 2: The values in each column are divided by the respective column sums to obtain the normalized column sums. The values in each column sum up to 1 as depicted in Table 3.2.

Step 3: The values in each row are averaged as shown in the Table 3.3. The eigenvector or row averages also sum up to 1 as depicted in Table 3.3.

These row averages provide the company with their preferences for each criterion. As far as the case study firm is concerned, product quality is the most important criterion with the reliability/capacity attribute in second position. Price is viewed as the least favourable attribute and used as a basis for differentiating suppliers who tie on the more important attributes of quality and reliability/capacity. It is observed from the scores of the various criteria that the case study firm places much emphasis on the quality of raw materials as compared to the other factors.

The pair-wise comparison matrices of the various factor pair-wise comparison ratings provided by the case study firm are shown in Tables 4-9. The ranking of the various attributes and the consistency ratio results are as depicted in summary form from Table 4 to Table 9.

Table 4. Pair-wise Comparison Matrix with Respect to Quality Criterion for Suppliers of API's

QUALITY	Clonoose	Indukern	S & D	Row Averages	Rank
Clonoose	1	1/5	1/5	0.0909	3
Indukern	5	1	1	0.4545	1
S & D	5	1	1	0.4545	1

Source: Field survey, 2011 CR= 0 < 0.1

Table 5. Pair-wise Comparison Matrix with Respect to Price Criterion for Suppliers of API's

PRICE	Clonoose	Indukern	S & D	Row Averages	Rank
Clonoose	1	3	1/3	0.2721	2
Indukern	1/3	1	1/4	0.1199	3
S & D	3	4	1	0.6080	1

Source: Field survey, 2011 CR = 0.0638 < 0.1

Table 6. Pair-wise Comparison Matrix with Respect to Rel./Cap. Criterion for Suppliers of API's

Rel./Cap.	Clonoose	Indukern	S & D	Row Averages	Rank
Clonoose	1	1/3	1/3	0.1415	3
Indukern	3	1	1/2	0.3338	2
S & D	3	2	1	0.5247	1

Source: Field survey, 2011 CR = 0.0479 < 0.1

Table 7. Pair-wise Comparison Matrix with Respect to Quality Criterion for Suppliers of Excipients

QUALITY	Clonoose	Lavina	Hellmuth	Thosco	Row Averages	Rank
Clonoose	1	3	1/5	1/2	0.1514	3
Lavina	1/3	1	1/5	1/3	0.0789	4
Hellmuth	5	5	1	2	0.5162	1
Thosco	2	3	1/2	1	0.2535	2

Source: Field survey, 2011 CR = 0.0427 < 0.1

Table 8. Pair-wise Comparison Matrix with Respect to Price Criterion for Suppliers of Excipients

PRICE	Clonoose	Lavina	Hellmuth	Thosco	Row Averages	Rank
Clonoose	1	1	1	1	0.2420	2
Lavina	1	1	3	2	0.3690	1
Hellmuth	1	1/3	1	1/2	0.1554	4
Thosco	1	1/2	2	1	0.2336	3

Source: Field survey, 2011 CR = 0.0532 < 0.1

Table 9. Pair-wise Comparison Matrix with Respect to Reliability/Capacity Criterion for Suppliers of Excipients

REL./CAP.	Clonoose	Lavina	Hellmuth	Thosco	Row Averages	Rank
Clonoose	1	5	2	1/2	0.3154	2
Lavina	1/5	1	1/5	1/4	0.0648	4
Hellmuth	1/2	5	1	1	0.2675	3
Thosco	2	4	1	1	0.3522	1

Source: Field survey, 2011 CR = 0.0782 < 0.1

4.2 Overall Ranking of API Suppliers

The overall score for each API supplier was computed by multiplying the matrix summarizing the company's preference for each API supplier for each criterion developed previously by the preference vector for the three criteria as depicted in Table 10.

Table 10. Overall API Suppliers' Score

	Criteria					
Supplier	Quality	Price	Rel. / Cap.		Criteria	
Clonoose	0.0909	0.2721	0.1415		Quality	0.6334
Indukern	0.4545	0.1199	0.3338	×	Price	0.1061
S & D	0.4545	0.6080	0.5247		Rel./Cap.	0.2605

Source: Field survey, 2011

$$\begin{aligned}
\text{Overall score for Clonoose} &= 0.6334(0.0909) + 0.1061(0.2721) + 0.2605(0.1415)\\
&= 0.0576 + 0.0289 + 0.0369\\
&= 0.1234\\
\text{Overall score for Indukern} &= 0.6334(0.4545) + 0.1061(0.1199) + 0.2605(0.3338)\\
&= 0.2879 + 0.0127 + 0.0870\\
&= 0.3876\\
\text{Overall score for S \& D} &= 0.6334(0.4545) + 0.1061(0.6080) + 0.2605(0.5247)\\
&= 0.2879 + 0.0645 + 0.1367\\
&= 0.4891
\end{aligned}$$

The ranking of the three suppliers of API's in order of the magnitude of their overall score is depicted in Table 11.

Table 11. Summary of API Supplier' Score in Order of Preference

SUPPLIER	SCORE
S & D	0.4891
INDUKERN	0.3876
CLONOOSE	0.1234
	1.0000

4.3 Overall Ranking of Excipient Suppliers

The overall score for each excipient supplier was computed by multiplying the matrix summarizing the company's preference for each excipient supplier for each criterion developed previously by the preference vector for the three criteria as depicted in Table 12.

Table 12. Overall Excipient Suppliers' Score

	Criteria					
Supplier	Quality	Price	Rel. / Cap.		Criteria	
Clonoose	0.1514	0.2420	0.3154		Quality	0.6334
Lavina	0.0789	0.3690	0.0648	×	Price	0.1061
Hellmuth	0.5162	0.1554	0.2675		Rel./Cap.	0.2605
Thosco	0.2535	0.2336	0.3522			

Source: Field survey, 2011

$$\begin{aligned}
\text{Overall score for Clonoose} &= 0.6334(0.1514) + 0.1061(0.2420) + 0.2605(0.3154)\\
&= 0.0959 + 0.0257 + 0.0822\\
&= 0.2038\\
\text{Overall score for Lavina} &= 0.6334(0.0789) + 0.1061(0.3690) + 0.2605(0.0648)\\
&= 0.0410 + 0.0392 + 0.0169\\
&= 0.0971\\
\text{Overall score for Hellmuth} &= 0.6334(0.5162) + 0.1061(0.1554) + 0.2605(0.2675)\\
&= 0.3270 + 0.0165 + 0.0697\\
&= 0.4132\\
\text{Overall score for Thosco} &= 0.6334(0.2535) + 0.1061(0.2336) + 0.2605(0.3522)\\
&= 0.1606 + 0.0248 + 0.0917\\
&= 0.2771
\end{aligned}$$

The ranking of the four suppliers of excipients in order of the magnitude of their overall score is depicted in Table 13.

Table 13. Summary of Excipient Supplier' Score in Order of Preference

SUPPLIER	SCORE
HELLMUTH	0.4132
THOSCO	0.2771
CLONOOSE	0.2038
LAVINA	0.0971
	1.0000

4.4 Discussion of Results

For the organization chosen for this study, the quality criterion was found to be the most important attribute with a score of 0.6334. The quality criterion was followed by reliability/capacity in second place with a score of 0.2605 and then with the price criterion having a marginal score of 0.1061 as the least important criterion. The scores for the various attributes clearly denote that the firm under study places much emphasis on the quality of raw materials as compared to the other factors. Enyinda et al., (2010), indicated that regulatory compliance criterion was most favored, followed by quality, risk, cost, supplier profile, and service confirming the importance of quality. There is a growing indication that quality is an important criterion other than price/cost which used to be the major determining factor in supplier selection. And since, medicines are essential, the quality of raw material is very much an integral component. The regulatory compliance used by Enyinda et al., (2010) goes to emphasis the need for a bench mark.

Based on the overall scores for API suppliers, S & D Chemicals should be selected as the overall best supplier of API's for Ernest Chemists Limited as it obtained the highest overall ranking with a score of 0.4891. The pair-wise comparison results indicated that S & D Chemicals and Indukern Chemie AG were on the same level with respect to the quality criterion, with a score of 0.4545 each as shown in Table 4. However, when it came to the price and reliability criteria, S & D Chemicals ranked highest above all the other suppliers with scores of 0.6080 and 0.5247 respectively. Thus, it is not surprising to discover that in the overall score for API Suppliers, S & D Chemicals ranked highest with a score of 0.4891 positioning them as the best suppliers of API's for the firm under study.

Based on the overall scores for excipient suppliers, Hellmuth Carroux should be selected as the overall best supplier of excipients for Ernest Chemists Limited as it obtained the highest overall ranking with a score of 0.4132. Even though Hellmuth Carroux ranked lowest with respect to the price criterion, it still emerged as the best supplier of excipients since the weight of quality and reliability/capacity were very strong for this supplier. It is observed that as the company places much emphasis on the quality of raw materials and the reliability/capacity of suppliers, there is a visible trade-off of price as against the quality and reliability/capacity criteria. Thus, it is a combination of all these factors that actually positions Hellmuth Carroux as the overall best supplier of excipients for the organization under study. Although the key objective function of most supplier selection decision is to maximize buyer's profit focusing on minimizing the total cost of the supply chain (Gheidar-Kheljani et al., 2010) requires that the focal firm concentrate on quality and reliability/capacity which ensures maximum consumer satisfaction.

5. Conclusions and Implications

This research work considered the evaluation and selection of suppliers for a pharmaceutical manufacturing firm. Supplier evaluation and selection process represents one of the most important activities that organizations must incorporate into their core strategic decisions. Supplier evaluation and selection has a direct bearing on the supply chain performance of manufacturing firms. As such suppliers are viewed as critical resources for manufacturing firms especially as these firms spend up to 70% of their total expenditure on suppliers for the procurement of necessary raw materials (Tahriri, Osman, Ali et al. 2008). Thus, manufacturing firms have to expediently evaluate, select and manage these suppliers to derive the maximum potential in the supply chain.

The primary goals of supplier selection and evaluation include reducing costs, attaining real-time delivery, ensuring world-class quality, mitigating risks, and receiving better services (Enyinda et al., 2010). To achieve such goals, a suitable methodology is needed to rank, evaluate and select the right suppliers that manufacturing

firms can effectively work with. In view of this, an AHP-based approach was applied to a pharmaceutical manufacturing firm to evaluate and select the best suppliers of APIs as well as excipients for the manufacture of artemether-lumefantrine anti-malarial drugs. It must be said that the mathematical steps (approximation method for synthesization) put forward by (Taylor, 1991) for evaluating and selecting the desired alternative based on the AHP approach was really effective in enabling the researchers come up with the best suppliers of active pharmaceutical ingredients and excipients for the firm under study.

(Enyinda et al., 2010) also used the AHP methodology to do an analysis of strategic supplier selection and evaluation in a generic pharmaceutical firm supply chain. Unlike this study which adopted Taylor's approximation method for synthesization of the AHP in ranking alternative suppliers, the researchers (Enyinda, et al 2010) developed a hierarchical model which facilitated the study, allowing them to prioritise the various criteria and factor pair-wise comparisons, thus establishing the best suppliers of the generic pharmaceutical firm supply chain.

The AHP approach enables decision makers to rank alternative suppliers based on the decision makers' subjective judgements regarding the significance of the various attributes (Enyinda, et al 2010). This process actually enables decision makers to examine the strengths and weaknesses of the various suppliers by comparing them using appropriate criteria.

With the use of the AHP model software, the data can easily be imputed into the software for easy computations and the results can be transferred to a spreadsheet for analysis. This approach will make it easier for the purchasing and other supply chain staff to evaluate and select the best suppliers for the company. However, for this to be achieved, the purchasing and supply chain staff of the firm must be given adequate training on the pros and cons of the AHP methodology as well as its usage to achieve excellent results. With the increasingly huge expenses made on the procurement of raw materials, it is very imperative that organizations begin to use such scientific tools to evaluate and select their suppliers to enable them to obtain the best value for their purchases.

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